
NANO ENERGY

4th International Conference on Nanotechnology, Nanomaterials & Thin Films for Energy Applications

26-28 July 2017

ABSTRACTS BOOK

Venue: Aalto University, Finland

Editors: Professor Peter Lund (Aalto University, Finland); Dr Imran Asghar (Aalto University, Finland)



From Maxwell's displacement current to nanogenerator driven self-powered systems and blue energy**Zhong Lin Wang***School of Materials Science and Engineering, Georgia Institute of Technology, Atlanta, Georgia, USA
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Self-powered system is a system that can sustainably operate without an external power supply for sensing, detection, data processing and data transmission. Nanogenerators (NG) were first developed for self-powered systems based on piezoelectric effect and triboelectrification effect for converting tiny mechanical energy into electricity, which have applications in internet of things, environmental/infrastructural monitoring, medical science, environmental science and security. Here, we first present the fundamental theory of the NGs starting from the Maxwell equations. In the

Maxwell's displacement current, the term $\epsilon \frac{\partial E}{\partial t}$ gives the birth of electromagnetic wave, which is the foundation of wireless communication, radar and later the information technology. Our study indicates that, owing to the presence of surface polarization charges present on the surfaces of the dielectric

media in NG, an additional term $\frac{\partial P_s}{\partial t}$ should be added in the Maxwell's displacement current, which is the output electric current of the NG. Therefore, our NGs are the applications of Maxwell's displacement current in energy and sensors. NGs have three major application fields: micro/nano-power source, self-powered sensors and blue energy. We will present the applications of the NGs for harvesting all kind mechanical energy that is available but wasted in our daily life, such as human motion, walking, vibration, mechanical triggering, rotating tire, wind, flowing water and more. Then, we will illustrate the networks based on triboelectric NGs for harvesting ocean water wave energy, for exploring its possibility as a sustainable large-scale power supply. Lastly, we will show that NGs as self-powered sensors for actively detecting the static and dynamic processes arising from mechanical agitation using the voltage and current output signals.

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INV-5

Recent process on anode materials for direct hydrocarbon solid oxide fuel cells

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A solid oxide fuel cell (SOFC) is an electrochemical device which directly converts chemical energy in fuels into electrical energy[1]. Liquid fuels are considered as promising fuels for portable applications due to their high volumetric energy density. For small-scale portable applications, it is meaningful to directly use methanol in SOFCs because it has low content of impurities which can poison the anode. Mo was impregnated into Ni-Sm_{0.2}Ce_{0.8}O_{1.9} (Ni-SDC) to form Ni-Mo-SDC[2]. The addition of Mo improves the catalytic activity for methanol pyrolysis and the resistance to carbon deposition of Ni-SDC anode. The cell shows the best cell performance, 680 mW cm⁻² at 700 °C, when the mole ratio of Mo to Ni is 0.03:1. The stability of the cell is enhanced with the increase of the content of Mo in the anode. Furthermore, oxides of La and Sm are added into Ni-Mo-SDC as anodes of solid oxide fuel cells with methanol as fuel. The addition of the oxides improves the catalytic oxidation of the fuel, resulting in the decrease of anodic polarization resistance. The single cell with LaO-Ni-Mo-SDC as the anode and SDC-carbonate composite as the electrolyte exhibits a maximum power density of 765 mW cm⁻² at 700 °C. The oxides in the anodes also improve the stability of single cells due to the accelerated oxidation of the deposited carbon and the suppression of the deposition of carbon with a high graphitization degree.

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INV-10

Semiconductor-ionic and Topological materials for energy applications

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Currently two research fields are strongly correlated from semiconductor and ionic materials (SIMs), semiconductor physics and Ionics, which have created "Three in one" (1) electrolyte-free fuel cell technology and science (2-6) because one SIM can integrate fuel cell all functions of anode, electrolyte and cathode. Some SIMs have shown properties as analogs of topological insulators. Semiconductor and topological electronic band can induce ionic conducting properties and band structure changes resulting in superionic conduction. Strongly crosslink approaches from electrons and ions based on extensive experimental discoveries have made a strong indication for a promising research frontier: Semiconductor-ionics (Semionics) and Topoionics. In a brief, Semionics studies the ionic properties and transport phenomena in semiconductors, and Topoionics for the same properties and phenomena in topological materials (TMs). It gives a new scientific thinking and idea to a combination of SIMs and TMs based on a fact: large numbers of the TMs (insulators and semi-metals) have been discovered to be compatible to the semiconductor-ionic devices, e.g. electrolyte (layer)-free fuel cell (EFFC) or semiconductor-ionic fuel cells (SIFCs).

We are working on both theoretical approaches and experiments to develop and establish a new discipline on Semionics and Topoionics for energy applications.

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INV-16

Nano-structured Carbon Materials Derived from Waste Biomass and Their Applications in DSSC/AD Systems

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Two challenges human society faces are energy shortage and environmental pollution, and the developing the renewable energy is a critical strategy to solve this issue. Solar energy and biomass energy as the most abundant renewable energy resources, its development and utilization has become an important topic due to their renewability and cleanliness in recent years. Utilizing the waste biomass resources, nano-structured biomass carbon materials with diversified morphologies have been successfully fabricated by our group. These biomass carbon materials as counter electrode (CE) catalysts and as accelerants have been successfully applied in dye-sensitized solar cells (DSSCs) and anaerobic digestion (AD), which results in the remarkable improvement in catalytic activity and anaerobic fermentation performance for DSSC and AD systems. It is expected to open a new avenue for utilizing the nano-structured biomass carbon materials in various catalytic fields such as solar cell, fuel cell, biosensor, hydrogen generation, pollution and so on.

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ENR-1

Catalytic studies of nanocomposites electrodes {Ni_{0.5}Zn_{0.5-x}Ce_x & Ni_{0.5-x}Zn_{0.5}Ce_x where x = 0,0.1,0.2,0.3,0.4&0.5} for natural gas fed fuel cells

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In this paper, the ceria based nanocomposites electrodes have been developed for the natural gas (CH₄) based fuel cell. These Ce-based nanocomposite electrodes (Ni_{0.5}Zn_{0.5-x}Ce_x & Ni_{0.5-x}Zn_{0.5}Ce_x) were synthesized by wet chemical method for low temperature solid oxide fuel cell (LT-SOFC). These nanocomposite electrodes were characterized by different characterization techniques including X-ray diffractometer (XRD), SEM, Fourier transform infrared spectroscopy spectra (FTIR), VU-Visible analysis. The DC conductivities in hydrogen and air atmospheres can be measured by using two probe technique. Also, the AC Impedance spectra of were studied in hydrogen atmosphere at 450 °C. Fuel cell performance with natural gas was obtained about 400 mW/cm². The structural analysis of XRD (before and after testing) was showed that no phase change and carbon deposition observed.

ENR-5

Synthesis and characterization of samarium doped nano ZnO-Ag and its application to photocatalysis

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Pure and Sm-doped ZnO-Ag photocatalysts were synthesized by simple wet chemical method and samples were calcined at different temperatures. The synthesized nanopowders were characterized by XRD, SEM, STA and UV-Vis spectroscopy. The results revealed that the prepared samples were nanometer in size and samarium ions successfully doped into the ZnO lattice. The effect of addition of different concentration of samarium dopant on structural property, optical property, and photocatalytic activity of ZnO-Ag were analyzed. SEM images showed that, layered and porous like structures were formed. Optical characterizations indicated that the samarium doping can shift the absorption edge of ZnO to the visible range and reduce the band gap. By using methylene blue as a model dye the photocatalytic degradation was studied and the results showed that the samarium doped ZnO-Ag shows higher photocatalytic activity than the pure ZnO. The photocatalytic activity of the synthesized powder was found to be dependent on concentration of Sm, duration of irradiation time,

amount of photocatalyst and the initial dye concentration. A possible mechanism of the photocatalytic activity of samarium doped ZnO-Ag is suggested.

ENR-6

ZnO/SnO₂ PMMA Nanocomposites for Photocatalytic Applications

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Binary semiconducting oxides, like zinc oxide (ZnO) and tin oxide (SnO₂) nanoparticles exhibit a large potential for photocatalytic applications in environmental treatments, such as degradation of wastewater and sterilization of drinking water[1]. Coupled oxide semiconductors, such as ZnO/SnO₂ nanoparticles have been proven as even more effective photocatalysts[2]. Despite their high photocatalytic efficiency, the time consuming filtration and elimination of nanoparticles from the water after the treatment is still an open problem. Here we report a novel method of encapsulation of ZnO/SnO₂ nanoparticles in PMMA matrix and formation of nanocomposite films with photocatalytic activity with no filtration needed. The efficiency of PMMA ZnO/SnO₂ thin films with different weight fractions of nanoparticles was examined in the photocatalytic degradation of naproxen suspended in water. Optimization of this method in terms of nanoparticle content in the polymer matrix and the active area of the film would extend the potential of semiconducting oxide nanoparticles for future practical large-scale applications in environment-related fields.

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Ellipsometric Characterization of Ag-As-S-Se Chalcogenide Thin FilmsK. Čajko¹, S.R. Lukić-Petrović¹, T. Wagner², J. Prikryl², D.M. Petrović¹*University of Novi Sad, Faculty of Sciences, Trg D. Obradovića 4, 21000 Novi Sad, Serbia**²University of Pardubice, Faculty of Chemical Technology, Legion's sq. 565, 53210 Pardubice, Czech Republic*

Large number of chalcogenide glasses shows reversible photoinduced structural transformations and photoinduced anisotropy. These processes are linked with the changes in band gap energy (photodarkening or photobleaching), absorption coefficient and refractive index (photorefraction). One of the most significant potential applications of amorphous chalcogenide thin films, especially those containing silver, is in optics and optoelectronics. They arise from their specific properties such as high indices of refraction, transparencies in the wide wavelengths range, photosensitivity, possibility of thermal-annealing of light-induced changes and good reproducibility in the processes of writing-deleting.

In this work we present results from the ellipsometric measurements of chalcogenide thin films from the $\text{Ag}_x(\text{As}_{40}\text{S}_{30}\text{Se}_{30})_{100-x}$ system. Amorphous films were prepared by pulsed laser deposition (PLD), while spectroscopic ellipsometry (SE) measurements were done using the SpecEL2000-VIA with rotating analyzer in 450–900 nm wavelength range.

The ellipsometric methods are fast, nondestructive, highly sensitive to the presence of surface inclusions and provide high accuracy for determination of the refractive index and thickness of thin layers. Our measurements showed that the thicknesses of the films are $d \sim 1.6\mu\text{m}$. Since it is known that the Tauc-Lorentz (TL) model is suitable to describe the optical functions of amorphous materials and interpret SE results, we analyzed our experimental data in that way.

It was shown that thin films from the studied system possess normal dispersion, as well as that values of indices of refraction increase with silver content in the chalcogenide matrices (for 600 nm, $n = 2.88, 2.94, 3.11, 3.35$ and 3.53 for films with $x = 0, 0.5, 1, 2$ and 3 at. % Ag), while the optical bandgap decreases ($1.70 - 1.59$ eV).

ENR-8

Silicon-based Organic-inorganic Hybrid Solar Cell with High Photon-to-Electron Conversion Efficiency

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Silicon is the most widely used material for solar cells due to its abundance, non-toxicity, reliability, and mature fabrication process. We fabricated silicon nanoholes (SiNHS)/gold nanoparticles (AuNPS)/organic hybrid solar cells and investigated their spectral and opto-electron conversion properties. SiNHS nanocomposite films were fabricated by metal-assisted electroless etching (EE) method. Then, we modified the surface of the nanocomposite films by exposing the samples in the air. After that, polymer poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) blended with AuNPS were spin-coated on the surface of the SiNHS nanocomposite films as a hole-transporting layer. The external quantum efficiency (EQE) values of the solar cells with AuNPS are higher than that of the samples without AuNPS in the spectral region of 600–1000 nm, which were essential to achieve high performance photovoltaic cells. The power conversion efficiency (PCE) of the solar cells incorporating AuNPS exhibited an enhancement of 27 %, compared with that of the solar cells without AuNPS. We thought that the improved efficiency were attributed to localized surface plasmon resonance (LSPR) triggered by gold nanoparticles in SiNHS nanocomposite films.

ENR-9

Substantial Improvement of Short Wavelength Response in n-Silicon Nanowire Hybrid Solar Cells

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We report herein on the effects of silicon nanowire with different morphology on the device performance of n-SiNW/PEDOT:PSS hybrid solar cells. The power conversion efficiency (PCE) and external quantum efficiency (EQE) of the SiNW/PEDOT:PSS hybrid solar cells can be optimized by varying the length of the silicon nanowires. The optimal length of silicon nanowires is 0.23 μm , and the hybrid solar cell with the optimal length has the Voc of 569 mV, Jsc of 30.1 mA/cm², and PCE of 9.3 %. We fabricated more isolated silicon nanowires with the diluted etching solution. And the Jsc of the hybrid solar cell with more isolated nanowires has a significant enhancement, from 30.1 to 33.2 mA/cm². The remarkable EQE in the wavelength region of 300 and 600 nm was also obtained, which are in excess of 80 %. Our work provides a simple method to substantially improve the EQE of hybrid solar cell in the short wavelength region.

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ENR-10

Synthesis and Characterization of MnOx/TiO₂ Nano catalyst particles

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In this study, MnOx/TiO₂ catalysts were prepared and characterized using Chemical vapor condensation (CVC) method, used as a catalyst for the ozone (O₃) catalytic oxidation and efficient energy use. The Mn-based catalysts were impregnated on TiO₂ with two different crystalline phases, TiO₂ prepared with chemical vapor condensation (CVC) method and P25-TiO₂. The catalysts were characterized by specific surface area analysis (BET), X-ray photoelectron spectroscopy (XPS), H₂-Temperature Programmed Reduction (TPR).

In the chemical component and electrochemical performance analyses (such as XPS spectra and cyclic voltametry), CVC-TiO₂ has a higher quantity of Ti³⁺ ions, hydroxyl groups (OH), and larger current, than P25-TiO₂. The specific surface area of TiO₂ with smaller primary particles (≤10 nm), prepared by the CVC method, were 2–4 times larger than the catalysts prepared using P25-TiO₂. The Hydroxyl group (OH) on the surface of CVC-TiO₂ was more than 42%, three times higher than commercial TiO₂ (14%), which increases catalytic activity on the catalyst surface. CVC-TiO₂ has fewer acid sites than P25-TiO₂, which are mostly Lewis acids. However, in optical property analysis, CVC-TiO₂ has a higher absorbance in the short UV wavelength range than P25-TiO₂. In conclusion, CVC-TiO₂ exhibits stronger reducing power and oxidizing ability, and is superior in catalytic performance at lower temperature than P25-TiO₂.

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ENR-11

Surface Modification of Stainless Steel Bipolar Plates of PEMFC: the Basic Materials Design and Its Application in Fuel Cell Vehicles

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The bipolar plate is the most important component and major part in the proton exchange membrane fuel cells (PEMFC) stack manufacturing, and it contribute 60%-80% of the total components of PEMFC stack [1]. So reducing the cost of bipolar plate is one of the key factors to lower the price of PEMFC. However, the traditional artificial graphite bipolar plates are bulky and with high gas permeability, low impact safety and relatively high cost. The noble metal bipolar plates, such as gold or silver, have good performance in all respects, but they are so expensive that the high cost greatly prevents PEMFCs from commercial application. Stainless steel (SS) bipolar plates possess good electrical conductivity, high mechanical strength, and low cost, but poor corrosion resistance and high interfacial contact resistance (ICR). The main criteria properties that any material must present in order to be considered apt to a bipolar plate material are well established by the United States Department of Energy (DOE) as ICR ($<20 \text{ m}\Omega \text{ cm}^2$, DOE's 2020 technical targets $<10 \text{ m}\Omega \text{ cm}^2$) and current densities for corrosion resistance ($<1 \mu\text{A cm}^{-2}$) [2]. According to the criteria of DOE, SS cannot be used as bipolar plates directly. Surface coating of SS bipolar plates by physical vapor deposition (PVD) is an effective way to improve the ICR and the corrosion resistance of metallic bipolar plates.

This work will introduce the research and application of the surface modification technology of SS bipolar plate for PEMFC in China. Continuous Supported by the National High-tech R&D Program (863 Program) and the National Key Research and Development Program of China, a series of modified films on commercial SS316L plates with different chemical compositions and structures, such as Ni_xCr_y single layer, $\text{NiCr}/(\text{NiCr})\text{N}$ multilayer, $\text{Cr}/\text{CrN}_x/\text{Cr}$ single and multilayer, CrN_x single layer, and CrC_x single layer, were carried out. The research result showed that, coating of SS bipolar plates can improve the corrosion resistance of metallic bipolar plates. Excellent performance of bipolar plates was recorded by using $\text{Cr}_{0.23}\text{C}_{0.77}$ coating for SS materials. The ICR value was $2.8 \text{ m}\Omega \text{ cm}^2$ with a low current density (I_{corr}) $0.091 \mu\text{A cm}^{-2}$. And the $\text{Cr}_{0.50}\text{N}_{0.50}$ coating also shows well performance with ICR value $5.8 \text{ m}\Omega \text{ cm}^2$ and I_{corr} value $0.59 \mu\text{A cm}^{-2}$. The criteria for both current densities ($<1 \mu\text{A cm}^{-2}$) and electrical conductivity ($<10 \text{ m}\Omega \text{ cm}^2$) met the DOE's 2020 technical targets. The

PEMFC stack assembled with this $\text{Cr}_{0.23}\text{C}_{0.77}$ coated SS bipolar plate was successfully applied to the fuel cell vehicles and used as the designated VIP car in 2010 Shanghai World Expo.

Acknowledgement

This work was supported by the National Key Research and Development Program of China (Grant No.2016YFB0101206), and the Fundamental Research Funds for the Central Universities (DUT16LAB03) of China.

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ENR-12

The Atomic-scale Enhancement Mechanism of Nitrogen Vacancies Concentration Dependent Mechanical and Electrical Properties of Rocksalt ZrN_x Films

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For further understanding on the atomic-scale mechanism of nitrogen vacancies (VN) concentration dependent mechanical and electrical properties of transition-metal nitride ZrN , seven groups of substoichiometric ZrN films were synthesized on Si (100) substrates by enhanced magnetic filtering arc ion plating. The morphologies and thickness of the as-deposited films were characterized by FESEM; the microstructures and residual stresses were characterized by XRD; XPS and Nanoindenter were utilized to measure the chemical states and hardness (also the elastic modulus) respectively; Hall Effect was utilized to characterize the electrical conductivity, carrier concentration and mobility. The results revealed that the substoichiometric ZrN films (VN=26%~5%) performed stable rocksalt structure within the large VN concentration ranges. The preferred orientation, thickness, grain size and residual stress of the ZrN films with different VN concentrations maintained nearly constant within the error ranges. While the nanohardness and elastic modulus first increased and then decreased

with the decrease in VN concentration. The electrical conductivity showed a similar tendency with the hardness, and the peak value was obtained when VN near to 16%. The underlying enhancement mechanisms of VN concentration dependent mechanical and electrical properties were discussed and the decisive factors were found from the atomic-scale chemical bonding states and electronic structure in this work, rather than the conventional meso-scale factors, such as preferred orientation, grain size and residual stress.

ENR-14

Carbon based thin film heterojunction solar cells

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Carbon based nanomaterials have made dramatic contributions to the development of solar cells due to their advantages as in flexibility, surface area, carrier mobility, chemical stability and optoelectronic properties. This fulfills the requirement of heterojunction based solar cells. Several studies have been reported with C-Si and carbon nanomaterials as heterojunction solar cells with photo conversion efficiencies of about 15% [1]. But, owing to the complexity of problems for C-Si based devices like limited availability of the Si feedstock, high production costs and long energy payback time, an attractive alternative is hydrogenated amorphous silicon (a-Si:H) which can be deposited as thin film at very low temperatures ~150 deg C with advanced deposition techniques and process technology [2].

In this work, we demonstrate that a-Si:H and high quality pristine single-walled carbon nanotubes (SWCNTs) can form very good SWCNT/a-Si heterojunction solar cell. The novelty of the work involved is in the very low energy consuming process technology for fabrication of SWCNT/a-Si heterojunction with stable efficiency of >6% and high open circuit voltage exceeding 750 mV.

Acknowledgements: This research was supported by the Ministry of Education and Science of the Russian Federation (project identifier RFMEFI58114X0006).

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ENR-19

Fabrication of Molybdenum Trioxide Thin Films Using Precursors by Wet Process and Examination of Annealing Conditions

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Molybdenum trioxide (MoO₃) is a wide-gap material that has been used as both the hole-transporting layer and the buffer layer of photonic and electric devices. In this research, we fabricated MoO₃ thin films by a spin-coating method using ammonium molybdate tetrahydrate (AMT, (NH₄)₆Mo₇O₂₄·4H₂O) as a precursor because wet process enables low-cost production. As a precursor solution, we mixed an AMT solution with pure water. The thin films of the precursor solution were formed by a spin coating method. MoO₃ thin film is made by annealing them. We found that the characteristics of the MoO₃ thin films fabricated in this study strongly depend on the annealing conditions of the precursor solution films. Therefore, we examined the transmission spectra, the Fourier Transform Infrared (FT-IR) spectroscopy, and the atomic force microscope (AFM) and transmission electron microscope (TEM) observations of the thin films. We also evaluated the electroluminescence (EL) properties of organic light-emitting diodes (OLEDs) that contain the fabricated MoO₃ thin films as a hole-transporting layer. The precursor thin films became MoO₃ films by annealing at more than 340°C from the FT-IR observations. In addition, the surface roughness increased and the transmittance decreased by annealing at more than 380°C, based on the AFM and transmission spectra observations. Thus, we

concluded that the optimum annealing temperature ranges from 340°C to 360°C. The driving voltage of the OLEDs containing MoO₃, which was annealed at 360°C in air, was reduced by about 44% compared to an OLED containing a PEDOT:PSS layer as a hole-transporting layer. The power efficiency also improved by about 2.17 times. Moreover, we found that the flatness of the MoO₃ thin film surfaces improved by annealing the AMT thin films in air after annealing them in a vacuum.

