

Proceedings of the 2nd NanoWorld Conference in Boston (NWC-2017). Part III: Featured Presentations

Introduction

The session on Nano-electronics was initiated by Prof. Xiaosheng Fang, Fudan University, China and Session talk were delivered by renowned experts -Prof. Seongil Im from Yonsei University, S. Korea on the “Two Dimensional Semiconducting Nanosheets for Electron Device Applications”. Prof. Sanford Ruhman from The Hebrew University of Jerusalem, Israel elucidated work that he conducted in his lab on fresh ultrafast look at hot exciton dynamics in nanocrystals. Prof. Hai-Feng (Frank) Ji from Drexel University, USA talk on growth and potential applications of millimeter long fibrous red phosphorus nanowires. Prof. Caroline Sunyong Lee from Hanyang University, S. Korea proposed a new and emerging process to fabricate smart window. The second day of NWC-2017 started with three parallel sessions on Life Sciences & Medicine; Applications & Societal Aspects; Energy & Environment. The Life Sciences & Medicine session started by Prof. Stephen D Miller, Northwestern University Feinberg School of Medicine, USA followed by Prof. Aharon Gedanken, Bar-Ilan University, Israel and Prof. Michael Zharnikov, Heidelberg University, Germany and the session continued with twenty presentations on some of the important topics such as Treatment of Autoimmune Disease and Allergy, Making the Hospital a Safer Place, Alzheimer’s Disease and Reconstitution of Trans-membrane Proteins. The session further continued on third day with Prof. Chuan-Jian Zhong (State University of New York at Binghamton, USA) followed by six presentations. Wonderful session on Applications & Societal Aspects was inaugurated by Prof. Sokrates T. Pantelides, Vanderbilt University, USA and followed by Prof. Joey Mead, University of Massachusetts Lowell, USA and Dr. Jo Anne Shatkin, Vireo Advisors, USA. During this session eighteen speakers have presented their work on topics such as Probing the Nanoscale with a Combination of Microscopy and Theory; Scalable Nanomanufacturing Processes; Nanotechnology Safety; Discovery Solution for Nanotechnology – Challenges & Prospects. Prof. Gang Chen, Massachusetts Institute of Technology, USA has inaugurated the Energy & Environment session and followed by twenty presentations on the topics as Nanoparticle Assemblies, Nanostructured Colloid-Interface Engineering, Advanced Optoelectronic Devices, Hypersonic Phononic Structures, New Flat Nanomaterials Based on Carbon. The session continued third day, initiated by Prof. Aharon Gedanken (Bar-Ilan University, Israel) and followed by eleven presentations.

New Concept Low-Dimensional Ultraviolet Photodetectors

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Abstract

Benefitting from the continuous innovations in semiconductor materials and device fabricating techniques, ultraviolet (UV) photodetectors have been successfully used in advanced communications, flame detection, air purification, ozone sensing and leak detection in the past few decades.

Up to now, various sophisticated techniques, such as metal-organic chemical vapor deposition (MOCVD), molecular beam epitaxy (MBE), pulsed laser deposition (PLD), atomic layer deposition (ALD), and magnetron sputtering have been developing rapidly, which has provided vast opportunities for thin-film based materials, especially GaN, and GaAs based photodetectors, to be successfully commercialized. However, fabricating photodetectors focusing on the aforementioned techniques usually requires high operating costs, which will hamper further scale-up production of such photo electric devices. Therefore, it is of great importance to explore novel and facile techniques for fabricating high-performance photodetectors with low cost.

Nowadays, nanoscience, nanofabrication technologies and versatile materials have sparked a new vision of UV photodetectors, which move toward higher precision, lower energy consumption and greater miniaturization. Recently, our group developed several novel photodetectors based on various low-dimensional nanostructure materials by using several simple and low cost bottom-up approaches. It is expected that this novel kind of UV photodetectors with smart, intelligent and multifunctional design will benefit daily life and the well-being of society in the near future.