ENR-20

Transmission Electron Microscope Observation of Al- and Ga-doped ZnO Multi-Layer Transparent Conductive Films Fabricated by Wet Process

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Indium-tin-oxide (ITO) is the most widely used transparent conductive oxide. However, ITO is expensive because indium is a rare metal. Very recently, we fabricated aluminium (Al) and gallium (Ga) co-doped ZnO (AGZO) films using a spin-coating method and found that single-layer AGZO films reveal large resistances because of large surface roughness [1]. In addition, we found that recoated multi-layer AGZO films exhibit very

small resistances due to the improved surface roughness [2]. In particular, the triple-layer AGZO films exhibit minimum resistance. In this study, we evaluated their cross-sectional structures and atom distributions by cross-sectional transmission electron microscope and energy dispersive X-ray spectroscopy (TEM-EDS) observation.

AGZO precursor solution was fabricated using a mixture of Zn(OAc)₂, MEA, and 2-methoxyethanol [1, 2]. Single-layer AGZO films were found to be discontinuous because the glass substrate was unfavorably exposed. On the other hand, we found that the double-layer AGZO films were continuous and their resistances were reduced. The cross-sectional TEM-EDS image of the quintuple AGZO film clearly shows periodic distributions of zinc and oxygen atoms. This indicates that their distributions are not uniform. In particular, the quantity of oxygen atoms gradually decreases from the substrate to the surface, indicating that oxygen defects increased near the surface. This result demonstrates that the annealing condition of each recoated AGZO precursor solution film should be controlled to fabricate uniform multi-layer AGZO films.

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ENR-21

Nanoporous Cathodes from Copolymers for High-Energy-Density LiS-Batteries

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The storage of energy is a challenge for the effective use of regenerative energy sources like wind and solar energy. Efficient and high-energy-density batteries could help in this respect and at the same time make e-mobility more acceptable due to more affordable batteries with higher range. Besides other concepts LiS-

batteries would provide a solution since they promise a much higher energy-density and capacity compared to conventional Li-ion batteries. There are however still many problems to be solved and nano-structured materials

can help in this respect [1]. Copolymers can be used for the design of nanoporous cathodes which contain sulfur in a porous conductive structure [2,3,4]. Nanoporous carbon cathodes for LiS-batteries can be produced by pyrolysis of gyroid replicas based on polystyrene-b-poly-4-vinyl pyridine (PS-b-P4VP) block copolymer sacrificial templates. A free standing gyroid carbon network with highly ordered and interconnected porous structure is fabricated by impregnating the carbon precursor solution into the gyroid block copolymer nanotemplates and subsequently carbonizing them at elevated temperature in an inert media. A wide range of analytical tools are employed to characterize fabricated porous carbon materials. Prepared nanostructures exhibit morphologies with high surface area and uniform porosity with interconnected three-dimensional networks. Those nanoporous templates with gyroid structure provide high cycling stability of LiS-batteries over more than 100 cycles [4]. Further aspects include optimization of collector, separator and electrolyte to optimize battery performance and lifetime [5]. Funding by DFG and BMBF is greatly acknowledged.

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The importance of sequence in dual infiltrated LSCF/CGO nanostructured cathodes

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Solid oxide fuel cells (SOFCs) can convert chemical energy into electricity extremely efficiently. However, there are three significant barriers to their widespread use: long-term stability, low temperature operation and production cost. The typically high temperatures of operation (800 °C) lead to significant microstructure coarsening and the requirement for expensive high temperature resistant electrical interconnects.

Reducing the operating temperature improves the longevity and allows cheaper interconnects to be used but at the cost of unacceptably high polarisation losses. Decorating the porous electrode surface with oxide nanoparticles has been shown as an effective method to reduce polarisation losses [1]. Oxide nanoparticles enhance electrode performance in two ways: catalysing the oxygen reduction reaction (ORR) and geometrically extending the triple phase boundary (TPB). The TPB is the region where atmosphere meets electronic and ionic conductors and is the location for rate controlling electrochemical reactions. Both effects reduce the area specific resistance (ASR) as measured by electrical impedance spectroscopy (EIS) and therefore reduce the energy losses associated with electrode overpotentials.

Wet infiltration has been shown to be an effective method to incorporate nanoparticles [2]. A precursor solution is infiltrated into the porous electrode and nanoparticles grow on the surface during a simple heat treatment in air. Most lab-scale research involves laborious micro-pipetting and vacuum treatments. However, in the reported work nanoparticle precursor solutions are deposited into porous cathodes using drop-on-demand inkjet printing technology. This is a cost effective and scalable technique that also has advantages for reducing material waste and improving solution penetration [3], [4].

Cobalt oxide and CGO nanoparticle decoration both reduce the ASR of SOFC cathodes. Cobalt oxide has a higher activity for the ORR than CGO but poorer long-term stability. Hence, dual infiltration of both materials can capture both benefits [5]. It was found that the sequence of infiltration was important to the performance improvement and the stability of the cathodes. The current work reports EIS results for symmetric cathode cells demonstrating improved performance and cell stability when CGO is infiltrated before cobalt oxide precursors.

Symmetric cell EIS data are complemented by HR-SEM characterisation and large area (25 cm²) complete fuel cell testing.

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ENR-23

One-Dimensional Organo-Metal Halide Perovskite Nanorods and Nanowires: Applications to Photovoltaic Solar Cells

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Hybrid organo-metal halide perovskites have attracted much attention over the recent years, mainly due to the high conversion efficiency (of sun light to electricity, exceeding 20%) achieved for these perovskite-based solar cells. Yet, to date there are still problems and challenges that limit the exploitation of perovskites from use in commercial applications. For example, incomplete control over morphologies, creation of defects during growth and stability issues of perovskite thin films that suffer from degradation with time, have limited the use of these materials. A possible route to overcome some of these difficulties is by using low-dimensional perovskite nanostructures where size, shape and basic physical & electronic properties can be tailored and controlled.

Here, we demonstrate the use of small-diameter porous silicon (PSi) templates for growing one-dimensional (1D) alkyl-ammonium-lead-halide-perovskite (CH₃NH₃PbI₃) nanorods and nanowires [1-2], and the ability to control their size, shape, orientation and other fundamental properties. In particular, we demonstrate that 1D perovskite nanorods can be utilized to prevent structural phase-transitions in these nanostructures and to improve photoluminescent stability over time [2]. The exploitation of these nanostructures for developing a new class of hybrid (porous silicon – perovskite nanowires) photovoltaic solar cells will also be described.

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ENR-24

Thin film composite layer for electrochromic devices

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Electrochromic devices (ECDs) containing electroactive materials can reversibly change their optical absorbance and transmittance according to applied voltage, and this property is utilized in a variety of applications such as reflective displays, antiglare mirrors, smart windows and sensors. Electrochromic devices (EC), which dynamically change colour under applied potential, are widely studied for use in energy-efficient smart windows. To improve the viability of smart windows, many researchers are utilizing nanomaterials, which can provide electrochromic devices with improved coloration efficiencies, faster switching times, longer cycle lives, and potentially reduced costs. The flexible electrochromic films are promising film for applications in automobiles, buildings, etc. When the flexible substrate are used in EC, the barrier performances are needed for long term stability.

Here, solution processed polymer composite materials are synthesized and characterized. The composition and process condition exhibit the encapsulant performances. The performances as a barrier layer for flexible film and a side encapsulant material are characterized and will be discussed.

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Low energy consuming electrochromic devices using low temperature process**Su Mi Park, G. Rafeequl Bari, Haekyoung Kim***Yeungnam University, Gyeongsan, Korea*

Electrochromic devices (ECDs) containing electroactive materials can reversibly change their optical absorbance and transmittance according to applied voltage, and this property is utilized in a variety of applications such as reflective displays, antiglare mirrors, smart windows and sensors. Electrochromic devices (EC), which dynamically change colour under applied potential, are widely studied for use in energy-efficient smart windows. To improve the viability of smart windows, many researchers are utilizing nanomaterials, which can provide electrochromic devices with improved coloration efficiencies, faster switching times, longer cycle lives, and potentially reduced costs. The flexible electrochromic films are promising film for applications in automobiles, buildings, etc.

Solution processed tungsten trioxide (WO_3)-based electrochromic devices (ECDs) are successfully demonstrated. The thin layers with nanostructured materials of WO_3 inks were coated at room temperature, solution-processed method. In contrast to conventional ECDs based on metal oxides, we controlled the composition of electrolyte. We directly introduce ferrocene (Fc) as an anodic species into the electrolyte layer. Two types of polymer based electrolytes were fabricated and characterized. The operation voltages were controlled with electrolyte types and compositions. Ionic liquid based electrolyte showed higher ionic conductivity than liquid type or polymer type electrolyte. Also EC with the liquid electrolyte exhibited 40% of coloring/bleaching efficiencies and EC with the polymer gel electrolyte 60%.

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[2] V. K. Thakur, G. Ding, J. Ma, P. S. Lee and X. Lu, *Adv. Mater.*, 24, 4071 (2012).

Innovative Smart Coatings for thin Films Solar Cells PV Cells

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The UK energy sector is facing an energy problem, to deliver secure energy supplies in an affordable manner, all whilst reducing greenhouse gas (GHG) emissions. Therefore, in the last decade, solar PV has been rapidly growing to fill the gap that currently exists in energy market. Nevertheless, thin film systems are still limited due to their low operational efficiencies ($\leq 15\%$). Organic down-converters have the ability to increase efficiency with relatively low investment, whilst providing technical and commercial advantages for solar PV systems. However, addition of down-converter layers also creates additional light interactions, resulting in potential loss mechanisms from host material and luminescent species.

To address these challenges, we have explored the development of inorganic/organic coatings for thin film PV systems based on organic dyes encapsulated in a silica coating. Our findings on the preparation of porous silica nanoparticles, incorporating encapsulated organic down-converters into a resin matrix as well as the photophysical properties of the modified coating system will be presented.

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ENR-30

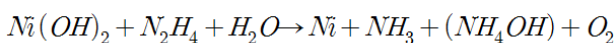
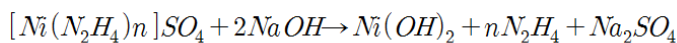
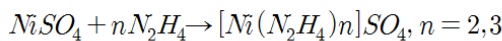
Fabrication of Nanosized Nickel Powder from Nickel Sulfate(NiSO₄)

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A study on the fabrication of nanosized nickel powder from nickel sulphate through reduction processing using hydrazine(N₂H₄) and sodium hydroxide(NaOH). The reduction reaction is shown as following:



[Ni(N₂H₄)_n]SO₄ was formed by reaction with hydrazine and NiSO₄ solution containing 6 wt.% of nickel. The formation of [Ni(N₂H₄)_n]SO₄ was found to be affected by temperature and time. Consequently, hydroxide was added to fabricate metallic nickel powder on the ratio of NiSO₄ to NaOH with 10:1, 10:1.5 and 10:5 respectively. Finally metallic nanosized nickel powder was successfully obtained and mean particle size was about 100 nm.

ENR-31

Oxidation of Solid Fuels in a Molten Carbonate Fuel Cell

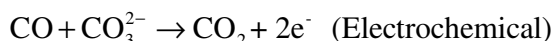
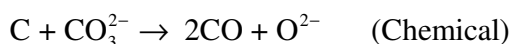
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A molten carbonate fuel cell (MCFC) has been employed in the world as a distributed heat and power source. In particular, the capacity of MCFC power plant only in Korea is about 150 MW. Against its distribution as a power source, the economics of MCFC systems could be a problem. One of the problems is fuel cost because the natural gas is a high grade fuel. In this work, two of solid fuels are tested in a coin type MCFC. One is the carbon which is quite abundant in the world. Especially carbons from biomasses, e.g., bamboo and oak are

employed. Another fuel is ash-free coal (AFC). Four kinds of raw coal, bituminous, sub-bituminous, lignite and anthracite are used.

The oxidation behaviours of carbon and AFC in a coin type molten carbonate fuel cell were investigated in terms of active species, generated gases, carbonate addition effect, temperature, raw coal species, etc. In conclusion, the carbon is oxidized chemical and electrochemical processes as follows;



On the other hand, the AFC is gasified to H₂ and CO, therefore its oxidation is different from that of carbon. The AFC is oxidized at the low temperature of 650°C where the carbon cannot be oxidized. In addition, the gasification of AFC does not require carbonate catalyst. The AFCs from different raw coal species showed similar oxidation behaviours.

ENR-32

A Method for Controlling the Synthesis of Stable Twisted Two-Dimensional Conjugated Molecules

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Thermodynamic stabilization (π -electron delocalization through effective conjugation) and kinetic stabilization (blocking the most reactive sites) are important considerations when designing stable polycyclic aromatic hydrocarbons displaying tunable optoelectronic properties. In this paper, we demonstrate an efficient method for preparing a series of stable two-dimensional (2D) twisted dibenzoterrylene-acenes. We investigated their electronic structures and geometries in the ground state through various experiments assisted by calculations using density functional theory. We found that the length of the acene had a clear effect on the photophysical, electrochemical, and magnetic properties. These molecules exhibited tunable ground-state structures, with a highly stable open-shell singlet tetraradical obtained for the first time. Such compounds are promising candidates for use in nonlinear optics, field effect transistors, and organic spintronics, and may enable broader applications of 2D small organic molecules in high-performance electronic and optical devices.

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ENR-33

Effects of Pulse Plating on Lithium Electrodeposition for Lithium ion Batteries

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Lithium metal has shown great promise as an anode material for high-energy storage systems, which delivers an ultrahigh theoretical specific capacity (3860 mA h g^{-1}) owing to its lowest density (0.59 g cm^{-3}) and electrochemical potential (-3.04 V SHE) among all metallic elements. However, uncontrolled dendrite growth not only causes serious safety problem but also produces “dead lithium” and broken solid electrolyte interfacial (SEI) film during charge/discharge cycles, which leads to low coulombic efficiency. In this study, we have deposited a densely lithium layer as anode electrodes on copper foils. Compared with Constant Current (CC) electrodeposition, Pulse Plating (PP) waveforms with short and widely spaced pulses improve lithium deposition morphology and cycling efficiency. Furthermore, we discussed the challenges and potential opportunities of lithium metal anode for practical applications.

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A study on the non-aqueous symmetric redox flow battery**J.Y. Seo, B.K. Kim, T.K. Yoo, C.-H. Chung****School of Chemical Engineering, Sungkyunkwan University, Suwon 16419, Republic of Korea*

Recently, numbers of researchers are actively working on electrochemical energy storage (EES) of high-energy density such as redox flow batteries. In this research, we conducted experiment to suggest effective solution for representative problems of conventional redox flow batteries. In case of using vanadium as a conventional redox material in aqueous system, water splits when the voltage increases over 1.23 V in charge-discharge process, and it downgrades the performance of redox flow batteries. Also, general vanadium redox flow batteries are of asymmetric system in which the oxidation number of vanadium in positive and negative site are sequential. In this case, if the cross-over of electrolyte or irreversible reaction happens, the performance decreases dramatically.

In order to settle this phenomenon and show excellent stability of redox flow batteries, identical redox materials were used to form a symmetric system and reverse charge-discharge process was employed in part. Additionally, the potential during charge-discharge process was increased by using all-organic materials, and finally the redox mechanism of 2,3-Dimethyl-1,4-di-N-oxide quinoxaline was analyzed with *in-situ* and *ex-situ* FT-IR.

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Study of Carbon-based hole transport material (HTM)-free perovskite solar cells**H.S. Zheng, C. H. Li, A. X. Wei, J. Liu, Y. Zhao, Z. M. Xiao***Guangdong Provincial Key Laboratory of Functional Soft Condensed Matter, School of Material and Energy, Guangdong University of Technology, Guangzhou 510006, China*

Hybrid organic/inorganic perovskite solar cells (PSCs) have recently emerged as attractive solar cell [1, 2]. A typical PSC consists of electron transport materials, perovskite layer, hole transport materials (HTMs), and noble metal electrode. However, the conventional organic HTMs (e.g. spiro-OMeTAD) and noble metal (Au) are usually expensive and unstable. Carbon-based HTM-free PSCs have shown much promise for practical applications because of their high stability and low cost [3]. However, the efficiencies of this kind of PSCs are still relatively low. In this paper, the PSCs with structure of glass/FTO/ compact TiO₂ / mesoporous TiO₂ /CH₃NH₃PbI₃/C were prepared and its photovoltaic performance was studied.

In the PSC fabrication process, compact layers and mesoporous layers of TiO₂ were prepared using dip-dropping method and spin-coating, respectively. C electrode was fabricated by blade-coating. The perovskite layers (CH₃NH₃PbI₃) were prepared by using two-step method. The first step, PbI₂ thin films were deposited by spin coating method using 1.0 M PbI₂/DMF solution. The second step, PbI₂ thin films were dipped in 7mg/mL of MAI/IPA solution for 0.5 h, 2.5 h, 3.5 h and 4.0 h, respectively. The SEM images and XRD patterns were shown in in Figs. (a) and (b) to evaluate the morphology and structure change of perovskite layers with reaction time. J-V characteristic curve of PSCs were shown in Fig. (c). Results indicated that the crystal size increase gradually with reaction time, and the average grain size of CH₃NH₃PbI₃ is the largest when reaction time is 3.5h. The most of the PbI₂ is converted to CH₃NH₃PbI₃ within the initial 0.5 h. But 3.5 h is needed to completely convert PbI₂ to CH₃NH₃PbI₃. The perovskite solar cells prepared at reaction time of 3.5h exhibits an optimal photovoltaic performance. The open circuit voltage is 0.881V, short-circuit current of 22.17mA/cm², power conversion efficiency of 6.79%, and the efficiently of the incident photons converting to the electrons (IPCE) is close to 50% in visible range.

Reference:

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Notes:

DMF: bis(pentane-2,4-dionato-O,O')bis(propan-2-olato)titanium, N,N-Dimethylformamide

MAI: methylammonium iodine

IPA: isopropanol

ENR-37**Synthesis of $\text{Cu}_2\text{ZnSn}(\text{S}_x\text{Se}_{1-x})_4$ nanocrystalline thin films directly on transparent conductive glass substrates by Solvothermal method**

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$\text{Cu}_2\text{ZnSn}(\text{S}_x\text{Se}_{1-x})_4$ (CZTSSe) have been proved to be promising materials for solar cell applications due to earth abundant elements, high absorption coefficient in the visible range and tunable band gap from 1.1 eV (CZTSe) to 1.5 (CZTS) [1, 2]. Solvothermal synthesis method is more suitable for inexpensive mass production. To date, there are a few reports with regard to solvothermal synthesis of CZTSSe nanocrystal, and then, the CZTSSe ink was prepared by dispersing the nanocrystals in solvent. Nanocrystals 'ink' can be 'printed' on nearly any type of surface to fabricate large-scale and low-cost solar cells [3, 4]. In this paper, we describe a simple solvothermal method for direct growth of CZTSSe thin films on transparent conductive fluorine-doped tin oxide (FTO) substrates

In the solvothermal fabrication process, precursors of hexadecyl trimethyl ammonium bromide(CTAB) , freshly prepared sodium selenosulfate, copper (II) chloride dihydrate, tin(II) chloride dehydrate, zinc(II) chloride, thiourea and ethanol were used. The single-step solvothermal method was proposed to grow $\text{Cu}_2\text{ZnSn}(\text{S}_x\text{Se}_{1-x})_4$ thin films directly on FTO substrates. The composition 'x' was varied by changing the concentration of thiourea and sodium selenosulphate in the precursors. The effects of composition 'x' on the structure, morphology,

optical properties and growth mechanism of CZTS thin films were investigated by X-ray diffraction, Raman spectroscopy, transmission electron microscopy, scanning electronic microscope, X-ray photoelectron spectrometer and UV-vis spectrophotometer. The results indicated that CZTSSe thin films are in kesterite phase, composed of a large number of uniform sphere-like particles with an average diameter of about 650nm. By varying the S/Se ratio in the solution, the chalcogen composition of CZTSSe NCs can be well controlled over the whole range, leading to a tunable bandgap. The growth mechanism of the CZTSSe films was discussed.

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ENR-38

The influence of annealing atmosphere on structure, ferroelectric and photovoltaic performance of BiFeO₃ thin films

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We have prepared BFO thin films on FTO substrates by sol-gel method, and they were rapidly annealed under different atmosphere for air or N₂ respectively. The influence of different annealing atmosphere on the structure, ferroelectric and photovoltaic performance was studied. The XRD and SEM results have shown that the BFO thin films annealed under N₂ atmosphere showed a smaller grain size and well crystallinity. Low leakage current density and P-E hysteresis were found only in the BFO film annealed in N₂ atmosphere. The ultraviolet-visible absorption spectrum of BFO thin films annealed under N₂ atmosphere showed broader wavelength range and stronger intensity, the band gap could be modulated to 2.33eV. At the same time, the BFO thin films annealed under N₂ atmosphere have greater open-circuit voltage and short-circuit current.

Above results show that the ferroelectric and optical performances of BFO thin films have been improved annealed under N₂ atmosphere.

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ENR-39

Graphdiyne for High Capacity and Long-Life Lithium Storage

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Although the Li capacity can be improved greatly with these different dimensionalities and morphologies, the nature of the Li-intercalated layer does not change significantly when compared to graphite. Graphdiyne (GDY) is a new carbon allotrope that was only synthesized recently. GDY is composed of sp²- and sp-hybridized carbon atoms and is predicted to be the most stable of the various diacetylenic non-natural carbon allotropes. Here, we will report the application of GDY as high efficiency lithium storage materials and elucidate the method of lithium storage in multilayer GDY (Fig 1).^[1,2] Lithium-ion batteries featuring GDY-based electrode exhibit excellent electrochemical performance, including high specific capacities, outstanding rate performances, and a long cycle lives. We obtained reversible capacities of up to 901 mAh/g after 400 cycles at a current density of 100 mA/g. At an even higher current density of 2 A/g, cells incorporating GDY-based electrodes retained a high specific capacity of 420mAh/g after 1000 cycles. We hope that designing and preparing novel carbon-based materials with large pores will open up new approaches for the development of Li storage materials exhibiting high capacities and excellent cycling stabilities, thereby satisfying the future requirements of next-generation Li storage batteries.

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ENR-41

Surfactant-free Synthesis of 3D PtNi Nanosponges Wrapped with Graphene-dots and their Application to Effective Catalysts for Oxygen Reduction Reaction

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In this study, we first report how to synthesize 3D PtNi nanosponges without using surfactants. A 3D PtNi nanosponge wrapped with graphene dots was synthesized at room temperature using formic acid as a reducing agent and N-doped carbon dot as a structure-directing reagent. 3D PtNi nanosponge was formed only in the presence of carbon dots in the reaction solution. During the reaction, the N-doped carbon dots were reduced and exfoliated to graphene dots, which encapsulated PtNi nanocrystals. The composition of the developed nanosponge can be easily controlled by adjusting the reaction temperature. The prepared material exhibited excellent catalytic activity and durability for oxygen reduction reaction as compared with commercially available Pt/C. This is due to the self-supporting structure of interconnected nanosponge and the role of the graphene shell wrapping around the PtNi nanosponge. The proposed strategy has the potential to synthesize other multi-metal nanocrystals with 3D nano sponge structures that are expected to provide high catalytic performance in other electrocatalyses such as hydrogen evolution reaction and oxygen evolution reaction.

ENR-42

N-Cdot/Pd Nanosponge with Enhanced Electrocatalytic Activity for Hydrogen Evolution Reaction and Methanol Oxidation Reaction

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N-Cdot/Pd nanosponge was effectively synthesized by using N-doped carbon dots (N-Cdot) as a structure directing agent and L-ascobic acid as a reducing agent. The N-Cdot/Pd nanosponge electrode exhibited a low overpotential of -55 mV at a current density of 10 mAcm⁻², while providing excellent stability for hydrogen evolution reaction in acidic conditions. In addition, the N-Cdot/Pd nanosponge electrode showed high catalytic activity and stability for the methanol oxidation reaction in 0.1 M KOH aqueous solution containing 1 M methanol. The high catalytic activity of the N-Cdot/Pd nanosponge is mainly due to the synergistic effect caused by intimate contact between the Pd and the N-doped carbon dots, as well as the larger electrochemically active surface area (ECSA) provided by the sponge structure.

ENR-45

Ultrasonically spray coated silver layers from designed precursor inks for flexible electronics

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The integration of electronic components in flexible materials such as paper, textiles and plastics is identified as a key challenge for the development of future smart applications for energy harvesting such as photovoltaics, but also for sensors, RFID tags and wearables. In this perspective, the fast and scalable low-temperature deposition of nanoscale metallic features is of utmost importance. This study focusses on the combination of novel silver inks and deposition via ultrasonic spray coating (USSC) to meet the above prerequisite. The use of different amine ligands and solvent combinations to stabilize the silver ions in solution were explored. By evaluating properties of the ink and the deposited silver layers such as shelf-life, adhesion, sheet resistance, roughness and composition, the optimal ink formulation and deposition temperature could be determined. Furthermore, an in-depth analysis of the silver layers yields detailed chemical insights related to the ink

decomposition. In the end, stable, non-toxic and spray coat compatible silver MOD (metal organic decomposition) inks were formulated that allowed deposition of Ag thin films on plastic substrates at low temperature (< 120 °C). This new combination of USSC with MOD inks resulted in smooth (< 20 nm RMS roughness), semi-transparent silver layers with 15% bulk conductivity, without the need for time-consuming post-treatments or complex rheological ink optimization as often required for inkjet printing. In addition, the formulated inks and applied deposition technique hold promise to coat virtually any substrate (including 3D structures) and are compatible with fast R2R processing. As a first application, the deposition of silver RIFD tags on PET substrates was targeted.

Acknowledgements: The authors acknowledge the research foundation of Flanders (FWO) for the financial support (Grant G041913N).

ENR-46

Catalytic synthesis of MoSe₂ nanorods on TiO₂ nanoparticles by hydrothermal method

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Recently, transition-metal dichalcogenide (TMD) materials synthesized via physical/chemical procedures have received attention owing to their potential for utilization in energy conversion and storage, catalysis, sensing, memory devices, and other applications. Among them, MoSe₂ has received considerable attention as it has been proved to be an excellent catalysis for applications like hydrogen evolution [1], lithium storage[2], supercapacitor [3], and DSSCs [4]. However, MoSe₂ tends to have a layered structure and can be easily re-stacked together owing to their interlayer van der Waals attractions and high surface energy, leading to the loss of catalytic active sites [5]. One-dimensional (1D) TMD, such as nanorod and nanotube, does not have the problem of stacking and exhibits less dangling bond. Besides, 1D TMD are supposed to display rich physical and chemical properties, which offers an exciting material system for exploring the fundamental science and developing novel technologies. However, to the best of our knowledge, reliable realization of MoSe₂ nanorod or nanotube in experiment has not been reported so far. Catalytic deposition is a widely used strategy for the control growth of 1D nanomaterials, which has boosted the numerous research of carbon nanotube in the past two decades [6]. In this paper, for the first time, we successfully synthesize MoSe₂ nanorods using TiO₂

nanoparticles as catalysis by a facile hydrothermal method. The 1D MoSe₂ was characterized using SEM, TEM, XRD and Raman spectrum. The photocatalytic properties of MoSe₂ nanorods on TiO₂ nanoparticles were also discussed as to explore its potential for energy application. The synthesis of MoSe₂ nanorods was described briefly as follow. 0.004mol Se powder was dissolved in hydrazine hydrate solution (10 ml) in a flask and unchanged under atmospheric conditions at least for one day. In a separate flask, 0.002 mol Na₂MoO₄ was dispersed in 50ml distilled water. Then two kinds of solution mixed slowly at room temperature. The commercialized TiO₂ nanoparticles was screen-printed on FTO glass and placed in a 100 ml teflon liner where the mixed precursor was added. Hydrothermal process was subsequently performed at 200°C for 10h.

Fig. 1 gives the typical SEM and TEM images of MoSe₂ nanorods on TiO₂ nanoparticles. MoSe₂ nanorods was randomly grown from the underneath TiO₂ nanoparticles with length around several micrometres and diameter in the range of tens of nanometers. Note that the diameter of MoSe₂ nanorods is very close to the particle size of TiO₂. Additionally, MoSe₂ nanorods cannot be found on bare FTO and quartz in our experiment. Such results imply that TiO₂ nanoparticles are active for the growth of MoSe₂ nanorods.

The XRD pattern of the sample in Fig. 2(a) reveals typical peaks of both hexagonal MoSe₂ (JCPDS: 29-0914) and anatase TiO₂ (JCPDS: 21-1272) simultaneously. The peaks of 13.0°, 33.2°, 37.9°, 48.2° and 55.3° can be indexed to (002), (004), (100), (105) and (008) planes for MoSe₂, while the peaks of 25.5°, 37.9°, 48.2°, 54.2°, 55.3° and 62.8° can be assigned to (101), (004), (200), (105), (211) and (204) planes for TiO₂, standing as evidence of the formation of the MoSe₂ and TiO₂ composite. The Raman spectrum of the sample in Fig. 2(b) indicates the existence of both MoSe₂ and TiO₂. Beside the characteristic Raman peak for TiO₂, the A_g¹ and E_{2g}¹ Raman modes of MoSe₂ were observed at 238 and 288 cm⁻¹. The Raman peak of TiO₂ at 144 cm⁻¹ shifted to a larger value after the growth of MoSe₂ nanorods, which might results from the increased size of the TiO₂ particles during the hydrothermal process.

The great amount of MoSe₂ nanorods grown on TiO₂ nanoparticles actually constructs a kind of 0D/1D heterogeneous structure. The calculated Fermi level of bare TiO₂ when compared to the vacuum one is lower than that of MoSe₂ [7]. So that an effective electron migration can be generated from TiO₂ to MoSe₂ at the interface of the MoSe₂/TiO₂, prolonging the lifetime of massive photogenerated carriers from irradiating TiO₂ and thus decreasing the recombination rate of photoinduced carriers. Prolonged lifetime of MoSe₂/TiO₂ heterogeneous structure can be adequately involved in photocatalysis.

As to explore the photocatalysis activity of MoSe₂/TiO₂ heterogeneous structure, the fabricated samples were used as photoanode for dye-sensitized solar cells (DSSCs). The J-V characteristics of the DSSCs were measured and analyzed.

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ENR-47

Ag-ZnO@C Nanocomposite for Visible Light Photocatalysis

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The development of coupled photoactive materials (metal/semiconductor) has resulted in significant advancements in heterogeneous visible light photocatalysis. This work reports the novel biogenic synthesis of visible light active Ag-decorated zinc oxide-carbon (ZnO@C) core-shell nanoparticles for photocatalysis using an electrochemically active biofilm (EAB). ZnO@C core-shell nanoparticles were synthesized using a facile and single-step method, which involved the thermal degradation of a zinc aniline nitrate complex in methanol. The results showed that the EAB functioned as a biogenic reducing tool for the reduction of Ag⁺, thereby eliminating the need for conventional reducing agents. The as-prepared Ag-ZnO@C nanocomposite was characterized by X-ray diffraction, transmission electron microscopy, diffuse reflectance spectroscopy, photoluminescence spectroscopy, and X-ray photoelectron spectroscopy. The photocatalytic experiments showed that the Ag-ZnO@C nanocomposite possessed excellent visible light photocatalytic activity for the degradation of rhodamine B. The enhanced visible light degradation of rhodamine B by Ag-decorated ZnO@C nanocomposite was much higher than that by pure ZnO and ZnO@C. The enhanced photocatalytic activity was attributed to the delayed charge recombination due to the Ag- and nano-coating of carbon on ZnO along with

the presence of oxygen vacancies. The Ag-ZnO@C nanocomposite also showed exceptionally high stability and reusability could be exploited as potential candidate for visible light photocatalysis.

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ENR-48

Annealing Effect on The Spin Coated CZTS Thin Films

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As an alternative to $\text{CuIn}_x\text{Ga}_{1-x}\text{Se}_2$ (CIGS) photovoltaic absorber thin films, elimination of undesirable phases in copper zinc tin sulfide ($\text{Cu}_2\text{ZnSnS}_4$, CZTS) thin film structures is not easy. Therefore, the preparation of CZTS single crystal thin films depends on the complete elimination of these undesired phases which act as a crystal defects in the structure. Many studies using the sol-gel method show that the most important factors in overcoming this crystal defects in the thin films are the heat treatment.^[1-6] However, there are no detailed studies covering temperature, time and atmosphere concentrations. The stoichiometry analysis through such a study will give valuable information about the quality of crystallinity due to the annealing. In this work, we aimed to investigate the relationship between annealing parameters and thin film crystallinity. The CZTS layers were spin coated on soda lime glass substrates with optimal deposition parameters. CuCl_2 , SnCl_2 , ZnCl_2 and thiourea metal salt precursor chemicals were dissolved in 2-metho and MEA mixture. The ratio of the Cu, Sn, Zn and thiourea in solutions was fixed at 2:1:1:8. In order to be able to compare the effects of the annealing time, temperature and atmosphere, samples were annealed for different period of times and temperature in air, N_2 and combination of N_2 with powdered S vapor.

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ENR-51

Modification of the LCD devices interface and body by carbon nanotubes and lanthanides

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Due to the intensive use of organic optoelectronic elements with sandwich constructions in laser modulators, liquid crystal (LC) display and biomedical instruments the technology becomes the relevant question of the design optimization and interface conditions modification. The advantages are the followings: reduces of the bias voltage, decreasing the number of functional layers and other thin-film conductive contacts at the interface: solid-state substrate-liquid crystal mesophase. In this case the problem connected with the study of the relief formation mechanism on the surface of different materials during their structuring by carbon nano-objects, mainly carbon nanotubes (CNT), is quite timely.

Based on our previous results [1-3] and current study the laser-deposited ITO conducting coatings have been modified with vertically oriented CNTs and treated with the surface electromagnetic waves using CO₂-laser. This procedure permits to produce the transparent conducting structures with good mechanical and laser strength, high wetting angle and decreased value of the bias voltage. In addition, it creates a non-toxic orienting surface topography for liquid crystal cells and can be useful under the conditions to work with biological objects, such as red blood cells and DNA.

Moreover, the modification of the volumetric nematic LC mesophase by the lanthanides nanoparticles permits to obtain the LC materials with the quasi-smectic transition via simple procedure to develop the intermolecular charge transfer complex formation.

Results of our work were also partially supported by Russian Foundation for Basic Research, grant No.13-03-00044 as well as by FP7 Marie Curie International researchers exchange proposal "BIOMOLEC" (2011-2015).

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Subscriptions:

ITO - Indium tin oxide;

LCD – liquid crystal display;

LC - liquid crystal;

CNT – carbon nanotubes;

CO₂ - carbon dioxide laser;

DNA - Deoxyribonucleic acid.

ENR-52

The reaction energy, mechanical behavior and impact insensitivity of core–shell Al–PTFE/W composites.

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Polytetrafluoroethylene (PTFE) and active metal are a new kind of energetic materials, which react to release high energy. At present, the tungsten, PTFE and aluminum are widely used in energetic materials and reaction fragment. However, the alumina has a high melting point, which hinders the reaction of PTFE and aluminum. In order to solve the problem of insufficient W-Al-PTFE reaction, we study the interfacial treatment of active materials. We use PTFE instead of alumina to form a core-shell structure of PTFE and aluminum. The PTFE

shell not only prevents nano-Al oxide, but enhances the reaction kinetics as well, greatly improving the fuel reactivity. So this core-shell nanostructure makes the reaction more fully and more energy than that of ordinary physically mixed W/Al/PTFE. We use PTFE coated aluminum without the oxide layer, which can product PTFE shells with only a few nanometers in thickness. This method may provide a general approach to the preparation of other high-energy fuel. Furthermore, we investigate the reaction energy, mechanical behavior and impact insensitivity of core-shell Al-PTFE /W composites.

ENR-53

Photocatalytic degradation of Organic Dyes with Titania Nanotube and Nanorod powders prepared by Rapid Breakdown Anodization

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Single-walled titania nanotube powder is prepared using 0.1 M HClO₄ electrolyte at 20 V by a rapid breakdown anodization (RBA) method. The as-prepared nanotubes are calcined at 250-550 °C to study the effect of annealing on the morphology and structure of the nanotubes. The as-prepared nanotubes displayed the highest specific surface area and 80 % reduction in the specific surface area is observed upon calcination. The 52 % decrease in the specific surface area is obtained at 350 °C due to the nanotubes diffusing into nanorods. The nanotubes and nanorods have anatase crystal structure until 450 °C, while nanorods start to transform into rutile phase at 550 °C. The bandgap energy of observed as-prepared titania nanotubes is 3.18 eV and it reduces upon calcination. The photocatalytic efficiency of the powders was evaluated under UV light by decolorization of both anionic and cationic organic dyes, i.e. methyl orange (MO) and rhodamine B (RhB), as model pollutants. The nanorods calcined at 350 °C displayed a higher decolorization efficiency for MO compared to the as-prepared nanotubes. However, both the as-prepared nanotubes and the nanorods calcined at 350 °C displayed similar decolorization of RhB.

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ENR-56

Fabrication of $\text{CoIr}_x/\gamma\text{-Al}_2\text{O}_3$ modified electrode and use in electrochemical oxidation of hydrazine

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Electrocatalytic oxidation of hydrazine was investigated on $\text{CoIr}_x/\gamma\text{-Al}_2\text{O}_3$ modified glassy carbon electrode (GCE) using cyclic voltammetry. The prepared catalysts were characterized using AAS, XRD, N_2 physisorption, TPR, TPO, and SEM equipped with EDX which showed the formation of Co-Ir nanoalloy particles well dispersed on $\gamma\text{-Al}_2\text{O}_3$ support. All catalysts showed activity for oxidation of hydrazine owing to synergistic effect of Co-Ir nanoparticles. Moreover, the optimum composition of $\text{CoIr}_{0.081}/\gamma\text{-Al}_2\text{O}_3$ exhibited an excellent electrocatalytic activity towards hydrazine oxidation with anodic peak current of 47.2 μA at active potential of 0.86 V. The aim of present work was optimal loading of CoIr_x over $\gamma\text{-Al}_2\text{O}_3$ in electrode fabrication for hydrazine electrolysis.

ENR-58

Atomic Layer Deposited Materials for Energy Applications

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In energy technology new materials and structures are taken in use and thin films and nanomaterials will play an important role. Nanomaterials may offer innovative solutions for all renewable energy technologies from energy conversion to energy storage and usage. In preparation of thin films of nanomaterials and nanostructures

Atomic Layer Deposition (ALD) can be beneficial since ALD as a layer-by-layer thin film deposition technique is known to enable deposition of conformal and homogeneous films which follow precisely the shape of the substrate [1]. ALD has several superior characteristics, most notably conformality, uniformity over large substrates and batches, accurate thickness and composition control, and low defect densities. But ALD has also a weakness in being slow technique in terms of film thickness deposited per time unit. Batch processing and spatial ALD (roll-to-roll) [2] help in compensating for the low growth rate by increasing the surface area coated and hence film volume produced in a single tool, but still ALD has difficulties in competing cost-wise with other methods. Therefore ALD research is focused on applications where there are no competing techniques or they are facing major difficulties in meeting the requirements on film quality. Most often this means strongly three-dimensionally structured devices (porous substrates, nanotubes, nanowires etc.) with high aspect-ratio features that are challenging to be coated conformally.

Since late 1990's materials for microelectronics have formed the most important application area for ALD. New emerging areas such as optics, energy technology, and different barriers and coatings have developed within the time [3]. The utilization of the ALD method in energy technology materials has already been widely studied but real applications are still sparse. In this presentation the ALD literature concerning materials for energy conversion (solar cells, thermoelectrics), energy storage (Li-ion batteries, supercapacitors) and use of energy (fuel cells) are briefly discussed.

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ENR-59

Corrosion Behavior of Y_2SiO_5 Environmental Barrier Coatings by CMAS (CaO–MgO–Al₂O₃–SiO₂)

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Silicon-based ceramics such as SiC/SiC_f composites and silicon carbide (SiC) are of interest as candidate materials for the hot-section components of new-generation gas turbines in order to meet future higher fuel efficiency and lower emission goals for engines because of their excellent high-temperature mechanical properties (e.g., retention of high-temperature strength and toughness up to 1400°C) [1,2]. However, since it is

prone to hot-corrosion in thermally extreme environments (ex, steam), the development of environmental barrier coatings (EBCs) is mandatory. In the present work, Y_2SiO_5 EBCs have been deposited by plasma spray technique as protection layer of SiC substrate from oxidation and steam corrosion. Y_2SiO_5 coatings were exposed at 1400°C for 1~50hr by isothermal heat treatment in the presence of an erosive impurity of calcium-magnesium-aluminosilicate (CMAS). At the interface between the Y_2SiO_5 coatings and CMAS, the coatings were partially dissolved in the CMAS, resulting in the degradation of coatings by the formation of the reacted region. The chemically reacted region from the top surface of the Y_2SiO_5 coatings showed increasing tendency with an increase in isothermal heat-treatment time. In addition, the hardness and elastic modulus of Y_2SiO_5 coatings were evaluated by nano indentation.

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ENR-60

Enhancement of Photocatalytic Hydrogen Production by Liquid Phase Plasma Irradiation on Metal-loaded TiO_2 /Carbon Nanofiber Photocatalysts

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Hydrogen production by photocatalysis on high photosensitive catalysts has been studied under UV and visible light irradiation [1]. In particular, visible light sensitive photocatalysts for hydrogen generation from water have attracted considerable attention [2]. In addition, light sources are as important as the photocatalysts in a photochemical reaction. Although a range of light sources have been employed in photocatalysis, few studies have examined photocatalysis for hydrogen generation using liquid phase plasma (LPP) by irradiation into water directly. This study examined the hydrogen evolution by water photocatalysis using LPP on metal-loaded

TiO₂ photocatalysts. The photocatalysts were supported on carbon nanofiber (CNF) support. The photocatalytic activities of the photocatalysts were estimated for hydrogen production from water. The rates of hydrogen evolution by LPP irradiation was compared with those of UV light irradiation on the same photocatalysts. Effect of sacrificial reagent added into water was also evaluated in the photocatalysis for hydrogen evolution. Photocatalytic activity was improved significantly by LPP irradiation with metal loading on the TiO₂. The TiO₂ nanocrystallites prepared by sol-gel method were incorporated above 40 wt% on CNF support. The CNF acted as an efficient photocatalytic support for the fixation of TiO₂. Hydrogen evolution was enhanced with metal incorporation on the TiO₂ supported onto the CNF support. The rate of hydrogen evolution on the photocatalysis using the LPP was significantly higher than the rate obtained from UV light-driven hydrogen generation.

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ENR-61

Silver nanowire networks: prospects towards printed energy applications

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Several applications related to energy harvesting (e.g. photovoltaics) or energy efficient lighting (EL, OLEDs, ...) strongly rely on effective transparent electrodes. Recently, metal nanowire networks are put forward as a promising concept for replacing transparent conducting oxides, such as Indium Tin Oxide (ITO). In such

networks, the nanowires conduct charge carriers, while the open areas allow the transmission of light. Metal nanowires are both printable and achieve a performance equivalent to ITO upon thermal processing at moderate temperatures below 150°C, making them ideal for printing (flexible) transparent electrodes on plastic substrates.

Various formulations containing Ag NWs were prepared and their rheological behavior was assessed in view of screen printing on PET. The opto-electrical properties of the printed features are characterized by a Van der Pauw method and UV-Vis spectroscopy and analyzed by a semi-empirical model, relating the transparency and conductivity of the electrodes. Depending on the concentration and dimensions of the nanowires, the features have a transparency ranging from 50% up to 90% and a sheet resistance down to 20 Ohm/sq, fulfilling the requirements for a wide range of optoelectronic devices.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641864.