Two Dimensional Semiconducting Nanosheets for Electron Device Applications

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Abstract

Two-dimensional (2D) semiconductor materials with discrete bandgap have attracted much attention from many researchers owing to their interesting physical properties and potentials for future nanoscale electronics. Many of field effect transistors (FETs) have thus been reported. Several attempts to fabricate 2D complementary (CMOS) logic inverters have been made, too. Here, we adopted p-WSe₂ and n-MoS₂ nanosheets separately for the channels of bottom gate-patterned FETs, to fabricate 2D transition metal dichalcogenide (TMD)-based hetero-CMOS inverter on a same glass substrate by a direct printing technique. Our hetero-CMOS inverters with electrically-isolated FETs demonstrate novel and superior device performances of a maximum voltage gain as ~27, subnanowatt power consumption, almost ideal noise margin approaching to $0.5 \times V_{DD}$ (supply voltage, $V_{DD}=5$ V) with a transition voltage of 2.3 V, and ~800 μ s for switching delay. On the one hand, we extended our 2D-CMOS studies to n-MoS₂ and p-MoTe₂ couple for faster switching of less than 60 us. Our p-channel FET with nanosheet α -MoTe₂ showed much high ON-current, since we used a properly-deep work function metal, platinum (Pt), for S/D contact. As a result, our Mo-based CMOS device with nanosheet channels demonstrated high CMOS performances in switching dynamics and electrostatic behavior; high voltage gain of ~22 in maximum, good noise margin ($NM_L \sim 0.35 V_{DD}$, $NM_H \sim 0.39 V_{DD}$), positive transition voltage of 2.5 V at 5 V V_{DD} , and 60 us switching delay at longest were displayed at a few volts. In the presentation, our recent results on dual gated BP sheet FET and MoS₂ MESFET are also introduced.

Fresh Ultrafast Look at Hot Exciton Dynamics in Nanocrystals

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Abstract

A series of studies into the spectroscopic signatures of exciton cooling and recombination in various nanocrystals (NC) will be described. Using ultrafast spectroscopy, we demonstrate that in InAs and in lead chalcogenide NCs no MEG is detected when exciting up to 4 times the band gap energy. Furthermore, analysis of transient absorption (TA) data in NCs of these materials shows that the mechanisms used to interpret such data, namely bi-exciton shifts and state filling are insufficient for explaining all aspects of our observations. Three pulse experiments used to test the effects of cold spectator excitons on TA of hot additional excitations prove that the resulting 1Se1Sh bleach is not linear with the number of excitons per nanocrystal. This very prominent TA feature has been used extensively to quantify the total concentration of band edge excitons in NC samples, assuming the linearity which we find absent. Analysis of the results suggests that below band edge induced absorption in hot exciton states is due to excited-state absorption and not to shifted absorption of cold carriers and that 1Se1Sh bleach signals are not an accurate counter of sample excitons when their distribution includes multi-exciton states. Finally, the similarity of TA signatures in nanocrystals and in bulk semiconductor samples will be discussed in light of these findings.

Growth and Potential Applications of Millimeter Long Fibrous Red Phosphorus Nanowires

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Abstract

We present the growth of ultra-long 1D red phosphorus nanowires (> 1 mm). Raman spectra and XRD characterization suggested these crystalline nanowires belong to red phosphorus. I-V curves suggest these nanowires are semi conductive with a similar mobility as black phosphorus. The potential applications of the nanowires will also be discussed.