ENR-62(2)

Hydrogen interaction properties of Cr₂O₃ passive films upon Helium ions irradiation

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Controlled nuclear fusion is a new way to produce ideal energy utilising hydrogen isotopes as fuel, where deuterium and tritium undergo a nuclear reaction at extremely high temperatures to form helium and a neutron. A growing interest in hydrogen permeation barriers is driven by approaches aimed at reducing hydrogen embrittlement on structural materials as well as radiological isotope leakage induced hazards during the service of fusion reactor. Cr₂O₃ is one of the potential surface coatings to improve the hydrogen resistance of stainless steel substrates, but so far the irradiation effect of high energy particles as well as the helium created by radioactive decay on the hydrogen permeation properties are far from clear. Herein, nanoscale Cr₂O₃ passive film formed on electroplated chromium coating and then oxidized by oxygen-poor plasma was used to investigate the influence of irradiated helium on the hydrogen permeation behaviors. Passive films have been irradiated with 300 keV helium ions at the fluence of 1×10^{16} ions·cm⁻² prior to exposure of hydrogen at 500°C.

The interactions between the embedded helium and hydrogen were analyzed by comprehensive surface analyses. The depth of ion implantation has been simulated by SRIM, microstructural evolution of these irradiated passive films has been estimated by using the non-destructive conductive atomic force microscopy, the chemical states and defect characteristics of sample were measured by X-ray photoelectron spectroscopy and electrochemical impedance spectroscopy. Measurements indicate that He bubbles are formed in the destroyed passive film and lead to enhanced diffusion of hydrogen of the sample surface.

ENR-62

Hydrogen efficient sensor based on Schottky barrier diode of the point contact between Pd_xO decorated TiO₂ nanotube arrays

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To enhance the detection sensitivity towards hydrogen, a novel point contact TiO₂ nanotube decorated with Pd_xO Schottky barrier diode (SBD) was proposed and investigated in this paper. TiO₂ nanotube arrays were fabricated on Ti wires by electrochemical anodic oxidation, and Pd catalytic nanoparticles were modified by micro-emulsion electrochemical deposition. The surface morphology was characterized by field emission scanning electron microscopy (FESEM), and the hydrogen sensitivity of the point contact between TiO₂ nanotubes was investigated. It exhibited high sensitivity under working temperature of 70°C, and the sensitivity of SBD to 2000ppm hydrogen was about 8500. Impedance spectroscopy, the current–voltage (I-V) characteristic measurement and infrared spectroscopy were also employed for further mechanism investigation. From the I-V curves, we found the Schottky barrier was formed on the contact and the barrier height decreased with increase of hydrogen. The sensing processes of the charge transfer were unveiled according to the different time constants and that mechanism was in reasonable support of IR surface analysis. This information may provide some insight on the understanding of the device physics of this new emerging nanotube array based SBD which will have broaden application in hydrogen energy and related security system.

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Electrochemical Behaviors LDPE-based Activated Carbon by Steam Activation

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Supercapacitor are very attractive as a potential energy storage system because of their high energy density, quick charge–discharge rate, low cost, and maintenance-free long life operation. Carbon materials with high specific surface area, such as activated carbon, activated carbon fiber cloth, and carbon aerogels/foams are usually used as electrode materials of electrochemical capacitors [1]. Most commercial grade activated carbons are derived from naturally occurring carbonaceous materials such as coal, wood and coconut shell. However, the large amount of mineral species contained in these naturally occurring carbon precursors generally affects the properties and thus the performance of the resulting carbon in various applications [2]. Polymeric precursor have structural features similar to those in coal, but contain much fewer mineral impurities, which can be controlled to very low levels during their synthesis. Because of the low content of the retained ash, which has a negligible porosity, the specific porosity of the carbon prepared from the resins is expected to be high.

In this study, activated carbons (ACs) were prepared for supercapacitor electrode applications by using cross-linked LDPE under various activation conditions. The cross-linked LDPE was prepared by using sulfuric acid cross-liked method. From the results, it was found that specific surface area and pore volumes were enhanced with increasing activation time. It was also observed that various pore size distribution were found to be depended on the functions of activation time. The ACs were applied as an electrode for EDLCs and analyzed in relation to the activation conditions.

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ENR-63(3)

Preparation and analysis of paraffin-based phase change material using aluminum nitride as the reinforcing agent

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Ceramic powder in form of aluminum nitride (AlN) was employed to improve the thermal properties of paraffin, known as one of the most significant materials for thermal energy storage. This was attempted considering the superior thermal properties and chemical inertness of AlN. Reinforcing powder was carefully mixed with paraffin in a controlled environment to ensure the well-dispersed AlN particles within the phase change matrix. Results of thermal characterization of the final composite phase change material (PCM) are presented in this study. Differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA) were performed to thoroughly portray the thermophysical changes of the fabricated composite PCM as a function of temperature. Thermal conductivity measurement was also carried out to further characterize the material. Findings reveal an increase in thermal conductivity and specific heat capacity of pure paraffin.

ENR-63

Effect of H₂O Activation on the Electrochemical Performance of Pitch-based Activated Carbon Fibers for EDLC

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Electrochemical capacitors are very attractive as a potential energy storage system because of their high energy density, quick charge–discharge rate, and maintenance-free long life operation [1]. Carbon materials with high specific surface area, such as activated carbons, activated carbon fibers, and carbon aerogels/foams are usually used as electrode materials of electrochemical capacitors. Activated carbon fibers (ACFs) are a microporous

carbonaceous adsorbent developed from organic precursors either by physical or chemical activation [2]. The advantages of ACFs are smaller fiber diameter, more concentrated pore size distribution, and excellent adsorption capacity at low concentrations, in comparison with conventional activated granular or powdered carbons.

The present study developed electrode materials for supercapacitors by pitch-based ACFs with H₂O. For the activation reaction, after setting the temperature at 900°C, four types of activated carbons were produced, over an activation time of 0-40 minutes and with an interval of 10 minutes as the unit. The surface and structural characteristics of ACFs were observed by scanning electron microscopy (SEM) and X-ray diffraction (XRD), respectively. Pore characteristics were investigated by N₂/77K adsorption isotherms. Specific surface area of the ACFs were increased up to 2790 m²/g and the ACFs were found to be mainly composed of mesoporous structures.

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ENR-64

Sm³⁺, Pr³⁺ and Nd³⁺ Triple-Doped Ceria Applied for Low Temperature Solid Oxide Fuel Cells

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Co-doped ceria have the great potential to perform on low temperature solid oxide fuel cell (LT- SOFC) applications [1-3]. Wet chemical method was employed here to prepare the Sm³⁺, Pr³⁺ and Nd³⁺ triple-doped ceria. Samarium doped ceria (SDC) was synthesized firstly and then the Pr³⁺/Nd³⁺ ions as secondary doping elements were loaded on SDC skeleton. The structural analysis indicated that the Pr³⁺ and Nd³⁺ ions mainly behave ionic doping effect when the secondary doping contents of Pr³⁺ and Nd³⁺ ions are below 1.8 mol%. Impurity phases, e.g. PrNdO_{1.5}, can be detected, when the doping contents of Pr³⁺ and Nd³⁺ ions are above a certain content, e.g. 4.0 mol%. Among the Pr³⁺ and Nd³⁺ modified SDC samples, the 1.8 mol% PrNd doped SDC (1.8PrNd-SDC) exhibited so far the highest conductivity, 0.125 S/cm at 600 °C. The fuel cell devices were fabricated using the as-prepared PrNd-doped SDC samples as the electrolyte layer and NCAL pasted on nickel

foam was attached on the both sides of the devices. Such fuel cell devices have delivered a maximum output power density 710 mW/cm² at 550 °C for 1.8PrNd-SDC electrolyte. The mechanisms for such great performances were studied related to the ion transport, the formation of schottky junction and electrocatalyst. It demonstrates that the Sm³⁺, Pr³⁺ and Nd³⁺ doped-ceria materials have a great potential for advanced LT-SOFC applications.

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ENR-67

Enhanced Adhesion Strength of Polymer on Inverse-Opal based Metal

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The use of polymer on metal is increasing by the needs of high strength and light weight of device and material. The bonding strength between metal and polymer is important not only material application but also product shielding. We developed method to form the inverse-opal structure on metal surface to increase the adhesion power with polymer. The inverse-opal structure was formed through four step process; i) surface modification of metal surface by using plasma treatment with reactive gas, ii) formation of opal structure with monolayer or double layers using polystyrene (PS) sphere with ~1 μm diameter, iii) Ni electroplating by the control of deposition time, and iv) Formation of inverse-opal structure by removing of PS spheres. Plasms treatment with Ar/O₂, Ar/N₂, Ar/H₂ gases was performed to modify chemical environment of metal surface. The surface property of metal was changed more hydrophilic after plasma treatment with Ar/O₂. The change of surface chemical states and morphologies of the metal surface was measured by x-ray photoelectron spectroscopy and electron microscopy. The adhesion power according to PS coating layer and Ni electroplating time was investigated. The adhesion power of the untreated and chemical treated samples after bonding with polymer was compared through tensile strength test. For the inverse-opal structure formed on metal surface, their adhesion power showed highest value and reached to 25~30 MPa.

This research is supported by "The Project of Conversion by the Past R&D Results "through the Ministry of Trade, Industry and Energy (MOTIE) (N0002136)

ENR-68

Synthesis of MoS₂/TiNb₂O₇ Nanostructures and Their Electrochemical Performance for Li-Ion Battery anodes

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Recently, several research groups have assembled MoS₂ on various inactive one-dimensional conducting matrices such as carbon nanotubes, mesoporous CMK-3, carbon nanofibers, and carbon fiber cloth as anode materials for the reversible storage of Li⁺. These structures are known to exhibit additional advantages of outstanding electric conductivity, high charge mobility, and large specific surface area. However, all of the discussed approaches have not yet been successful in satisfying various requirements for next-generation LIB applications. Here, we rationally designed and synthesized TNO@MS HRs composed of two-dimensional MoS₂ nanosheets grown around one-dimensional TiNb₂O₇ nanofiber cores with a robust MS/TNO interface using simple and cost-competitive electrospinning/hydrothermal processes. We examined the synergetic advantages of TNO@MS HRs based on the structural properties. The TNO@MS HR exhibited synergistic performance including high capacity, excellent rate capability, and outstanding cycling stability. We anticipate that this hierarchical nanostructure can be applied in high-power LIBs, supercapacitors, and various catalysts.

This research is supported by "The Project of Conversion by the Past R&D Results "through the Ministry of Trade, Industry and Energy (MOTIE) (N0002136) and a research program (Grant No. NRF-2015R1D1A3A01018611) through the Ministry of Education of the Korean government.

Insight into the oxygen ion conduction mechanism of $Gd_{0.2}Ce_{0.8}O_2$ electrolytes with different microstructures**G. Chen^{1,2}, W.K. Sun¹, Y.D. Luo¹, H.L. Liu¹, K. Yu¹, S.J. Geng^{1,2}**¹*School of Metallurgy, Northeastern University, Shenyang, 110819, China*²*Liaoning Key Laboratory for Metallurgical Sensor and Technology, Northeastern University, Shenyang, 110819, China*

More and more people believe that lower operating temperature below 600°C becomes a necessary condition to achieve the commercialization of solid oxide fuel cell (SOFC). The lower conductivity of the state of the art electrolyte at low temperature is an obstacle to the low temperature SOFCs. Gadolinia-doped ceria (GDC) is a kind of electrolyte material with relatively high conductivity at low temperature (0.019 S/cm at 500°C), which still cannot meet the needs of LTSOFC^[1]. In recent years, it has been reported that a kind of composite electrolyte mixed with some carbonates in GDC and without high temperature densification can exhibit unusually high conductivity [2]. Greatly increased ionic conductivity in GDC electrolyte without high temperature sintering was considered to own to an interfacial conduction^[2]. However, there is still no systematic comparative study on the oxygen ion conduction mechanism of two different microstructures of GDC electrolyte, which are the GDC electrolyte densified by high temperature sintering and GDC electrolyte without high temperature densification. In this study, electrolyte-supported SOFC with two different GDC electrolyte microstructures will be performed in H₂. The ionic conduction mechanism of GDC with different microstructures will be investigated with the same SOFC structure and the same electrode. Specific content will be reported at the meeting.

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The authors thank the National Natural Science Foundation of China (No. 51302033), the Fundamental Research Funds for the Central Universities (No. N140204005), the Natural Science Foundation of Liaoning Province (No. 2015020637)

Nitrogen Functionalized Carbon Nanotubes for Hydrogen Evolution Reaction**S. Tuomi^a, M. Borghei^b, T. Kallio^a***^aResearch Group of Electrochemical Energy Conversion and Storage, Department of Chemistry, Aalto University, P.O. Box 16100, 00076 Aalto, Finland**^bBio-based Colloids and Materials, Department of Bioproducts and Biosynthesis, Aalto University P.O. Box 16300, 00076 Aalto, Finland*

Nitrogen functionalized carbon nanotubes are an interesting option for electrochemical applications due to their good electrical conductive and active sites origin from nitrogen functionalization. The catalyst material is abundantly available in earth giving it a cutting edge over noble metal catalysts. Previous measurements [1] have shown the catalyst to be active for oxygen reduction reaction but now it have been verified to be efficient catalyst also for hydrogen evolution reaction.

Activity of the catalyst have been measured both in electrochemical cell as well as in electrolyzer system. The obtained hydrogen evolution current of 62 mA cm⁻² at 400 mV overpotential are comparable to similar non-nobel metal catalysts. At the methanol electrolyzer cell the hydrogen evolution current was 380 mA cm⁻² at 1 V overpotential which is relatively close to 514 mA cm⁻² that was obtained with platinum catalyst.

The reaction have been studied with varying pHs to better understand the reaction mechanism of hydrogen evolution. At low overpotentials and moderate pHs the reaction seems to occur through Volmer-Tafel mechanism but at high overpotentials and low pH the reactions is dominated by Volmer-Heyrovsky mechanism.

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Synthesis of Cu₂ZnSnS₄ Thin Films as an Absorber Layer for Thin Film Solar Cells Prepared by Highly Efficient Convective Deposition**N. Khothong¹, P. Kumnorkaew², P. Vas-Umnuay¹**

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Cu₂ZnSnS₄ (CZTS) is a *p*-type semiconductor material which has been reported as one of the most promising candidates for absorber layer in thin film solar cells. Due to its earth-abundant material, low-cost, non-toxicity, and high absorption coefficient ($>10^4 \text{ cm}^{-1}$), it has been replacing Cu(In,Ga)Se₂ (CIGS) thin film solar cells, because indium (In) and gallium (Ga) are rare and extremely expensive [1]. Current development of CZTS thin film photovoltaic technology has been directing towards effective manufacturing costs, efficiency, and high-throughput production. CZTS thin films can be synthesized by both vacuum and non-vacuum based techniques, such as sputtering, thermal evaporation, spray pyrolysis, pulsed laser deposition, sol-gel, spray pyrolysis, electrochemical deposition, and successive ionic layer adsorption and reaction (SILAR) technique [2]. Although CZTS synthesized by vacuum-based techniques has been reported with a high efficiency (maximum at 8.4% in 2011 [3]) and can be easily controlled of the reactant compositions, these techniques are energy intensive, requiring high vacuum and temperature that indirectly increases the effective cost [2]. In contrast, non-vacuum techniques are simple, low-cost, consume less energy, high-throughput production, and scalable synthetic routes. Convective deposition method, in particular, is one of the non-vacuum approaches which is considered to be simple, rapid and requires inexpensive equipment. The process involves a moving substrate with respect to a blade, where the precursor solution is stretched into thin film via evaporation and capillary attraction [4]. In this study, the fabrication of CZTS thin films was focused on convective deposition process prepared by using non-toxic chemicals of metal chloride, thiourea, and 2-methoxyethanol as precursors and solvent, respectively. The obtained films were annealed under N₂ atmosphere to yield high quality of CZTS films. Variation in operating conditions such as deposition velocity, number of depositions, and annealing temperature will be investigated to produce smooth and uniform CZTS thin films. The structure, morphology, composition, phase, and optical properties of CZTS thin films were characterized by Scanning electron microscopy (SEM), Energy

dispersive X-ray analysis (EDX), X-ray diffraction (XRD), Raman, and UV-Vis spectrophotometer, respectively.

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ENR-74

Tetrathiotetracene as a base of planar thermoelectric generator

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Improving efficiency in energy usage has become a global megatrend not only within all industries but also across the entirety of society. Minimizing greenhouse gas emissions while simultaneously improving industrial output and competitiveness is a pressing goal. Presently, it is estimated that mankind wastes at least 20% of global power consumption as low level heat (<200 °C). It is obvious that direct conversion of this wasted energy in to electrical power by means of devices exploiting thermoelectrical (TE) effect will have huge impact on energy production. Wider usage of such TE convertors for harvesting of waste energy is limited by cost and availability of TE active materials. Organic materials attract increasing attention due to the advantages of mechanical flexibility and low-cost synthesis. Within this contribution, a proof of concept device of planar thin film TE generator based on organic materials is built and its power generation characterized. We have demonstrated that by appropriate doping of low cost TTT [1] it is possible to obtain TE active organic thin films of both p- and n-types. We have prepared p-type TTT iodide thin films with a power factor of $0.52 \mu\text{W m}^{-1} \text{K}^{-2}$, an electrical conductivity of 130 S m^{-1} , and a Seebeck coefficient of $63 \mu\text{V K}^{-1}$ and n-type TCNQ:TTT films with a power factor of $0.33 \mu\text{W m}^{-1} \text{K}^{-2}$, an electrical conductivity of 57 S m^{-1} , and a Seebeck coefficient of $-75 \mu\text{V K}^{-1}$. This achievement has allowed demonstration of the feasibility of thin film TEG based on organic p- and n-type materials operating under near ambient conditions. Particularly a “proof of concept” single couple TEG of p-type TTT iodide thin films coupled with n-type thin films produced by co-deposition of TTT and

TCNQ were prepared. [2] The simple fabrication process proposed allows easy duplication of such TEG modules therefore the power of device could be multiplied several times. Power of 5.5 pW K^{-1} was measured for fabricated single couple TEG close to room temperature.

Acknowledgement: This work has been supported by ERAF project Nr. 1.1.1.1/16/A/046

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ENR-75

Investigations of Photocatalysis-related Properties of Fe-doped and Mo-Fe co-doped Bismuth Vanadate

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Bismuth vanadate (BiVO_4) has adequate energy bandgap (2.4 eV) and chemical stability for being a photocatalyst as the photoanode in water splitting. However, its interior and surface properties, such as the existence of a high density of detrimental surface states, greatly degrade its performance as in photoelectrochemical reactions [1]. To improve the photocatalytic performance of BiVO_4 , Mo-doping [2] and surface treatment using FeOOH and NiOOH [3,4] have been reported. In this work, using a photoelectrochemical testing facility, we examined the photocatalysis-related properties of Fe-doped and Fe-Mo co-doped nano-porous BiVO_4 grown on ITO-coated glass. Comparing with pure BiVO_4 , our Fe-doped sample showed higher photocurrent density, lower electron-hole recombination rate and better stability. For the Fe-Mo co-doped samples, we observed further improvement in these properties. The optimal improvement is observed at a certain moderate Mo-doping level for a fix Fe-doping.

Minimization of losses in latex-nanodiamond films for dielectric energy harvesting**A. Shakun, E.L. Sarlin, J.E. Vuorinen***Tampere University of Technology, Laboratory of Materials Science, Tampere, Finland.*

Dielectric elastomer generators (DEGs) are known as a promising class of wave energy harvesters. Such harvesters are based on soft rubber capacitors that change their capacitance with stretching. However, most of the existing DEG prototypes utilize dielectric membranes that are not optimal for DEG applications and restrict their performance and economic viability. Therefore, materials designed specifically for DEGs are in demand.

Electromechanical properties of a synthetic latex have recently been studied and showed promising results for the possible utilization in dielectric energy harvesters. Nitrile rubber (NBR) is known for its comparably high polarity resulting in relatively high dielectric constant, and it is available in latex form. NBR has good mechanical and electromechanical properties, as well as elasticity. However, most NBR-based materials show comparably high dielectric losses. Therefore, minimization of material-related dielectric losses is of high importance, and it can be achieved with the addition of a filler.

Detonation produced nanodiamonds (NDs) are dielectric particles with an active surface that are expected to reduce the dielectric losses in some elastomers. The present research investigates the effect of different surface-functionalized NDs on dielectric properties of NBR latex films. Addition of NDs, especially with hydrogenfunctionalized surface (ND-H), reduced the dielectric losses in low frequency region. Moreover, ND-H led to lowered electrical conductivity and higher dielectric constant at a low frequency area that is favourable for DEG applications. Next, two methods of composite preparation were compared – one using sonicating bath and another one involving high-energy sonotrode that allows obtaining more stable ND suspensions with smaller aggregate size. Finally, mechanical and dynamic mechanical properties of the composites were measured.

Low-temperature synthesized agglomerated nanoparticles of $\text{Li}_4\text{Ti}_5\text{O}_{12}$ for energy storage**D. De Sloovere, G. Bonneux, F. Ulu, T. Vranken, M. Verheijen, M.K. Van Bael, A. Hardy***UHasselt, Hasselt University, Institute for Materials Research (IMO) and imo division imomec, Inorganic and Physical Chemistry, Agoralaan, 3590 Diepenbeek, Belgium.*

The development and improvement of lithium ion batteries is of major importance in our current day society. Due to its high stability and inherent safety, $\text{Li}_4\text{Ti}_5\text{O}_{12}$ is an interesting alternative anode material for lithium ion batteries. The synthesis of this material typically requires demanding synthesis conditions, such as a high temperature (~800 °C) and a long reaction time (up to 24 hours). This means that, even though batteries are a valuable way of storing renewable energy, the eco-friendliness of batteries containing $\text{Li}_4\text{Ti}_5\text{O}_{12}$ is rather limited and could be improved by using a less energy-consuming synthesis method. Due to its self-heating nature, combustion synthesis requires a lower external temperature for the formation of oxides. Using this synthesis method, the temperature and time for formation of $\text{Li}_4\text{Ti}_5\text{O}_{12}$ were reduced to 300 °C and seconds, respectively. These more beneficial synthesis conditions resulted in the presence of a minor amount of impurities, although these did not have a big influence on the electrochemical characteristics. When used in a coin cell battery, the sample can provide a capacity and stability comparable to high temperature synthesized $\text{Li}_4\text{Ti}_5\text{O}_{12}$ (164 mAh g⁻¹). While the particle size distribution was broad and the sample contained particles with a size up to 2 μm, TEM analysis showed that the bigger particles were in fact agglomerates of nanosized particles, resulting in a rough surface morphology. This explains why increasing the current twentyfold resulted in a limited capacity decrease of only 15%. The effect of slurry preparation and of galvanostatic cycling on the particle size distribution of the sample was investigated by post-mortem analysis.

This work was supported by the FWO, the Research Foundation Flanders [project G041913N]. This project receives the support of the European Union, the European Regional Development Fund ERDF, Flanders Innovation & Entrepreneurship and the Province of Limburg.

Polyaniline Coated Carbon Nanotubes as Positive Electrode Material in Asymmetric Supercapacitor**F. Davodi¹, O. Sorsa¹, T. Rauhala¹, B. Rausch¹, T. Kallio¹***¹Aalto University School Chemical Engineering, P.O. Box 16100, FI-00076 AALTO, Finland*

Increasing amount of electrical devices and their increasing amount of energy consumption requires more powerful energy storage solutions. Lithium ion batteries are currently considered as one of the main portable energy storage solutions. However, they have a relatively low power density. Supercapacitors, instead, can operate with high power densities. However, they are limited by low capacity. In a hybrid device, one electrode utilizes a faradaic redox reaction and the other capacitive electric bilayer. This device is often called as a hybrid supercapacitor or an asymmetric supercapacitor.

Polyaniline (PANI) is a polymer that is known for its electrical conductivity and redox reactions [1]. Even though polyaniline is considered a conducting polymer, it still has a low conductivity compared to metals or most carbonaceous materials. Polyaniline electrodes are usually fabricated by using a binder to increase its cohesion. However, binders decrease the conductivity so that a conductive material (usually carbon black) is needed. Carbon nanotubes (CNTs) have high surface area and conductivity. By combining these two materials, we can create a composite that has a redox reaction, high conductivity and relatively high surface area. Carbon nanotubes are also cohesive enough so that no binder is required. By all accounts, PANI-CNT is an ideal material to be used in hybrid supercapacitors.

We have synthesized carbon nanotubes wrapped by polyaniline and tested it as a positive electrode material in aqueous supercapacitor cells. Activated carbon has been used as the negative electrode.

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Electrochemical performance of the infiltrated Ni-Fe/YSZ anodes in the ScSZ supported IT-SOFCs for H₂ and ethanol fuels.**A. Fakeeh¹, R.I. Tomov¹, B.A. Glowacki^{1,2,3}, R.V. Kumar¹**¹*University of Cambridge, Department of Materials and Metallurgy, Cambridge, CB3 0FS, UK.*²*Department of Physics and Energy, University of Limerick, Plassey, Ireland.*³*Institute of Power Engineering, ul Augustówka 6, 02-981 Warsaw, Poland.*

Ink-Jet printing technology, utilising drop-on-demand electromagnetic nozzle with a 100µm diameter orifice, was used as an infiltration technique for a controlled delivery of precursor inks into porous anode scaffolds. Following an optimisation of inks contents and concentrations, the process can achieve a laterally uniform loading of nano-litres of inks into the electrode scaffolds, providing a substantial waste reduction and higher resolution precision. The following inks were used in the primary series of infiltration cycles of the Ni-Fe/YSZ anode scaffolds: Ni(NO₃)₂, Cu(NO₃)₂, Co(NO₃)₂ and Co(NO₃)₂ • Mn(NO₃)₂. The secondary infiltrations were done with the gadolinium doped ceria (CGO) based ink. Each individual infiltration cycle contributed to around 5wt% loading relative to the electrode weight. Electrochemical Impedance Spectroscopy of the symmetrical infiltrated anode cells was undertaken in a 5%H₂ in Ar atmosphere with a 48 hours durability measurement. The SEM imaging and the energy dispersive X-ray spectroscopy helped investigating the surface morphology and the compositional analysis. It was confirmed that the dual infiltrations have an effect of extending the triple phase boundary by forming chains of interconnected nanoparticles (~50nm in diameter), on the surface of the Ni-Fe/YSZ scaffolds. In addition, the CGO based ink was found to be responsible for the inhibition of the primary infiltrated nanoparticles as well as for preventing the agglomeration of Ni in the Ni-Fe alloy within the anode scaffold, thus improving the durability of the cell performance. Conjointly, a series of full electrolyte supported SOFCs with infiltrated electrodes were tested in pure H₂ and hydrocarbon based fuels. Alongside the power densities and the open-circuit potentials, parameters such as the resistance to carbonisation and the changes in surface morphology, particularly the signs of Ni coarsening, were also noted, compared and analysed.

Experiment Investigation of Nanoparticle-assisted Enhanced Oil Recovery and Oil Reservoir Characterization**Z. Hu¹, E. Nourafkan¹, G. Raza¹, D. Wen^{1,2,*}**¹*School of Chemical and Process Engineering, University of Leeds, Leeds, LS29JT, UK.*²*School of Aeronautic Science and Engineering, Beihang University, Beijing, 100191, China*

Recently, the injection of nanoparticles (NPs) has been proposed as a potential means to improve reservoir characterization and to increase oil production, resulting in the term NanoEOR. Compared to conventional EOR techniques, NanoEOR possesses a few advantages. It is thought that the small sizes of particles (<100 nm) could tailor the displacing fluid effective properties, alter the rock surface wettability, and introduce conformance control. In addition, the size-dependent properties (i.e., optical, magnetic) of nanoparticles can be used as sensitive down-hole sensors to target locations that are inaccessible by conventional methods [1]. This work reports a systematic work being conducted at the University of Leeds to investigate engineered nanoparticles for subsurface applications, including i) functional NPs design and fabrication, ii) NPs stability and transport ability under reservoir-like conditions [2], iii) NPs as modifier to improve the performance of chemical flooding [3], and iv) the development of ‘contrast-agent’ for better reservoir characterization.

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Earth-abundant and Indium Free CuSbS₂ for solar cell applications**S. Moosakhani¹, A. A. Sabbagh Alvani¹, R. Mohammadpour², S-P. Hannula³**¹*Amirkabir University of Technology, Tehran, P.O. Box 15875-4413, Iran.*²*Sharif University of Technology, Tehran, P.O. Box 14588-89694, Iran.*³*Aalto University, Espoo, P.O. Box 16200, FI-00076 Aalto, Finland.*

Copper antimony sulfide (CuSbS₂) is an emerging semiconductor that is relatively less explored despite of its unique properties. Study on this material as a potential absorber for sustainable and scalable thin film solar cells has been developed [1,2]. CuSbS₂ were successfully prepared using hot injection method. High quality colloidal particles can be obtained via this route [3]. Oleylamine solvent and elemental sulfur were used for synthesis. Obtained powders were investigated by X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM) and UV-Vis spectroscopy. The results revealed that synthesized CuSbS₂ have an orthorhombic structure with Pnma space group. The XRD pattern was in good agreement with the standard pattern (JCPDS 98-017-1051) and no impurities were detected. The particles have a plate-like morphology with relative shape uniformity. This morphology is promising for application in solar cells and supercapacitors [4]. The SEM and TEM images also clearly indicated that the plates are composed of several stacks of layers with distinct plate edges.

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Cobalt Doping Efficiency in ZnO Nanostructures

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In this study we investigated cobalt doping in ZnO nanostructures by varying the doping content from 0 to 20% in nanostructured ZnO thin films fabricated by a chemical bath deposition technique (CBD). ZnO nanorods were deposited on fluorinated tin oxide (FTO) substrates by CBD using equimolar ratios (selected at 0.1 M, 0.5 M and 1 M) of zinc (II) nitrate and hexamethylenetetramine in solution at 95°C. Cobalt doping in ZnO was achieved by adding either cobalt nitrate, cobalt chloride or cobalt acetate to the precursor solutions of the CBD in a set of samples. Regardless of the doping process, X-ray diffraction (XRD) measurements on doped ZnO samples and analysis of the (002) peak show that the average nanorod diameter in doped samples increased up to 15% doping and then decreased in 20% doped sample. We also extracted lattice parameters a , and c from XRD studies. Based on these measurements, we estimated the strain in the doped nanostructured thin films with increase in cobalt doping. The strain in the doped films decreased from 0 to 15% cobalt doping and increased significantly as the doping was increased to 20%. We compared the doping efficiency in two sets of samples doped with cobalt via cobalt nitrate and cobalt chloride. Measurements of the cobalt incorporated into the ZnO matrix were performed using atomic emission spectroscopy (AES). AES measurements show that cobalt incorporation is much more efficient at 1M concentration of the precursor solution using cobalt chloride than using cobalt nitrates for doping. SEM images show that at 0.1 M ratio of the CBD precursor solutions, the morphology of ZnO deposited resulted in hexagonally shaped nanorods. The nanostructure morphology is maintained in 0.1 M cobalt doping, irrespective of the route (cobalt nitrate, cobalt acetate or cobalt chloride) taken to achieve the doping. I-V and C-V measurements show that the average barrier height increases up to 15% doping and then decreases at 20% doping. We will discuss the implications of these measurements on establishing parameters for cobalt doping efficiency in ZnO nanostructures.

Cu₂O/TiO₂ nanotube arrays film with controlled morphology for photoelectrochemical water splitting

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Cu₂O is a promising sensitizer of TiO₂ nanotube arrays (TNTs) for photoelectrochemical water splitting because it is an environment friendly p-type semiconductor with narrow band gap (2.0~2.2 eV). In this paper, TNTs were prepared by anodic oxidation method, and then Cu₂O nanoparticles were deposited on TNTs in the three-electrode system via electrochemical deposition method. The morphology and the size of Cu₂O nanoparticles on the TNTs can be controlled through adding PVP K30 in electrolyte or by adjusting deposition potentials and time. Octahedral Cu₂O particles only obtained at deposition potential of -0.8V, and Cu₂O particles deposit at -0.3V and -0.4V were almost amorphous. The size of Cu₂O nanoparticles remarkable can be decreased to 35nm with the help of surfactant PVP K30, and Cu₂O deposited on the inner and outer walls of TiO₂ nanotube. The resulting Cu₂O/TNTs have the significant photo response in visible light region. Under irradiation of solar simulator (AM1.5, 100mW/cm²), the photocurrent density of the Cu₂O/TNTs is more than that of TNTs when Cu₂O was deposited on TNTs. The sample obtained at -0.3V for 5min exhibits better photoelectrochemical properties. In addition, combined with the open potential transient curves and the cyclic voltammetry curves, Cu₂O nanoparticles may be oxidized during the photoelectric testing process, but the photocurrent of Cu₂O/TNTs remains stable.

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Proximity Induced magnetism in Graphene for Energy Storage Application**D. Seifu¹, H. Verma¹, S. P. Karna,² Haiping Hong,³ and M. S. Seehra⁴**¹*Dept. of Physics, Morgan State University, Baltimore, MD 21251, USA*²*Army Research Laboratory, WMRD, Aberdeen Proving Ground, MD 21005, USA*³*Dept. of Materials, SD School of Mines and Tech., Rapid City, SD 57701, USA*⁴*Dept. of Physics and Astronomy, West Virginia Univ., Morgantown, WV 26506, USA*

Evidence of significant induced ferromagnetism in multilayer graphene (MLG) coated with ferrimagnetic nanoparticles (NPs) will be reported. In this presentation, we will report evidence of induced ferromagnetism at room temperature in bulk samples of MLG, coated with ferrimagnetic magnetite (Fe_3O_4) Nps through a facile one-step ultrasonic treatment [1]. This observation of proximity induced ferromagnetism in bulk samples of commercial MLG may open up several applications. Magnetization versus magnetic field shows that the saturation magnetization $M_S = 58.6$ emu/gm for pristine Fe_3O_4 increased to $M_S = 158.4$ emu/gm for a 1:1 composite of Fe_3O_4 to MLG. These results lead to induced $M_S = 253$ emu/gm in MLG resulting from its proximity to Fe_3O_4 . From TEM images of Fe_3O_4 /MLG it is evident that MLG surface is coated by a large quantity of Fe_3O_4 NPs. In addition, application of Fe_3O_4 NPs of predetermined size enabled the control over magnetic properties since magnetic properties depend upon the dimensions of materials used. The TEM image clearly shows equally spaced lattice fringes of Fe_3O_4 NPs. From the TEM analysis, it can be concluded that highly crystalline Fe_3O_4 NPs are uniformly coated onto MLG.

We will also present enhanced magnetic properties of MLG coated with several other NPs including Fe_2O_3 , Co_3O_4 [2] and FeCoO_4 for possible energy storage application [3].

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Shape anisotropy and hybridization enhanced magnetization in nanowires**D. Seifu¹**¹*Dept. of Physics, Morgan State University, Baltimore, MD 21251, USA*

Arrays of tunneling magnetoresistance (TMR) nanowires were synthesized for the first time by filling Fe/MgO/Fe inside vertically grown and substrate supported carbon nanotubes. The magnetic properties of nanowires and planar nanoscale thin films of Fe/MgO/Fe showed several similarities, such as two-fold magnetic symmetry and ratio of orbital moment to spin moment. Nanowires of Fe/MgO/Fe showed higher saturation magnetization by a factor of 2.7 compared to planar thin films of Fe/MgO/Fe at 1.5 kOe. The enhanced magnetic properties likely resulted from shape anisotropy of the nanowires and as well as the hybridization that occur between the π -electronic states of carbon and 3d-bands of the Fe-surface [1, 2].

This comparative study of the structural and magnetic properties of Fe/MgO/Fe nanowires grown inside substrate supported carbon nanotubes for the first time and planar thin films MTJs showed several similarities, such as two-fold magnetic symmetry and ratio of orbital moment to spin moment. Deposition conditions in particular substrate temperature influences both structural and magnetic properties of the Fe/MgO/Fe planar films. Nanowires of Fe/MgO/Fe prepared at 100°C substrate temperature showed improved magnetic property compared to planar thin films, and we attribute this to the shape anisotropy of nanowires. The saturation magnetization is higher by 173% for nanowires compared to planar thin films prepared at the same substrate temperature. The coercive field of nanowires of Fe/ MgO/Fe is 54% higher than thin film of Fe/MgO/Fe both synthesized at 100°C of substrate temperature. Nanowires of Fe/MgO/Fe showed higher saturation magnetization by a factor of 2.7 compared to planar thin films of Fe/MgO/Fe at 1.5 kOe. These enhanced magnetic properties may result from shape anisotropy of the nanowires as well as hybridization that occurs between the π -electronic states of carbon and 3d-bands of the Fe-surface. The small change in the coercive field as the angle between the sample surface and the applied field is changed in both nanowires and films confirmed that most of the magnetization variation occur by domain wall motion. Strong dependence on angle was observed on the values of coercive field much more in films than in nanowires indicating domination of uniaxial anisotropy over magnetocrystalline anisotropy. The well-defined XMCD spectra of both nanowires and films synthesized at substrate temperature of 100°C indicate the Fe film is magnetically active. Previous predictions of magnetically dead layers were based on the study of Fe films that were synthesized at room temperature.

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Electrode materials for supercapacitors based on reduced graphene oxide aerogel**M.V. Gudkov¹, A.Ya. Gorenberg¹, V.N. Kalinichenko¹, A.A. Maltsev², V.P. Melnikov¹**¹*Semenov Institute of Chemical Physics of Russian Academy, Moscow, Russia*²*Emanuel Institute of Biochemical Physics of Russian Academy of Sciences, Moscow, Russia*

The main goal of this study is obtaining and studying of promising electrode materials with 3D structure based on reduced graphene oxide with a high surface area and electrical conductivity as well as various polymers, which are stable under cyclic electrochemical influences. The dependence of the structural organization of nanocomposites on the size parameters of the initial particles of graphene oxide, on the ratio of the carbon and polymer components, on electro-chemical parameters was investigated.

The production and use of aerogel as the basis of the composite with segregated structure will allow obtaining a continuous electrically conductive network and will open the possibilities for its modification. The methods of introducing the polymer binder will allow varying the properties of composites in a wide range and optimizing them. Several different methods for the preparation of composite materials have been investigated and analyzed, including: incorporation of polymer particles into aerogel, impregnation of aerogel with polymer solution, and in situ polymerization on the surface of aerogel particles. Graphene oxide was synthesized by Hummer's method [1]. It was shown that electrode materials obtained on the basis of such aerogels have a highly developed structure with a specific surface area up to 500 m²/g and a capacity of more than 50 F/g.

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ENR-92

Solar Selective Absorbing Coatings for Concentrated Solar Thermal Power

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Solar thermal energy is one of clean and renewable energies with great potential applications. Solar spectral selective absorbing coatings are the fundamental component of a solar photo-thermal conversion absorber which is required to have a high absorptance in the wavelength 300-2500 nm and a low thermal emissivity in the wavelength 2.5-50 μm . For parabolic trough concentrated solar power, the high temperature stability of the coating is more critical besides its spectral selectivity. A solar absorptivity above 0.95 and a normal emissivity below 0.06 have been obtained in our new designed coatings, such as $\text{Al}_2\text{O}_3/\text{AlNi}-\text{Al}_2\text{O}_3/\text{AlNi}-\text{Al}_2\text{O}_3/\text{Mo}$, $\text{SiO}_2/\text{NbXON}/\text{NbXN}/\text{Al}$ (X=Ti, Mo, Si etc.) and $\text{SiO}_2/\text{ZrSiON}/\text{ZrSiN}/\text{Mo}$ multilayer coatings. The thermal stability above 500°C in vacuum was evaluated for the potential applications in parabolic trough concentrated solar power (CSP).

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ENR-94

“Status and Future for CSP’s development in China”

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Professor Wang Jun is the expert from the Southeast University (Nanjing, China) who has been studying on CSP technology for many years. His research fields mainly relate to solar thermal energy application in high temperature levels, and optical concentrating process. Wang presided many important scientific projects and programmes, including of China “863” projects, “973” projects as well as other key programmes funded by National Ministry of Education and provincial departments relevant. He has published more than 40 articles and 40 patents so far. As the president of the board of Institute of Renewable Energy Nanjing, Wang knows the development status of CSP technology in China very well. In addition, he is also employed as the director of

Solar Energy Professional Committee of Energy Research Council Jiangsu and the editorial board membership of <China Solar Energy> and <Journal of Solar Energy Academic>. Wang prepares a presentation, called “Status and Future for CSP’s development in China”, for this conference, in which a short overview of the state-of-the-art of CSP including the status in China is presented, and a blueprint for China’s CSP development is elaborated based on China’s 13th 5-year program and other guides from politics and markets. Wang supposes that China could play a more prominent global role in CSP, but this would require stronger efforts in several areas ranging from innovation to policies.

ENR-96

Synthesis and Characterisation of Kesterite Thin Films by a Wet Chemical Method

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One of the challenges for the PV market is the balance of the expense of production and the efficiency of the cell produced. CZTS ($\text{Cu}_2\text{ZnSnS}_4$) has a great deal of potential for PV applications due to its close relationship with other thin-film solar cell absorbers with high efficiencies, such as CIGS, but without the use of rare or toxic elements. CZTS is desirable mainly due to its direct band gap in the range of 1.0 to 1.5 eV and high absorption coefficient [1]. More notably, IBM have produced CZTSSe devices with 12.6% efficiency when introducing selenium [2]. Further studies of alloying CZTS with other elements including Cd, Ag, Ge, Bi, Li, Mn, Fe, [3][4][5][6][7][8][9] have shown to improve device efficiencies by tailoring the band gap, effecting defect size, unwanted secondary phases, and carrier concentration. The main aims of this study were to determine reliable, low cost deposition methods for the thin films, as well as obtain solutions to the problems surrounding the low efficiencies of present devices.

Several alloying studies were performed, replacing the Cu, Zn and Sn sites with isoelectronic and non-isoelectronic elements. CZTS films were synthesised by chemical bath deposition whilst varying the alloy concentrations. The films were then selenised by close space sublimation, in order to improve material quality and device efficiency. The morphological characterisation of the synthesised films was performed using XRD and Raman spectroscopy, to inspect the phases of the material. The electronic and optical characterisation was carried out on a variety of photoemission techniques, including XPS and IPES to study the oxidation states, band structure and the work function of the thin films. As well as this, UV-vis was used for comparison with the band gap measured from XPS and IPES. The band structure determined from experiment was also compared to DFT calculations performed at UCL.

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ENR-97

Silver Nanowire based Percolating Networks for Transparent Flexible Thin Films Synthesis, Nanoscale Characterization and Integration into Functional Devices.

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New generation of transparent electrodes are expected to exhibit three main physical properties: high electrical conductivity, high transparency and mechanical flexibility. The most efficient and widely used transparent conducting material is currently indium tin oxide (ITO). However the indium scarcity associated to the lack of flexibility of ITO as well as relatively high cost of fabrication has prompted the search for alternative materials. Among emerging transparent electrodes (TE), silver nanowire (NW) networks appear as a promising substitute since they exhibit excellent properties with sheet resistance of a few Ω/sq at optical transparency of 90%, fulfilling the requirements for many applications. In addition, the fabrication of these electrodes involves low-temperature processes which renders this technology very promising.

In this communication, we will first present results on the synthesis and on the purification process of silver nanowires. Then, after fabrication of homogeneous random networks, specific characterizations performed to understand the physical phenomena taking place at the scales of the NW-to-NW junctions (nanoscale) up to the

entire network (macroscale) will be presented. Finally, we will show efficient use of these flexible transparent conductive layer through integration into functional devices, in particular solar modules.