A New and Emerging Process to Fabricate Smart Window

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Abstract

Electrochromic (EC) materials can reversibly change color by electrochemical oxidation and reduction reactions, via application of external potential. EC films have been recently developed for its application in smart window, which represents part of the emerging energy efficiency advances in buildings and automobile technologies. The transmittance of these smart windows can be controlled using an applied voltage, allowing us to control the amount of daylight, solar heat gain, and internal heat loss through the windows of buildings and vehicles. Conventionally, EC film was fabricated via wet chemical method, such as sol-gel, electrodeposition. However, these wet chemical method involves many chemicals, requiring post treatment since it is solution-based process. In contrast, thin film deposition processes such as sputtering, chemical vapor deposition, thermal evaporation, are facile since it is dried deposition in chamber. Nevertheless, these can be time-consuming and costly, given the need for high-vacuum conditions and large area deposition. Therefore, to overcome these problems, nanoparticle deposition system (NPDS), a kinetic spray technique, was used to fabricate an EC layer. NPDS is a recently developed dry-deposition technique capable of kinetically depositing both nano- and sub-micron-sized metal and ceramic particles at room temperature under low vacuum with low-cost compressed air. Since commercialized powders can be directly deposited by NPDS, the fabrication process for EC devices can be simplified, without pre- or post-processing steps nor requiring precursor. Therefore, it is a relatively facile and low-cost method suitable for the mass production of EC device application.

Spintronics and Caloritronics Related Problems in the Context of Graphene like Nanoribbons

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Abstract

This presentation is devoted to studies of important class of nanostructured materials akin to well-known graphene. These materials have got a quasi two-dimensional buckled structure and in contrast to graphene a non-negligible spin-orbit coupling. Here it is shown that narrow graphene like nanoribbons are magnetic with antiparallel magnetized opposite zigzag edges. Noteworthy, the ground state corresponds to the in-plane arrangement of the magnetic moments, although in the literature the most commonly studied configuration is the out-of-plane one. It turns out that the edge magnetism has a strong impact on the electronic band structure and thereby on electrical and thermal transport in these materials. In particular, due to the edge magnetism both the Seebeck power factor and the figure of merit become strongly enhanced.

Acknowledgements: This work was supported by the Polish National Science Centre from funds awarded through the decision No. DEC-2013/10/M/ST3/00488.

Intra- and Inter-shell Kondo Effects in Carbon Nanotube

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Abstract

Using slave boson mean field finite U formalism we investigate the impact of spin-orbit interaction (SOI) on transport through carbon nanotube quantum dot. Spin-orbit coupling breaks the fourfold degeneracy and destroys Kondo correlation in even occupied dot valleys and induces crossover from SU(4) to SU(2) Kondo physics in odd valleys. It manifests in suppression of conductance in even valleys and reduction of the number of transport channels in odd valleys. For strong SOI transport becomes noiseless in odd valleys and reaches the maximal value for half filling. We also analyze the evolution of thermopower with the increase of s-o coupling and examine the role of intervalley mixing. In magnetic field the destroyed degeneracy might be recovered and revival of Kondo effect is observed. We compare our results with the experiments. For high fields, apart from the many-body effects within a single shell also intershell resonances can occur (spin, valley or spinvalley Kondo effects). Our

analysis is focused also on narrow gap nanotubes, where full spin-orbital degeneracy might be recovered. We discuss field induced spin and orbital polarization effects and we point to the possibility of controlling these values through gate voltage.

Support of the Polish National Science Center from the funds awarded through decision No. Dec-2013/10/M/ ST3/00488 is gratefully acknowledged.

Functionalized Graphene for Nano Electronics, Photonics and Optoelectronics

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Abstract

Graphene—a single layer of carbon atoms - has emerged as a material for nano electronics, photonics and optoelectronics due to the gamut of unique physical properties such as high electrical conductivity, optical transparency and mechanical flexibility. These properties can be further tailored to fit specific device functionalities by means of chemical functionalization. The most recent example of the potential of chemical functionalization is GraphExeter, a composite graphene material developed by Prof Craciun's team at Exeter. This material consists of few-layer graphene intercalated with FeCl₃ and is currently the best performing carbon-based transparent conductor [1], with resilience to extreme conditions [2].