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ENR-98

Band Gap Engineering and Defect Design of Metal Oxides using Molecular Layer Deposition

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Metal Oxides (MOs) are central in a wide range of research fields and for numerous applications including catalysis, sensing, photonics, optoelectronic devices, renewable energy, electrochemistry and more. Molecular Layer Deposition (MLD) was demonstrated as a method for preparation of highly photoactive thin films that can be prepared on macroscopic as well as on nano-scale substrates.[1] The use of MLD in the context of photocatalysis opens new routes towards non-stoichiometric oxides for tuning and optimizing the reactivity and performances of MO catalysts.[3-4] Specifically for MOs, oxygen vacancies (OV) are important structural defect that alter the reactivity of MOs by introduction of new electronic states within the band gap (BG). The use of MLD for defect design offers additional valuable handles for optimizing MO electronic structure further to control over the crystalline phase and impurity doping. A widely studied MO in the context of OV is non-stoichiometric Titania, TiO_{2-x} . The electronic structure, charge transport, and surface properties of TiO_{2-x} are closely related to the details of the defects and OV. Hybrid organic-inorganic Ti-Ethylene glycol (Ti-EG) thin films prepared by MLD are demonstrated for attaining oxygen-deficient Titania with control over the electronic defect states and electronic bands positions. In my talk I will present our current understanding of the electronic structure evolution that takes place when annealing hybrid films leading to the highly photocatalytic oxide thin

films. The correlation of OV details and band positioning with the unique photocatalytic performance demonstrated for annealed films will be discussed.

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ENR-99

SDC-Na₂CO₃ nanocomposites: one step synthesis and electrochemical performances for low temperature ceramic fuel cells

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Ceramic fuel cells (CFCs) or solid oxide fuel cells are promising electrochemical device for highly efficient and green energy conversion of chemical energy to electricity. It is recognized that the running temperature of CFCs should be declined to reduce system investment while improve the lifespan. The key solution is to develop highly active electrolyte materials since they determine the working temperature of CFCs and related cell components, as well as the balance of plant. Ceria-carbonate composite presents a type of alternative and promising electrolyte materials for such purposes. It is well accepted that the composite utilize the interface between cerium oxide and carbonate as highway for super ionic conduction pathway. Various nanomaterial fabrication techniques have been applied in the past decades to increase the interfaces, like impregnation, and co-precipitation methods. However, those methods suffer from uncontrollable residual carbonate content and insufficient interface area [1, 2]. In this work, we adopt the sol-gel method to one-step synthesize samarium oxide doped cerium oxide-Na₂CO₃ (SDC-Na₂CO₃) nanocomposite as electrolyte materials for CFCs. Their morphologies, crystal phases, the ac conductivity and dc conductivity, as well as ceramic fuel cells/electrolysis cells electrochemical performances of SDC- Na₂CO₃ with different residual carbonate contents are

investigated. It is suggested that sol-gel method is a promising method to obtain highly active nanocomposite electrolyte for low temperature CFCs.

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ENR-101

Critical review on state-of-the-art of stability tests of dye and perovskite solar cells and suggestions for improvements

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Long-term stability is a key factor affecting the commercialization of new solar cell technologies such as dye and perovskite solar cells. Testing of stability is therefore of utmost importance. However, we seldom see sufficient information been reported on stability tests and how these are performed, even for high efficiency cell results. In this contribution, we present a review on how stability tests are currently performed in practice. We have analysed in detail stability-related experimental dye and perovskite solar cell papers published in 2016 and listed in Web of Science, focusing on methods and ageing conditions in stability tests. Our review shows that the quality and impact of stability tests could be improved. In our contribution, we outline common shortcomings in stability tests and practical ways to overcome them. These methods help researchers to design better aging tests in the future, and hence speeding up the commercialization of these solar cell technologies.

ENR-102

Novel Binary Nanoparticle Systems of Mixed Heterostructure Ag₂O-TiO₂ with Different Shapes for Enhancing Photoreforming Hydrogen Production

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In order to improve photocatalytic hydrogen production over TiO₂ based catalyst, a series of Ag₂O-TiO₂ nanoparticles with heterostructures have been synthesized. However, the nanoparticles have a drawback of spontaneous aggregation in aqueous suspension which could bring about low optical absorption property and photocatalytic activity. In this work, the dispersion stability of Ag₂O-TiO₂ nanoparticles with different shapes in aqueous suspension were investigated. A simple and novel approach was proposed for enhancing the dispersion stability by mixing two types of Ag₂O-TiO₂ nanoparticles with different shapes in glycerol aqueous solution without adding any dispersant. This approach was experimentally confirmed as an effective method for stabilizing the suspensions and significantly enhancing the photoreforming H₂ production. This strategy of mixing different shaped particles may enlightening new ideas for designing efficient photocatalytic hydrogen production system.

ENR-103

Effect of Ultrasound on Solidification of TiO₂ Nanoparticle Suspensions

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Ultrasound was used to solidify an aqueous suspension of TiO₂ nanoparticles. The effects of ultrasonic power and nanoparticle concentration on supercooling degree for the ice nucleation in the TiO₂ nanoparticle suspension were investigated through the cooling curve and infrared thermal imaging methods. Results showed

that the supercooling degree of TiO₂ nanoparticle suspension can be reduced by ultrasound, and the reduction rate increases with the increase in ultrasonic power and nanoparticle concentration. The mechanism of ultrasound-controlled nucleation was analyzed by measuring the states of the TiO₂ nanoparticles and cavitation bubbles during the solidification of nanoparticle suspension at different ultrasonic powers. The small bubbles formed by rectified diffusion at low ultrasonic powers initiated ice nucleation through their collapse, and the large bubbles formed by bubble coalescence at high ultrasonic powers initiated ice nucleation by providing heterogeneous nucleation sites. The role of bubble-coalescence-induced bubbles in the promotion of ice nucleation is more significant than that of rectified-diffusion-induced bubbles. Additionally, the advantage of TiO₂ nanoparticle suspension over deionized water on the supercooling degree was found to disappear when ultrasonic power exceeded 195 W. This finding can be attributed to the agglomeration of TiO₂ nanoparticles and cavitation bubbles, which also deteriorated the dispersion stability of the nanoparticle suspension during solidification and consequently led to failure. With regard to the reduction in the supercooling degree and improvement in the dispersion stability, introducing a low-power ultrasound is a viable option for the nanoparticle suspension.

ENR-104

Synthesis and Size-control of Microencapsulated Phase Change Materials by Using a Microfluidic Device

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Control the size polydispersity and morphology of phase change material microcapsules is important for using them to enhance the heat transfer performance of conventional fluids. Here we established a method to synthesis phase change material microcapsules with low polydispersity and good spherical shape. The phase change material microcapsules, which consisted of heptadecane as core and polyurea as shell, were synthesized via a 3D glass microfluidic chip. The effect of fluid velocity on the morphology and the size of the microcapsules were investigated and the corresponding thermophysical properties of microcapsules at different particle sizes were studied. The results showed that the phase change material microcapsules were arranged uniformly and spherically, and the particle size of the obtained microcapsules increased from 50 μm to 300 μm by increasing the velocity ratio of continuous phase and disperse phase from 2.5 to 10. The differential scanning calorimetry (DSC) and the thermal gravimetric analyzer (TGA) were used to measure the

thermophysical properties and thermal reliability of the microencapsulated phase change materials. The DSC results showed that the encapsulation ratio of heptadecane was about 80.15 percent at the particle diameter of 100 μm . The TGA results showed that the microencapsulated heptadecane had good thermal reliability compared to pure heptadecane. The above observations confirmed that the 3D glass microfluidic device was a simple and effective method for synthesizing phase change material micocapsules.

ENR-106

Outdoor testing station for studying performance and stability of solar cells

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The focus of this study is on the preparation and testing of a measurement system for real life outdoor testing of emerging photovoltaic devices, namely dye-sensitized solar cells and perovskite solar cells. While laboratory level accelerated aging tests for solar cells are a powerful tool for studying the stability of the cells in longtime operation, such tests do not cover all environmental variations present under real outdoor environment. Hence, when going forward in lifetime testing, outdoor testing of the emerging solar cell technologies becomes critical in evaluation of their suitability for commercialization.

The new measurement system was designed according to ISOS standards for organic solar cell outdoor aging tests [1]: it is capable to monitor the current-voltage characteristics of the tested cells, provide adjustable electric load for the cells, and record weather values. A short aging test was performed with this new station for dye-sensitized solar cells during late autumn in Finland, when the weather varied from mildly warm autumn weather to freezing and snowy. The lightly encapsulated cells did suffer from degradation during the test since their short circuit current decreased. The degradation did not occur during the frosty period but instead during the warmer, rainy periods so the cause of degradation was most likely moisture.

Additionally, the tested cells were able to generate current at sub-zero temperatures about as well as in warmer environments, which has not been previously reported in literature for dye-sensitized solar cells.

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Photocatalytic degradation of cationic and anionic dyes in water using hydrogen- terminated silicon nanowires as catalyst**N. Brahiti^{1,2}, T.Hadjersi¹, S. Amirouche², H. Menari¹, O. ElKechai²**

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Semiconductor photocatalysis is a newly developed AOP, which can be used for the degradation of dye pollutants. A lot of studies were reported on the photocatalytic degradation of refractory organics. TiO₂ was the most used in photocatalysis because of its exceptional stability towards chemical and photochemical corrosion. Silicon is a low cost and environmental friendly semiconductor, which prevails in integrated microelectronics. However, it is not used in pollution control because its valence band is not positive enough to oxidize pollutant species. Nevertheless; the nanostructured silicon has recently attracted a great deal of attention because of their high specific surface. It is expected to have potential applications in the development of new catalysts [1]. Indeed, it was reported by Yoneyama et al. that platinized n-type crystalline silicon and silicon powder are good photocatalysts for formic acid decomposition [2]. Also, Chen et al. used one dimensional hydrogen-terminated silicon nanowires (SiNWs) prepared by oxide-assisted- growth, under ultrasonic agitation for the degradation of methyl red [3]. Shao et al. investigated the performance of hydrogen-terminated SiNWs substrates prepared by the VLS method for the degradation of Rhodamine B under visible light irradiation. It was found that hydrogen-terminated SiNWs exhibited a high efficiency which was attributed to an electron deficiency of H atoms in Si-H_x terminating the surface [4]. In addition, Pan et al. found that Cu- modified silicon nanowires show enhanced catalytic activity for the coupling reaction of benzene halides (iodobenzene, bromobenzene, and chlorobenzene) and aniline [5]. Also, Tsang and al. show that Au- and Cu-modified Si nanowires (SiNWs) are superior catalysts for selective oxidation of hydrocarbons [6].

In this work, the photocatalytic degradation of cationic (methylene blue (MB)) and anionic (methyl orange (MO)) dyes was investigated using hydrogen-terminated silicon nanowires (H-SiNWs) as photocatalysts. Several silicon nanowires samples with different morphologies were elaborated and the morphology was changed by acting on the silicon nanowires formation parameters such as substrate type, doping level, crystallographic orientation, silver deposition time and etching time. It was shown that the photocatalytic

activity strongly depends on the morphology of SiNWs arrays. Indeed, it was found that n-type H-SiNWs elaborated on highly doped Si (100) substrates exhibit the highest photocatalytic activity for the degradation of MB. In addition, it was demonstrated that H-SiNWs are more efficient for the photodegradation of MO than MB in the solutions with pH values higher than the pH of zero charge point of silica (pH_{pzc}).

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ENR-109

Comparison of thermal conductivity measurement techniques with silver nanofluids

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“Nanofluids” consists of nanoparticles (typically 1-100 nm in size) dispersed in a base fluid, such as water or oil. Recently, nanofluids have been studied widely due to the reported anomalous enhancements in their convective heat transfer properties [1,2] and thermal conductivity [3] as compared to conventional heat transfer fluids. However, these results are remarkably inconsistent among different research groups. Most of these contradictions are probably due to poor characterization and stability of the nanofluids and differences or high measurement uncertainties of the measurement apparatuses. In addition, the analysis of nanofluids is often incomplete and does not present the overall efficiency of the nanofluids in a realistic manner [4,5].

In this work, thermal conductivity of silver nanofluids is studied with three different measurement methods: C-Therm thermal conductivity analyser based on a modified transient source plane technique and a static ring-gap apparatus (RGA) developed by ILK Dresden. The measurement apparatuses are compared, and the

measurement principles and errors are evaluated. Silver nanofluids with small particle size (<10 nm) and high concentration (up to 5000 ppm) are prepared using novel, modified Tollen's method [6]. Particle sizes, size distributions and stability of the nanofluids are also studied.

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ENR-110

A ceramic nanocomposite fuel cell model for studying internal phenomena in a fuel cell

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All the complex phenomena and processes in fuel cells are not yet fully understood. For example the degradation processes affecting fuel cell performance are still somewhat unclear and there are some stability problems with the cells. These phenomena need to be studied in detail to enable better performance and durability of fuel cells. Fuel cell modelling is a valuable tool for understanding the electrochemical reactions and internal phenomena of fuel cells. With the help of modelling and validating the model with experimental data, new technologies can be developed and fuel cell operating conditions can be optimized.

A general 2D fuel cell model was created with COMSOL Multiphysics ® to simulate the behavior of an operational fuel cell. The model includes ion and electron transport, reaction kinetics, gas diffusion and thermal considerations at a moderate level of accuracy. In addition, a simplified engineering model with fundamental

equations was created for comparison. In the future, the 2D model will be developed further to account for degradation phenomena, temperature dependencies of the parameters and the composite nature of the electrolytes. Experimental data will also be gathered for use in validating the model and developing it further.

ENR-113

Molecule -Based Materials From 1 Dimension to 2 Dimension Nanostructures

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Molecule based materials nanoarchitectures have been employed as important nanoscale building blocks for advanced materials and smart miniature devices to fulfil the increasing needs of high materials usage efficiency. Different dimension Molecule based materials based nanoarchitectures, especially low dimension nanostructures, attract significant attention due to its fascinating controlled structure and functionality-easy tailoring with excellent semi-conductive properties and stability. In this report, we discuss the some molecule based materials self-assembled oriented functional nanoarchitectures by coordinated inducing. The molecular material building blocks, aggregate structures and their properties in optical, electrical and photoelectrical properties were shown.

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ENR-115

Effect of Ethylene Oxide Unit Number on Thickness and Ionic Conductivity of Ionic-based Polymer Electrolytes**Kyung-Ho Bae, Ohsuk Kim, Quoc Chinh Tran, Ho-Suk Choi***Chungnam National University, 220 Gung-Dong, Yuseong-Gu, Daejeon 305-764, Republic of Korea*

Ethylene oxide (EO) unit of the Triton X family is critical for the surfactant-assisted polymerization of the ionic liquid-based polymer electrolytes film at the plasma-liquid interface. This unit employed as an assisted-cross linking agent for the liquid plasma polymerization while ionic liquids are used as building blocks. The relationship between number of the EO unit and thickness and ionic conductivity of the ionic-based polymer electrolyte film was examined. Three different types of the Triton X were used as Triton X100, Triton X405 and Triton X705 with the number of EO unit of 9, 35 and 55, respectively. The thickness of the films increased from 1.94 μm to 8.24 μm at the same Triton X molar content of 6% in liquid mixture when the number of the EO unit increased from 9 to 55, respectively. The ionic conductivity of the obtained polymer electrolytes increased with increasing of the number of the EO unit. This unit plays a decisive role in the growth in thickness and the increase in ionic conductivity of the polymer electrolytes beside the critical role as an cross-linking agent for the the liquid plasma polymerization.

ENR-116

Simple one-pot Aqueous Synthesis of PtMo Sponge-like Nanoporous/Ultrathin N,S-Co-doped Carbon Dot Enhanced Electrocatalytic Activity for Hydrogen Evolution Reaction and Oxygen Reduction Reaction**Van-Toan Nguyen, Ho-Suk Choi***Chungnam National University, 220 Gung-Dong, Yuseong-Gu, Daejeon 305-764, Republic of Korea.*

A simple one-pot aqueous method is proposed to synthesize PtMo sponge-like nanoporous wrapped with ultrathin nitrogen and sulfur co-doped carbon dots by using NaBH_4 as the reductant without any surfactants. The materials are carefully investigated by microscopic (SEM, TEM), spectroscopic (high resolution photoemission, Raman spectroscopy) techniques, evidencing that N,S-co-doped Cdots wraps PtMo sponge-like nanoporous. The electrocatalytic activity of the material is tested toward the electrochemical evolution of

hydrogen and the electrochemical reduction of oxygen. The obtained N,S-co-doped Cd/PtMo nanohybrids display enlarged electrochemically active surface area and superior electrocatalytic performances toward hydrogen evolution reaction (HER) and oxygen reduction reaction with respect to single PtMo and c-Pt/C catalysts, exhibiting promising applications in energy storage and conversion.

ENR-117

Polyhedral Gold Nanocrystals/Polyelectrolyte Composite Film: One-Pot Synthesis via Interfacial Liquid Plasma Polymerization

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In contrast with the conventional in situ and ex situ methods for the preparation of polymer-based nanocomposites in which the polymer matrix (for both methods) and metal nanoparticles (for the ex situ method only) are prepared separately prior to being combined to form the composite, polyhedral gold nanocrystal/polymer composite film was successfully synthesized through combining the in situ formation of gold nanocrystals (AuNCs) and simultaneous polymerization of the polyelectrolytes from ionic liquids and surfactants under atmospheric pressure plasma. The composite film contained a large number of well-shaped AuNCs. The AuNCs are stereoscopically distributed in the polyelectrolyte matrix without agglomeration. Both the size and shape of the AuNCs were controlled through changing the plasma exposure time. The size of the AuNCs prepared in a 2 mm deep reactor decreased along the cross section of the composite film from top to bottom, while they were uniform in size when they were prepared in a 5 mm deep reactor. In the presence of the Au precursors, the polymer film thickness increases to 7.03 μm , which is two-fold thicker than that of the polymer film prepared without adding Au precursors. Through the density functional theory (DFT) calculations, the critical role of Triton X100 was clearly demonstrated in the formation of the well-shaped AuNCs. Based on the experimental and theoretical results, an appropriate mechanism is proposed for the formation of the polyhedral AuNC/polyelectrolyte composite film.

ENR-118

Pt-coated cylindrical micropatterned honeycomb Petri dishes as an efficient TCO-free counter electrode in liquid junction photovoltaic devices

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The Pt layer deposited on a cylindrical micropore patterned Petri dish, which is prepared using one-step solvent-immersion phase separation, is fabricated for the first time as an FTO-free counter electrode (CE) for dye-sensitized solar cells (DSCs). The surface topology of the honeycomb Petri dish is controlled effectively through varying the experimental conditions; notably, the obtained porous structure is part of the substrate, which reveals an increase in the structure's stability for the fabrication of devices. Due to the high specific active surface area of the Pt-deposited honeycomb substrate CE, the efficiency of the DSC using the developed CE substrate is enhanced by 14.5% compared with the device using a Pt-sputtered flat substrate. This design strategy has potential in fabricating highly efficient and low-cost CE materials with FTO-free substrates for DSCs and flexible DSCs.

ENR-120**Single-walled carbon nanotubes decorated with platinum nanoparticles electrocatalysing hydrogen evolution and oxidation**

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Current technologies for converting and storing energy in hydrogen rely heavily on scarce and costly platinum. To enable large-scale deployment of polymer electrolyte fuel cells (PEFCs) and electrolyzers, it appears imperative to minimise the exploitation of precious metals, especially in the long term. In fact, global demand for platinum already outstrips supply.[1] Another key hindrance of state-of-the-art PEFCs is the degradation of catalyst support.[2] To address these issues, we have developed a simple synthesis for depositing less than 10 $\mu\text{g}/\text{cm}^2$ of platinum on single-walled carbon nanotubes (SWNTs), exhibiting promising activity for hydrogen oxidation and evolution. Carbon nanotubes provide higher conductivity and electrochemical durability[3],[4] and allow lower platinum loadings[5] in PEFCs than the common standard carbon black.

The electrochemical activity of Pt-SWNT was verified in RDE experiments for hydrogen evolution and oxidation. The feasibility of a PEFC employing Pt-SWNT at the anode has been demonstrated. Platinum nanoparticle size and the extent of dispersion will be analysed by XRD, XPS, and HR-TEM.

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ENR-121

A facile method to synthesize TiO₂/Graphene- metal nanocomposites via microwave irradiation (MWI) technique for solar energy harvesting

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Solar energy harvesting is considered one of the most promising clean alternative energy resources. Dye Sensitized solar cells based on TiO₂ has been extensively studied in the last two decades. With the excellent thermal and electrical properties of graphene and plasmonic properties of metal nanoparticles, nanocomposites based on the aforementioned materials will be excellent candidates for solar energy harvesting. In this work, we are reporting a facile method of preparing photoactive materials based on TiO₂/Graphene/AgI nanocomposites via microwave irradiation (MWI). The nanocomposites were characterized via XRD, TEM, XPS, UV-visible spectroscopy, FT-IR, and Raman spectroscopy. The thermal stability of the prepared nanocomposites were tested by the thermal gravimetric analysis technique (TGA). The results show that we have the most active phase of TiO₂, the anatase, with no other phases of TiO₂. The materials also were tested for photo-degradation of MB dye, and phenols in both the UV and Visible spectra respectively and shows excellent photo-degradation (100% in 4 hours for the MB and 70% in 3 hours for the phenol). The prepared nanocomposites were tested as active materials in Dye-Sensitized Solar Cells DSSCs.