In this talk I will review our latest developments in the use of graphene and functionalized graphene for nano electronics, photonics and optoelectronics. I will present our recent studies on the growth and use of high quality graphene for next generation transparent and flexible graphene capacitive touch-sensor [3], and for graphene coated textile fibers for future wearable devices that can be woven into cloths [4]. Furthermore, we have demonstrated the potential of functionalized graphene material (GraphExeter) for transparent photo-detectors [5], energy harvesting and flexible electronic devices [6] and for flexible and foldable light-emitting devices [7].

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Highly Sensitive NO₂ Gas Sensors Based on Electrolytically Exfoliated Graphene/Au-Catalyzed WO₃ Composite Films

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Abstract

The effect of functionalized additives of high-aspect-ratio WO₃ nanorods on nitrogen dioxide (NO₂) gas-sensing properties were systematically studied by doping with 0.25–2.0 wt% gold (Au) and additional loading with 0.1–10 wt% electrolytically exfoliated graphene (G). The WO₃ nanorods were synthesized by the modified precipitation method utilizing ethylene glycol as a dispersing agent while Au-loaded WO₃ nanoparticles and their graphene composites were also prepared by the impregnation method to achieve high responsive NO₂ sensors. The sensing films were prepared by spin coating technique and evaluated for low detection of NO₂ (0.125–5.0 ppm) sensing performances at operating temperatures ranging from 25 to 350 °C in dry air. Gas-sensing measurement indicated that WO₃ sensing film with optimal 5.0 wt% graphene exhibited the maximum response at 250 °C, while 0.5 wt% Au-loaded WO₃ optimally catalyzed the highest responses and shortest response time at 250 °C. Particularly, the additional loading of optimal 0.5 wt% graphene into optimal 0.5 wt% Au-loaded WO₃ composites led to a

drastic response enhancement with very short response time and fast recovery stabilization at 350 °C. Detailed mechanisms for the drastic NO₂ response enhancement by catalyzed-Au and graphene were proposed based on the formation of graphene/catalyzed Au-loaded WO₃ Ohmic metal-semiconductor junctions and accessible interfaces of graphene-metal oxide nanostructures. Therefore, G-Au/WO₃ composite has a potential for responsive low detections of NO₂.

Optimized Plasmonic Structure Integrated Superconducting Nanowire Single-photon Detectors for Quantum Information Processing Applications

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Abstract

Optimization of superconducting nanowire single photon detectors (SNSPD) consisting of different integrated plasmonic structures was performed to maximize the absorptance (A-SNSPD), as well as the polarization contrast with (C-SNSPD) and without (P-SNSPD) a criterion regarding the absorptance that have to be parallel met. The dispersion characteristic was tailored by varying the configuration parameters including the illumination direction and structure properties of four different integrated device structure types: nano-cavity-array (NCAI-), nanocavity-deflector-array (NCDAI-), nano-cavity-double-deflector-array (NCDDAI-) and nanocavity-trench-array (NCTAI-) integrated SNSPDs. It was shown that the optimal configurations of A-SNSPDs correspond to a device design and periodicity dependent tilting in S-orientation (90° azimuthal angle). The nanophotonical phenomena, which result in absorptance maxima, are related to the plasmonic Brewster angle and to plasmonic pass-bands. The highest ~95% absorptance is achieved in wavelength-scaled NCTAI-A-SNSPD at perpendicular incidence inside an inverted minigap, while the polarization contrast is moderate in all A-SNSPDs. In C-SNSPDs the correlation between the polarization contrast attainable at user defined absorptance criteria and the NbN/Au volume fraction ratio as well as the normalized cavity length parameters was uncovered. In P-SNSPD configurations capable of maximizing the polarization contrast the plasmonic Brewster angle is at play, which inside the region of suppressed s-polarized absorptance, and the highest polarization contrast achieved via NCDDAI-P-SNSPD is on the order of 10¹³. Two-dimensional plasmonic structure integrated X-SNSPDs were optimized, which make possible by symmetry breaking to overcome 93% absorptance independently of polarization inside narrow bands at perpendicular incidence.