Bottom-Up Constructing N-doped Graphdiyne for High-Performance Supercapacitors**Z.C. Zuo¹, Y. J. Li¹, H. B. Liu¹, Y. L. Li¹**

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A superfast bottom-up method is developed for constructing well-defined N-doped graphdiyne (GDYs) with controllable porous structure. Via our solvent- and metal-catalyst-free method, three diverse GDY monomers designed here are high-efficiently polymerized into GDYs nanostructures. Through monomer pre-design, the nitrogen-configuration and content in the GDYs are unanimously controlled, with the N-content high up to 16 %, meanwhile, the bandgap and porous structure is efficiently tuned. The as-obtained GDYs nanostructure have a high surface area up to 1150 m²/g and high conductivity up to 20 S/m, which are both preferred for the electrochemical applications. Notably, additional with the flexible nanochain-like structures, GDYs exhibit outstanding 3D continuousness for forming the electronic transfer network in the applications. Thus, the supercapacitors based on GDYs show remarkable performance in delivering a high energy density (30 Wh/kg) and power density (310 kW/kg). Besides, this method for high-efficiently preparing GDY is paving the way for constructing on-demand GDY structure for challenging some intractable problems in green energy, such as Li-ion battery, Li-S battery, fuel cell, and so on.

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Microscopic techniques as a tool to investigate ceramic nanocomposite fuel cells**S. V. Jouttijärvi¹, M. I. Asghar¹, P. D. Lund¹***¹New Energy Technologies Group, Department of Applied Physics, Aalto University, P.O. Box 15100, FI-00076 Aalto, Finland.*

Ceramic nanocomposite fuel cells are potential energy sources for the future applications [1]. Due to complex microscale structures of these devices, advanced microscopic techniques are needed to reveal the fundamental factors behind the macroscopic performance. This work reviews different microscopic techniques that have been used in ceramic nanocomposite fuel cell studies. The review starts from 2D techniques (SEM, TEM) [2], discussing about their applications and parameters that can be defined. Then the focus is moved on 3D techniques (FIB-SEM, X-ray nanotomography) [3], which allow characterizing crucial parameters (triple phase boundary length, porosity, tortuosity etc.) that are not possible to study with 2D techniques. Finally, linking the microscopic structure and macroscopic performance is discussed.

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ENR-124

Fabrication of advanced nanocomposite fuel cells using screen printing

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Solid oxide fuel cells (SOFCs) are a promising energy source for future applications [1]. For commercial purposes, SOFCs with low operating temperature and easily scalable manufacturing process are required. Screen printing is one possible technique to deposit SOFC components on a substrate due to its ability to deposit very thin layers, thus decreasing the area specific resistance of the cell [2]. In this study, electrolyte inks consisting of doped cerium oxide and terpeneol-based vehicle are deposited on anode pellets. The effect of ink composition and printing procedure to the half-cell performance is discussed with help of IV- and EIS-measurements in temperature range of 400 – 600 °C. Moreover, possibility to add molten carbonates to electrolyte to lower the operation temperature is investigated.

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ENR-125

Analysis of potential materials for single components fuel cells

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Single component fuel cell is a new promising technology consisting of one-layer nanocomposite mixture instead of a traditional three-layer anode-electrolyte-cathode structure. The advantages from this new technology are the lower fabrication cost and the simplification of the system. In this work, different potential mixtures of semiconductors and ionic conductor are utilised. As semiconductors, perovskite structure material

Lanthanum-Strontium-Cobalt-Ferrite (LSCF) is adopted for its capability of mixed ionic-electronic transport. Then, it is compared with a non-perovskite structure material Nickel-Cobalt-Aluminium-Lithium (NCAL), which has an excellent electronic conductivity, but, lower ionic conductivity. Gadolinium -doped Ceria (GDC) is used as an ionic conductor due to its sufficient ionic conductivity at relative low temperature of 550 °C. The unknown working mechanism has been deeply analysed by current-voltage measurements, electrochemical impedance spectroscopy, electromotive force measurements, high temperature X-diffraction and scanning electron microscopy. The main focus of this work is to develop better understanding of mechanisms involved in the reaction kinetics and ion transport, which would contribute in improving performance and stability of the device. In addition, preliminary device modelling is performed using Comsol software.

ENR-127

Analysis of Cell Life and Performance of Molten Carbonate Fuel Cells with Li-Na and Li-K Carbonate Electrolytes

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This work has been focused on the effect of Li-K carbonate and Li-Na carbonate electrolytes in a molten carbonate fuel cell. A coin type molten carbonate fuel cell was used in this experiment. All the cells were operated at 923 K and 1 atm with 300 mA/cm² of current density. The analysis of cell performance were carried out with steady state polarization and AC impedance methods. After operation, the cell was dissolved in 10 wt% acetic acid solution and the remaining amount of electrolyte was analyzed.

As a result, it was found that the cell using Li-Na electrolyte had slightly higher voltage at the polarization state than the cell using Li-K electrolyte, but the cell life of Li-Na electrolyte was shorter than that of Li-K electrolyte. This implies that the cell with Li-Na carbonates would have faster electrolyte loss rate than that with Li-K carbonates. The results of impedance also showed that internal resistance and reaction resistance of all cells increased with time. It was probably due to the electrolyte loss in the cells.

In order to find the relationship between electrolyte loss and cell life, remaining electrolyte amount has been estimated by weight reduction ratio of components using the 10 wt% acetic acid. Since the acetic acid only dissolves carbonates, the weight reduction of the components should have relation to the remaining carbonate electrolyte in the cell. Both cells showed about 20% of electrolyte reduction when the cell had significantly

large internal resistance. Thus it can be concluded that a permissible range of electrolyte loss is very narrow of ca. 20%.

ENR-129

A novel composite cathode material containing natural nanomineral material for solid oxide fuel cell

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Natural nanomineral material, attapulgite clay, was chosen to prepare novel composite SOFC cathode materials $\text{Pr}_{0.7}\text{Sr}_{0.3}\text{Cr}_{0.5}\text{Fe}_{0.5}\text{O}_{3-\delta}$ /attapulgite clay, due to its nano-scaled internal channel and large specific surface area^[1,2]. $\text{Pr}_{0.7}\text{Sr}_{0.3}\text{Cr}_{0.5}\text{Fe}_{0.5}\text{O}_{3-\delta}$ prepared by citrate-EDTA method was successfully loaded on the natural nanomineral substrate. XRD, BET and SEM were applied to analyze the characteristics of the cathode materials. The conductivities of $\text{Pr}_{0.7}\text{Sr}_{0.3}\text{Cr}_{0.5}\text{Fe}_{0.5}\text{O}_{3-\delta}$ /attapulgite clay and pure $\text{Pr}_{0.7}\text{Sr}_{0.3}\text{Cr}_{0.5}\text{Fe}_{0.5}\text{O}_{3-\delta}$ were compared by four-probe method in air, in order to evaluate the effect of attapulgite clay on the conductivity. The SOFC performances at 700-800°C were also tested when H_2 and ambient air were fed into anode and cathode, respectively.

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A novel method to prepare Pt-Au alloy and its electrochemical performance as oxygen reduction reaction catalyst in alkaline solution**Yali Li, Chuanxin He***College of Chemistry and Environmental Engineering, Shenzhen University, Shenzhen 518060, Guangdong, P. R. China*

Fine tuning of the properties such as particle size, shape, and composition through controlled synthesis of alloy nanomaterials represents a robust approach toward more sophisticated catalysts with enhanced activity, selectivity, and durability [1]. In this work, we report a novel method to prepare highly active Pt/Au nano alloy/composite as electro-catalyst for oxygen reduction reaction (ORR). The Pt-Au alloy or composite was formed on monodispersed spherical SiO₂ nano particle with a carbon interlayer derived from polydopamine hydrochloride (PDA) to form SiO₂@C@Pt/Au nanocomposite. High active interface of Pt and Au and alloy are formed by simply adjusting the sintering temperature. The electrochemical performance of SiO₂@C@Pt/Au was carefully investigated and compared with single metal electro catalyst. It is found that the grain size of the Pt-Au nanoparticle increases with the increase of applied temperature and period while composite material calcined at 600 °C gave the best performance over other samples. The high resolution TEM images showed the partial fusion of Pt and Au with the largest metal/metal interface provides the best performance of the target reaction. It is the first time, to our best knowledge, to discover such a relationship between metal alloy/composite activity with the interface microstructure.

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ENR-133

Durability of advanced structured ceramic solar absorbers for high temperature operation.

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In the field of solar energy harvesting, concentrated solar power (CSP) is facing major material challenges linked to the need to increase the operating temperatures for a better thermal to electrical conversion efficiency. One of the critical material is the solar absorber which absorbs most of the incident concentrated solar radiation. This surface material must have excellent optical properties with a very low reflectance to insure more than 95% absorption of the solar spectrum. In addition, its durability is a key contributor of the cost of electricity. Most of the CSP parabolic through plants operate below 450°C. Current materials usually consist in deposited interferential thin films or cermet materials [1, 2] suitable only for moderate temperatures (<580°C) and under vacuum [3].

This work will present a new type of solar absorber material suitable for very high temperature operation in air. It is based on the microstructuration of silicon carbide based materials to take advantage of their high thermal and chemical stability. The manufacturing process is based on the etching of the surface through a self-organized masking layer of particles. The morphology of the surface will be presented as well as the optical characterization of the solar absorption based of reflectance measurements. The durability results will demonstrate the ability of this structured material to be used at very high temperatures, especially in air. The work will present the evolution of optical properties as a function of the base material type (sintered SiC or biomorphic SiSiC), of the structuration pattern (random, periodic), of the structuration size (from 0.2 to 1.5 micrometer) and of the aging temperature, up to 1200°C. The results will show that the solar absorption achieves values up to 95 to 98% and that excellent solar absorption properties are maintained for more than 500h at 1000°C in accelerated tests in air. Morphology observations by scanning electron microscopy will be used to explain the impact of aging on the different structure types. This novel functional material opens the way to new durable solar absorbers for very high solar concentrations and temperatures, both for conventional CSP technologies that need to operate at higher temperatures and also for emerging high concentration centralized receivers or Solar Thermophotovoltaics (STPV).

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ENR-134

About complex refractive index of black Si and standard porous Si

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The paper deals with the complex refractive index in the NIR-VIS light region of following three types of samples i) as prepared black silicon, ii) thermally oxidized black silicon (BSi) nano-crystalline specimens produced both by the surface structure chemical transfer method using catalytic Ag evaporated spots (as prepared sample) and by the catalytic Pt catalytic mesh (thermally oxidized sample), and iii) standard porous Si prepared electrochemically. We present, compare, and discuss the values of the NIR-VIS complex refractive index obtained by calculation using the Kramers-Kronig transformation. Results indicate that small differences between optical properties of as prepared black Si, thermally oxidized BSi and standard porous Si are given by i) passivation oxidation procedure, ii) thickness of the formed black Si layer, mainly, not by utilization of different catalytic metals, and by iii) thickness of standard porous films. Contamination of the surface by different catalytic metals contributes almost equally to the calculated values of the corresponding complex refractive index. Calculated values of complex refractive index of standard porous Si structures are in more cases modified by interference phenomena. More additional optical and microscopic techniques will be used for confirmation of results obtained by Kramers-Kronig transformation.

Acknowledgements : Following Slovakian grant agencies: APVV – project No.0152/15 and VEGA – projects Nos.2/0076/15, 1/0900/16 partly financially supported this contribution.

Enhanced Electrical Conductivity of the Carbon Coils by Surface Modification**D.-C. Kim and S.-H. Kim***Silla University, Busan, 46958 KOREA.*

Free-standing carbon nanocoils or carbon microcoils were obtained using C_2H_2 as the source gas and SF_6 as the additive gas in a Ni-catalyzed thermal chemical vapor deposition system. Surface modification of the free-standing carbon coils was performed by H_2 -plasma or Ar-plasma in a microwave plasma enhanced chemical vapor deposition system. The measurement of the electrical conductivity was carried out using four-point probe system in the measuring temperature range of 20~200°C. Indeed, the ambient state of the electrical conductivity measurement was varied as vacuum, H_2 gas or Ar gas condition at every measuring sample. In general, samples show the decreased-resistivity with increasing the measuring temperature, indicating the semiconductor characteristics for the carbon coils and surface-modified carbon coils like the characteristics of multi-walled carbon nanotubes [1, 2]. Among the various carbon coils, H_2 -plasma treated carbon microcoils gave rise to the most high surface electrical conductivity in the measuring temperature range of 20~200°C. It is understood that the electron-conducting channels might be enhanced by H_2 -plasma treatment on the surface of the carbon coils. H_2 -ambient condition also results in the enhancement of the surface electrical conductivity of the sample, compared with the other ambient state. Ar-ambient condition of the carbon coils seemed to stabilize the values of the electrical conductivities. Based on these results, the cause for the enhancement of the surface electrical conductivity of the carbon coils by the surface treatment was suggested and discussed.

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Formation of the Aligned Carbon Microcoils**N.-Y. Lee and S.-H. Kim***Silla University, Busan, 46958 KOREA.*

The achievement of the aligned carbon nanomaterials has been one of the most difficult task to overcome [1]. Up to the present, few studies have been reported for the aligned carbon microcoils except Bajpai's work [2]. In this work, the formation of the aligned carbon microcoils could be achieved using C₂H₂ as the source gas and CS₂ as the additive gas in a Ni-catalyzed chemical vapor deposition system. To achieve the alignment of the carbon microcoils, C₂H₂ and CS₂ were injected via the different inlet port and then the injecting gas flows of C₂H₂ and CS₂ were varied, respectively. The well-aligned development of the carbon microcoils could be achieved at 500sccm for C₂H₂ flow rate and 15sccm for CS₂ flow rate, namely 0.3 for the CS₂/C₂H₂ flow rate ratio. When CS₂ flow rate was varied with maintaining C₂H₂ flow rate at 500sccm, even the formation of the carbon microcoils was deteriorated. However, the variation of C₂H₂ flow rate with maintaining CS₂ flow rate at 15sccm could give rise to the formation of the untangled carbon microcoils without the alignment of the carbon microcoils. The alignment of the carbon microcoils was not much influenced by Ni catalyst shape and size. When the total flow rate of the injection gas was increased by inflow of buffer gas (Ar) during the reaction, the degree of the alignment seemed to be slightly enhanced. Based on these results, we determined the critical factor to achieve the alignment of the carbon microcoils and discussed the cause for the formation of the aligned carbon microcoils.

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Further improvement of the unevenness of the edge portion of the coating film after drying by controlling the evaporation rate of the edge's side surface of the coating liquid film during drying**H. Kagami***Fujita Health University, Toyoake, Aichi, 470-1192, Japan.*

The drying of polymer solutions coated on a flat substrate is very important in various industrial applications such as fabricating flat polymer resist thin films in resist coating process in semiconductor process and so on. We have proposed and modified a model of the drying process of a polymer solution coated on a flat substrate for uniform polymer film deposition. And we clarified the dependence of the distribution of polymer molecules on a flat substrate after drying on various parameters based on the analysis of many numerical simulations of the model.

However, the mechanism of the drying process in the previous studies does not allow problems with thin films after drying, such as thickening of the edges and depressions near the edge, to be avoided. We used the model to control the thickness of a thin film after drying through management of the temperature, evaporation, and concentration [1]. As a result, we see that the thickening at the edge of the thin film after drying can be improved through appropriate thermal, evaporative and solute concentration management. In relation to this, the influence of the temperature distribution during drying on the film thickness distribution after drying was studied in detail [2].

In this study, in order to further reduce the thickening of the edge of the thin film after drying, we tried to adequately control the evaporation rate on the side of the liquid film at the edge. As a result, it was found that appropriate management of the evaporation rate on the side of the liquid film at the edge during drying further reduces the thickening at the edge after drying.

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Fuelling the future with fuel cell technologies at the forefront of innovation**A. Goyal¹, M. I. Asghar², P. D. Lund²**¹*Ressun Lukio IB World School 001419, Kalevankatu 8-10 00100, Helsinki, Finland*²*New Energy Technologies Group, Department of Applied Physics, Aalto University, P.O. Box 15100, FI-00076 Aalto, Finland.*

The principle idea of fuel cells is simple – they convert chemical energy into electrical energy; however the impact that emerging fuel cell technologies can have on the future is anything but minor. They can play an instrumental role in shaping the future if their true potential is realized. At an era where we are faced with the challenge of meeting a substantially growing population's energy needs and unsustainable fossil fuels are still governing around 85% of the world's energy production [1], there is an immense need of innovation and implementation of renewable energy technologies. Major energy sources are swiftly depleting and global warming has become a serious threat; increased public awareness and collaboration of green technologies is essential – before it is too late.

Fuel cell technologies are a feasible option to for clean energy generation [2,3], as they consume less raw materials while generating 2-3 times the energy output. There are several types of fuel cell technologies, which utilize different kinds of materials, and as a result have different operating temperatures. This work will provide a comprehensive overview of emerging fuel cell technologies. Their 3D structures will be investigated and modelled. Furthermore, their working principles will be discussed and their advantages and limitations will be compared. Finally, potential applications of these emerging fuel cell technologies will be presented. Especial emphasis will be given on the nanostructured biofuel cells[4].

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Multifunctional roles of semiconductors in solid oxide fuel cells**W.J. Dong¹, X.Q Liu¹, Y.Z Tong¹, X.Y. Wang¹, B.Y. Wang¹, B. Zhu^{1,2}**¹*Hubei University, Wuhan, Hubei 430062, P. R. China*²*Royal Institute of Technology, Stockholm S-10044, Sweden*

Lowering the operation temperature of solid oxide fuel cell (SOFC) is a long term object to achieve the commercialization of SOFC. Searching for high ionic conductors and high catalytic activity electrode materials is one of the most important issues in low temperature SOFC (LTSOFC). Semiconductors have been widely investigated in solar cells, water splitting and some other fields. Some semiconductors, such as TiO₂, provide impressive water splitting efficiency due to their high catalytic activity. Water splitting is a reverse reaction of SOFC. In this regards, we bring semiconductors into the investigation of SOFC. In addition, recent studies have revealed that the electrode materials of SOFC can be considered as p and n type materials according to their conductive property in different atmosphere ¹. Amphoteric oxide semiconductors have already been used as the electrode materials in SOFC ². Besides, defects in semiconductors, such as oxygen vacancies, are expected to cause ionic conductivity of the semiconductor. However, due to the high electronic conductivity of semiconductors, they have not yet been used in SOFC as electrolytes. In this study, we intended to explore the multifunctional roles of semiconductors in LTSOFC in order to develop new LTSOFC materials. Semiconductors acting as electrolyte layer, electrode layer of SOFC have been investigated.

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ENR-142

In search for breakthroughs in low-temperature ceramic nanocomposite fuel cells

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A continual improvement in the synthesis of nanocomposite materials have revolutionized the ceramic fuel cells with improved performance at a lower temperature (400-600°C) [1,2]. With the help of an optimized composition of electrolyte material, a record high ionic conductivity of 0.55 S/cm has been achieved at 600°C [3,4]. Furthermore, this improved ionic conductivity of the nanocomposite materials resulted in an improved fuel cell performance of 1.1 W/cm² at 550°C [3]. Electrochemical impedance spectroscopy reveals that the performance of the cells can be further improved by decreasing the ionic transport losses in the electrolyte layer and efficient reaction kinetics at the electrodes [3]. With the help of modern printing technologies, thin electrolyte layers of high ionic conductivity nanocomposite materials can be deposited to achieve beyond the state-of-the-art performance. This work focuses on the characterization of the nanocomposite inks developed for this purpose.

ENR-144

Synthesis of core-shell structures for advanced ceramic nanocomposite fuel cells

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Ceramic nanocomposite fuel cell belongs to an emerging fuel cell technology [1,2]. This fuel cell technology has achieved an outstanding performance of 1.1 W/cm² at 550°C [3]. It has been found that the synthesis method of the nanocomposite materials affects the electrochemical performance at the device level. In this work, several potential synthesis methods are investigated to study their effect on the materials properties. The nanomaterials produced from different synthesis routes are characterized through various characterization techniques. Some of the characterization techniques includes X-ray diffraction, High-resolution transmission

electron microscopy, scanning electron microscopy, energy dispersive spectroscopy and 3D tomography. Especial emphasis is given to the synthesis of the core-shell structures for ceramic nanocomposite fuel cell application.

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ENR-145

3D structures for efficient ceramic nanocomposite fuel cells

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Ceramic nanocomposite fuel cell is an emerging fuel cell technology [1,2]. Their performance has reached an outstanding power density of 1.1 W/cm² at 550°C [3]. However, these cells lack long-term stability due to several degradation issues. In order to improve the durability, it is important to understand the processes in the fuel cells in more detail. The processes in the fuel cell can be better understood with the help of 3D characterization and device modelling. In this work, ionic transport in the electrolyte layer is modelled to investigate the transport mechanisms. Furthermore, the electrode processes including diffusion of gases in the porous electrodes are modelled in this work. This work will provide an insight to the mechanisms in the fuel cells.

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Single-electron tunneling as a tool for quantum environment engineering**J. Goetz¹, K.Y. Tan¹, S. Masuda¹, M. Partanen¹, R. Lake^{1,2}, J. Govenius¹, M. Silveri^{1,3}, H. Grabert⁴, D. Hazra¹, V. Vesterinen^{1,5}, and M. Möttönen¹**¹ *QCD Labs, Department of Applied Physics, Aalto University, Aalto, Finland*² *National Institute of Standards and Technology, Boulder, United States*³ *University of Oulu, Research Unit of Theoretical Physics, Oulu, Finland*⁴ *University of Freiburg, Department of Physics, Freiburg, Germany*⁵ *VTT Technical Research Centre of Finland Ltd, VTT, Finland*

Superconducting quantum circuits hold great potential in providing revolutionizing practical applications such as quantum sensing or computing. For these applications, it is important to initialize the quantum devices very close to a pure state. Once initialized, the time evolution of the respective quantum states depends strongly on the effective temperature of the quantum degrees of freedom, which can be controlled by their coupling to the environment. Here, we present a method for fast circuit initialization and for an in-situ control of the coupling strength between quantum circuits and the environmental bath. We realize direct cooling of a superconducting resonator mode using voltage-controllable quantum tunneling of electrons in a nanoscale refrigerator [1]. In addition to cooling, we use the tunnel junctions to tune the resonator coupling strength to the environment, i.e., its internal quality factor by orders of magnitude [2]. We extend this concept to superconducting qubits, where the tunable environment can be used for fast qubit reset and to study non-Markovian qubit dynamics. Our highly integrable circuit architecture may prove useful in the initialization of qubit arrays and in dissipation-assisted quantum annealing.

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Energy Harvesting Color Prints Based on Dye Solar Cell Technology**S. G. Hashmi¹, M. Özkan², J. Halme^{1*}, S.M. Zakeeruddin³, J. Paltakari², M. Grätzel³ and P. D. Lund¹**

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One of the bottle-necks in fast, low-cost fabrication of dye-sensitized solar cells (DSSCs) has been the slow soaking process in which the photoactive dye molecules are adsorbed on the TiO₂ photoelectrode film. Another challenge for the commercialization of DSSCs has been to find applications where DSSCs could offer clear added value over the more efficient and stable conventional photovoltaics. We recently addressed both of these challenges by demonstrating color-printed DSSCs. Inkjet printing a precise amount of the photovoltaic dye (“ink”) on the nanocrystalline TiO₂ film (“canvas”) allows us to create solar cells in the form of arbitrary color patterns of desired transparency, mimicking the end-result of conventional color printing. The inkjet-dyed DSSCs were as efficient and stable as conventional DSSCs dyed with the soaking process, keeping almost 100 % of their conversion efficiency (6.4 ± 0.2 %) and short circuit current density (14.2 ± 0.6 mA cm⁻²) in a 1000 h accelerated aging test under 1 Sun illumination at 35 °C, followed by additional 1154 hours under 0.5 Sun at 60 °C. This achievement shows a way to overcome one of the main hurdles in realizing fully printed DSSCs and opens new design avenues for building (BIPV) and product integrated photovoltaics (PIPV), attainable only with DSSC and other molecular photovoltaics.

[1] S. G. Hashmi, M. Özkan, J. Halme, S.M. Zakeeruddin, J. Paltakari, M. Grätzel and P. D. Lund, *Energy & Environmental Science*, 9(7), 2453-2462 (2016)

Theoretical Efficiency Limits of Colored Photovoltaics**P. Mäkinen, J. Halme***

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While crystalline silicon solar cell technology provides efficient, reliable, and relatively low-cost solar power generation at a large scale, other photovoltaic technologies such as thin film, organic, dye-sensitized, and most recently perovskite solar cells, are looking for market opportunities where their unique features, such as mechanical flexibility, semi-transparency and a wide range of color options could deliver additional value compared to the established silicon photovoltaics. Applications of colored and semi-transparent solar cells can be found for example in building and product integration where the photovoltaic surface doubles as a structural, architectural or design element. Our color-patterned dye-sensitized solar cells produced by inkjet printing is a recent example of progress towards this direction [1].

Because the color of a solar cell is created by reflecting or transmitting visible light that the cell would otherwise absorb and convert to electricity, a colorful or semi-transparent solar cell is always a compromise between energetic and aesthetic preferences. In this work, we report modeling results that quantify and visualize the fundamental theoretical efficiency limits of a universal colored, reflective or semi-transparent photovoltaic surface at given illumination conditions. The theoretical model is aimed as a practical tool to help engineers and designers navigate the compromise between power generation and aesthetics of photovoltaic cells in multi-disciplinary product development projects.

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ENR-150

Flexible Solid-state Supercapacitors of Transition Metal Oxide/Phosphides -Carbon Network with High Energy and Power Density

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Mechanically flexible and solid-state supercapacitors with high energy density, comparable with those of rechargeable batteries, and long term device cycling ability (>50 000 cycles) are inevitably required for next-generation energy storage devices, such as electrical and hybrid vehicles, and high power operations. The energy density and overall performance of graphene/carbonaceous material electrodes in supercapacitors can be effectively engineered by combining with certain metal oxides/hydroxides, phosphides and phosphates. For this purpose, we have successfully developed a new class of hierarchical graphene/carbon framework, which are surface decorated with thin layers/nanofibers of transition metal oxides, hydroxides and phosphides and phosphates, such as Mn_xO_4 , NiO, Fe_2O_3 , $Ni(OH)_2$ and Mn-phosphides/Co/Ni-phosphates Taking Mn_xO_4 as an example, a highly flexible Mn_3O_4 /reduced graphene oxide (rGO) nanohybrid paper with high electrical conductivity and high mass loading of metal oxide nanofibers can be developed via a facile gel formation and subsequent electrochemical reduction. When assembled with reduced rGO paper/carbon network, some of these oxides/phosphides and phosphates give rise to flexible ASC devices with remarkable electrochemical performance, not far away from those of the state of the art rechargeable batteries. In this talk, several new hierarchical structures, developed by hydrothermal, CVD, ALD and electrochemical depositions, are highlighted for their formation, performance as well as the operating principles behind.

ENR-153

High performance and stable carbon based fully printed perovskite solar cell technology

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Organic-Inorganic metal halide perovskite solar cells (PSCs) with efficiencies crossing over 22% with traditional geometries are the new entrants amongst next generation photovoltaic technologies 1. However, their expensive active materials, high lead (Pb) wastage along with their long-term performance stability have been the key challenges for their production at industrial scale 2. Instead of these traditional unstable devices, the carbon based printed perovskite solar cells (CPSCs) have drawn attention due to their scalable fabrication methods, abundant availability of their active materials as well as high stability in several environmental conditions 3-4. In this report, we present our latest results regarding the research and commercial development

of this promising photovoltaic technology. Through an ongoing academic research project (Cutting edge third generation advanced photovoltaic devices) we have achieved some promising milestones which includes the successful replacement of the manual infiltration of the perovskite precursor with automated infiltration via inkjet printing technology, very promising long term stability (first, under full sun light illumination at 35 °C and then under 1.5 Sun UV light illumination at 40 °C) and remarkable enhancements in the overall conversion efficiency for these CPSCs. These achievements indicate that the unique CPSCs technology could potentially provide a realistic pathway to produce electricity at affordable cost and the future progress might lead to quick commercial success compared to other next generation PV technologies.

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[2] S. G. Hashmi, A. Tiihonen, D. Martineau, Merve Ozkan, Paola Vivo, Kimmo Kaunisto, Vainio Ulla, S. M. Zakeeruddin, M. Grätzel, Long term stability of air processed inkjet infiltrated carbon-based printed perovskite solar cells in ultra-violet light soaking *J. Mater. Chem. A*, 2017, 5, 4797-4802.

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ENR-154

Analysis of perovskite-ceria functional layer-based electrolyte-layer free fuel cell

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An electrolyte-layer free fuel cell (EFFC) based on a functional layer of perovskite $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3-\delta}$ (BSCF) composited samarium doped ceria (SDC) has been developed. The device achieves a peak power density of 640 mW cm^{-2} with an open circuit voltage (OCV) of 1.04 V at 560 °C using hydrogen and air as the fuel and oxidant, respectively. A numerical model is applied to fit the experimental cell voltage. The kinetics of anodic and cathodic reactions are modeled based on the measurements obtained by electrochemical impedance spectroscopy (EIS). Modeling results are in well agreement with the experimental data. Mechanical stability of the cell is also examined by using analysis with field emission scanning electron microscope (FESEM) associated with energy dispersive spectroscopy (EDS) after testing the cell performance.

Solid Oxide Fuel Cells Using Doped CeO₂/SrTiO₃ Heterostructure Membrane with Strongly Enhanced Conductivity

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Since colossal ionic conductivity in 2D planar heterostructure was demonstrated, such as Y₂O₃-stabilized ZrO₂/SrTiO₃ (YSZ/STO) heterostructure [1,2], tremendous efforts have been contributed to this topic even though there has been much debate surrounding it. In this work, we made the first attempt to apply a new 3D heterostructured material doped CeO₂/SrTiO₃ replacing the conventional YSZ electrolyte layer into low temperature solid oxide fuel cells (LT-SOFCs). As a consequence, the cells demonstrated stable low-temperature operation and high power outputs, with 900 mW/cm² at 550 °C achieved by Sm-doped CeO₂/SrTiO₃ (SDC/STO) cell and above 800 mW/cm² at the same temperature by Gd-doped CeO₂/SrTiO₃ (GDC/STO) cell. Through investigation on the two materials from nanostructure and electrochemical perspectives, the extraordinary cell performances can be primarily attributed to the strongly improved ionic conduction of the material at heterophasic interface in the 3D heterostructure. This is the first study to realize greatly enhanced ionic conductivity in such heterostructure system, it brought about some new understanding on heterostructured materials for LT-SOFC applications.

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ENR-157

CeO₂ nanorods for low temperature solid oxide fuel cells

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CeO₂ nanorods (NRs) have been used as a novel photocatalyst for solar energy conversion. Hereby we report the CeO₂ NRs for advanced fuel cell applications. The CeO₂ NRs were synthesized by a hydrothermal approach, which showed the as-synthesized NRs with a length between 20 to 50 nm with a fluorite cubic structure. Under the optimized preparation conditions, the CeO₂ NRs showed the Brunauer-Emmett-Teller specific surface areas (65.26 m²/g), pore size (7.0 nm), and high surface oxygen vacancies. The CeO₂ NRs were applied for advanced fuel cells, and achieved 547 mW cm⁻² at 550 °C. These results demonstrate that CeO₂ NRs with idea surface properties can be applied as a promising ionic conductor for the electrolyte and advanced SOFCs.

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ENR-158

Advanced fuel cells using the correlated SmNiO₃ in two-phase composite system

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Mott-transition due to strong electronic correlations in the perovskite SmNiO_3 (SNO) has been reported and applied for high performance fuel cells because there was a proton conducting H-SNO formed by the transition. Such mechanism has explored a new way to develop advanced solid oxide fuel cells. Our work further reported a composite system composed by two types of the SNO phase structures formed in situ process. One is the cubic structure c-SNO and another is orthorhombic structure o-SNO, both are the perovskite-type materials. The composition dependence between the two structural SNO materials for the electrical properties and fuel cell performances has been investigated. The total electrical conductivity of the c-SNO and o-SNO composite was measured by the electrochemical impedance analysis to be 0.25 S/cm at 550 °C. The enhanced ionic properties and fuel cell performances, 780 mW/cm² using the SNO composite as the electrolyte have been achieved in an intermediate range between the c-SNO and o-SNO phases. This indicates in addition to structural electrical property, the interfacial ionic conduction between two phases may also play an important role to make enhanced conductivity resulting in better fuel cell performances. The ionic conduction mechanisms are under investigation.

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ENR-159

Electrical and electrochemical properties of insulating Sm_2O_3 and semiconductor NiO

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An emerging phenomenon of ionic conduction and transport in composite materials has been extensively investigated on ionic composite system. It is very rare to report on this subject between the insulator and semiconductor composite materials. This work at the first time reports electrical and electrochemical properties and fuel cell applications for a novel composite between the insulating Sm_2O_3 and semiconductor NiO based on

the ionic conduction process. Proton conduction was discovered dominantly in the NiO and especially the interface between the Sm₂O₃ and NiO. The composition dependence showed a strong proton conductivity enhancement in an intermediate composition of the Sm₂O₃ and NiO composite system. This indicates an interfacial ionic conducting phenomenon. Electrochemical impedance spectrum measured the total conductivity of the Sm₂O₃-NiO 0.31 S/cm at 550 °C. Applied as the electrolyte the Sm₂O₃-NiO has successfully demonstrated more than 0.8 W/cm² at 550 °C. An operation time of 40 h with reasonable stability is achieved at 500 °C under H₂/air condition. This work has explored a new methodology and promising technical applications for new low temperature solid oxide fuel cells.

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ENR-164

Effect of The Source Component Fraction on Quality of The Synthesized PVDF Nanofibers using Electrospinning Method

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High surface area flexible thin films of Polyvinylidene Difluoride (PVDF) nanofibers are vastly applied because of low cost, simple, safety and environmentally friendly production methods [1]. PVDF nanofibers are inherently piezoelectric when produced by high voltage electrospinning method [2]. In this paper, PVDF nanofibers are synthesis in a electrospinning equipment, from a mixed of two solutions, THF (Tetrahydroforan) and DMF (N,N-Di-Methyl Formamid), which DMF has a higher boiling point than THF. The effect of THF and DMF fraction and PVDF concentration on the morphology and diameter of the deposited nanofibers are studied. Field emission scanning electron microscopy analysis of the nanofiber thin films indicate that by adding THF in the source suspension, smoother and more uniform nanofibers with lower diameter will be result. However, by more increasing THF ratio, the cone-jet mode formed on the tip of the needle, rapidly dried, before reaching the collector substrate. Results of the further experiment indicate that decreasing of PVDF concentration in the deposition source solves the latter problem. On the other hand, by decreasing the THF ratio to DMF, the

solution cannot well be dried, before collecting by the substrate, which is due to the high melting point of DMF. The best and uniform nanofibers with the diameter of 200 to 300 nm are obtained from a ratio of 3:1 For THF:DMF and 10% PVDF concentration. Fabricated nanogenerator shows an output power of 40 $\mu\text{W}/\text{m}^2$ when actuated by a vibration mechanical force with the frequency of 4 Hz.

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[2] F. R. Fan, W. Tang, Z. L. Wang, Advanced Materials, Vol. 28 (22), p. 4283 (2016).

ENR-165

Utilizing Dip Coating to Prepare Uniform and Reproducible Perovskite Solar Cells

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Perovskite solar cells (PSCs) have proven to be a promising new photovoltaic technology, which potentially could outshine the conventional silicon-based solar cell technology, as their record efficiencies to date are over 22% [1]. However, before the PSC technology can break into the photovoltaics market, issues related to the poor reproducibility of the currently used processing methods have to be solved. Our approach is to utilize the dip coating method [2] or inkjet printing [3] to improve the quality and better understand the functions of the compact and mesoporous TiO_2 layers in PSCs. These layers are important for the selective charge extraction and for controlling the crystallization of the perovskite layer, respectively. By tuning the sol composition and the dip coating parameters, uniform TiO_2 thin films can be prepared, [2] while further addition of block copolymers produces well-ordered porous structures. These accurate processing tools have allowed us to study the influence of the compact TiO_2 layer in detail [2] as well as investigating the charge selectivity of similar layers in organic solar cells [4]. We are also currently working on replacing the conventional particle-based nanostructured TiO_2 layer with an ordered porous layer, which will allow for a better control and easier study of the perovskite crystallization process.

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ENR-166

Selective Pore Filling in Bimodal Mesoporous CMK-5 Carbon: Sulphur and SnO₂ for Lithium Battery Electrodes

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Mesoporous carbon (composite) materials play a prominent role in energy conversion, catalysis or as model systems for sorption investigation. [1,2] In this study we present novel mesoporous carbon composites [3] obtained by an optimized nanocasting procedure [3-5] Ordered mesoporous CMK-5 carbon exhibits two distinct pore systems that can be modified individually. This work demonstrates how one of the pore systems can be selectively filled with elemental sulphur, while the other pore system remains empty. The resulting sulphur-carbon composite material with high residual porosity can be used as cathode material in lithium-sulphur battery cells. We present an in-depth investigation of the synthesis and characterization of sulphur-loaded CMK-5 carbon and compare the results to the preparation of SnO₂ nanoparticle-loaded CMK-5 carbon. The selective deposition of the guest species can be analysed by N₂ physisorption and X-ray diffraction, as the type of guest species strongly affects the X-ray diffraction pattern depending on its scattering contrast compared to carbon.

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ENR-167

Synthesis of Calcium Gadolinium Co-doped Cerium Carbonate Nano-Composite electrolytes for Low Temperature Solid Oxide Fuel Cells

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Doped ceria-carbonates composites are a new class of electrolytes for low temperature solid oxide fuel cells [1-2]. These show very high ionic conductivity due to fast interfacial transport, previously reported by Chockalingum et al. [3], 25 wt% (LiNa)₂CO₃-GDC electrolyte exhibited an ionic conductivity of 0.1757 S cm⁻¹ at 550 °C and lowest activation energy of 0.127 eV in the temperature range 550–800 °C. To further improve the ionic conductivity, a series of calcium gadolinium co-doped cerium oxide, Gd_{0.2}Ca_xCe_{0.8-x}O₂ (x = 0.01 to x = 0.1) have been synthesised by solgel method. The electrolytes have been physically and electrochemically characterized with respect to their thermal behaviour, phase, microstructure, elemental analysis and electrochemical performance using thermogravimetric analysis, X-ray diffraction (XRD), scanning electron microscopy, Transmission electron microscopy (TEM), Energy-dispersive X-ray spectroscopy and electrochemical impedance spectroscopy respectively. The particle size of the electrolyte powders synthesized is in the range of 5-10 nm as observed from the TEM. XRD results of the prepared electrolytes show that the powders are phase pure with no distortion. The gadolinium calcium co-doped ceria-lithium sodium carbonate composite electrolytes exhibit high conductivity, as it combines both the advantages of co-doping and the composite effect. Among all co-doped composite electrolyte prepared, 25% (LiNa)₂CO₃-Gd_{0.2}Ca_{0.05}Ce_{0.75}O₂

composite electrolytes shows the maximum conductivity of 0.3 Scm^{-1} (650°C). Co-doped composite electrolytes show higher conductivity and stability due to the presence of calcium than the previously investigated composite electrolytes of $(\text{LiNa})_2\text{CO}_3\text{-GDC}$.

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ENR-168

Impact of film thickness of dip-coated compact TiO_2 layers on the performance of mesoscopic perovskite solar cells

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Perovskite solar cells gained tremendous attention since past few years due to fabrication cost and high efficiencies which was achieved within 5 years after the first perovskite solar cell was reported. In the PSCs, one of the most crucial layer is the electron selective contact which extracts electrons from the device. It usually comprises compact TiO_2 which must be uniform and pinholes free for the best performing solar cells. In this work [1], we prepared devices with a 5-50 nm thick compact TiO_2 layer on FTO coated glass by using dip coating approach while using different concentration of the dip coating solution. The TiCl_4 was used as a precursor for TiO_2 which performed very well in our previous work [2]. The film thickness and density of these layers were accurately determined by x-ray reflectometry (XRR). The effect of TiO_2 film thickness on the surface roughness over the underlying FTO substrate was investigated with atomic force microscopy. X-Ray diffraction and X-Ray Photoelectrons spectroscopy were used to study the crystallinity of the compact TiO_2 and the surface composition over the underlying FTO substrate respectively. When assembled into mesoscopic

perovskite solar cells, devices with thicker compact TiO₂ layers showed a better performance up to a certain thickness. Devices without or with very thin compact TiO₂ layers displayed *J-V* curves with an “s-shaped” form which is investigated in detail.

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ENR-169

Performance characteristics of tubular solid oxide co-electrolysis cells for syngas production by electrochemical conversion of H₂O/CO₂

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Using electricity from wind and solar sources, high-temperature solid oxide co-electrolysis cells (SOCs) can perform advantageous conversion of H₂O/CO₂ to high value syngas that can be used to produce electricity or synthetic hydrocarbons. In this work, the performance characteristics of tubular solid oxide co-electrolysis cells are reported for production of syngas by electrochemical conversion of H₂O/CO₂. Anode-supported tubular solid-oxide electrolysis cells were fabricated and tested at various operating temperatures and under various combinations of inlet-gas conditions. We also fabricated different electrolyte type SOC cells involving yttria-stabilized zirconia (YSZ) and scandium-stabilized ScSZ to improve the syngas yield. The electrochemical performance was analyzed using I-V curves, EIS analysis, and gas chromatography. Consequently, we confirm the correlation between the operating conditions and the electrochemical performance of the co-electrolysis process in the tubular SOC. Furthermore, it was found that the syngas yield of the ScSZ electrolyte-based SOC cell was better than that of the YSZ electrolyte-based SOC. The results show that using a tubular SOC offered a high-efficiency conversion of H₂O/CO₂, with high yield and good-quality syngas.

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Study of the durability of a hydrophobic resin to be used as coating on condensers in a Nuclear Power Plant

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Going from a continuous film condensation to dropwise condensation of water vapor can be made by using different techniques. In this work, we have used surface modification of tubes condensers by applying a hydrophobic nanocomposite based on a polysiloxane and silica nanoparticles. By doing this kind of coating, a study made at EDF R&D¹, demonstrated that the thermal transfer coefficient can be improved by up to 30%. The good durability of the coating under operating conditions in a nuclear power plant was verified at the lab scale. This work presents the developed methodology to identify the mechanisms and kinetics of degradation of the nanocomposite coating. The key results are: (1) an aging ruled by hydrolysis and depolymerization of the silicone and (2) lifetimes estimated between 5 years and 33 years for temperatures of 50° C and 30°C, respectively.

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On the Use of Hydrogen in the Automotive Sector

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According to studies promoted by the United Nations over the last hundred years, the average temperature of the atmosphere increased by 0.5 °C. The trend has been almost exponential since the 1960s, years of world industrial development and economic boom. Hydrogen offers an alternative to the fuels used today and proposes itself as a possible interesting solution for our future.

After showing the benefits that hydrogen can offer, the attention is then focused on its use in the automotive sector. The number of vehicles is expected to increase following the recent massive motorization in India and China. It is therefore necessary to find a transport means that allows to drastically cut the emissions. Various studies on the possibility of hydrogen propulsion are currently underway, many of them at the level of experimentation. The easiest way to use hydrogen in the vehicular context is to use it in current internal combustion engines with the addition of appropriate modifications, just as it happens for methane or LPG conversion to cars. The advantages over normal engines are considered.

Droplet on hot mixed wettability surface

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The bubble dynamic influences the liquid-vapor heat transfer especially when the heating surface with mixed wettability. The liquid vapor motion between interfaces of two wettabilities is very intensive on a superheated of mixed wettability surface. Higher wall temperature increased liquid-vapor motion efficiently. The surface energy difference between these two surface wettabilities, is the driving force of bubble motion. The forces occurred one of the energy in the system; it is the internal kinetic energy. This study investigated the droplet evaporation on the limited and superheated mixed wettability surface. Through the energy balance equation to prove the internal kinetic energy existed and it significantly influenced the heat transfer.