Antigen-Encapsulated Carboxylated PLG Nanoparticles Promote Therapeutic Tolerance Induction for the Treatment of Autoimmune Disease and Allergy

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Abstract

Ag-specific tolerance is the desired therapy for treatment of immune-mediated diseases. Our recent phase I clinical trial showed that infusion of myelin peptide-coupled autologous apoptotic PBMCs induced dose-dependent regulation of myelin-specific T cell responses in MS patients. Experiments in EAE models showed that antigen-coupled apoptotic leukocytes accumulate in the splenic marginal zone (MZ) and are engulfed by F4/80⁺ MZ macrophages and CD8⁺ DCs inducing upregulation of PD-L1 in an IL-10-dependent manner. Tolerance results from the combined effects of PDL1/PD-1-dependent T cell anergy and activation of Tregs recapitulating how tolerance is normally maintained in the hematopoietic compartment in response to uptake of senescing apoptotic blood cells.

To advance clinical translation of tolerogenic therapies, we have shown that tolerance is inducible by i.v. administration of (auto)antigens covalently linked to biodegradable 500nm carboxylated poly(lactide-co-glycolide) (PLG) nanoparticles (Ag-PLG) effective in preventing and treating of Th1/Th17-mediated autoimmune diseases (EAE and T1D) and Th2-mediated allergic airway. Ag-PLG-induced tolerance is mediated by the combined effects of cell-intrinsic anergy and Treg/Tr1 activation and is dependent on route of administration, particle size and charge, uptake by liver and MZ macrophages via the MARCO scavenger receptor, and can be induced either by PLG nanoparticles covalently coupled with or encapsulating the (auto) antigen. These findings demonstrate the utility of Ag-PLG as a novel, safe and cost-effective means for inducing antigen-specific tolerance for therapy of MS, T1D and other (auto)immune-mediated diseases using an FDA-approved biomaterial manufactured under GMP conditions. The technology is currently in clinical translation for treatment of celiac disease.

NanoMOFs a Novel Efficient Tool to Target Lung Cancer

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Abstract

Nowadays, people die more of Lung cancer (LC) than colon, breast, and prostate cancers all together [1]. To increase LC therapy, we report how the use of biodegradable porous iron(III) carboxylate Metal Organic Framework nanoparticles (nanoMOFs) to allow a passive targeting of the lungs without signs of toxicity. NanoMOFs were prepared as described elsewhere [2]. We have evaluated their *in vivo* biodistribution and toxicity up to 24 hours using rats. If an important accumulation of the NP was observed in the lungs at short times, a clearing occurred at longer times with no signs of toxicity. Then, we have evaluated the impact of the loading of Gemcitabine-monophosphate (GMP), a well-known drug used in LC treatment, into the nanoMOF, on drug organ accumulation. To quantify the amount of drug in the organs, we have encapsulated Tritiated-GMP through a simple green impregnation method [3]. C57BL/6J mice were then treated intravenously with 10 mg/kg of the free drug and the equivalent dose of nanoMOF encapsulated drug. Noteworthy, upon administration of the drug through the nanoMOFs, a strong increase of its concentration, compared to the free GMP, was observed after 15 min and remained three-fold larger after 8h, making nanoMOFs nanoparticles very promising nanovectors to treat pulmonary diseases [4].

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Making the Hospital a Safer Place by the Sonochemical Coating of all its Textiles with Antibacterial Nanoparticles

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Abstract

Sonochemistry is an excellent technique to coat nanomaterials on various substrates, imparting new properties to the substrates. After a short demonstration of coating NPs on ceramics and stainless steel, I'll present the coating of textiles such as polyester, cotton, and nylon. In all cases a homogeneous coating of NPs was achieved. Silver is known for generations as antibacterial, and indeed the Ag NPs have killed the gram-negative *E. Coli* as well as the gram-positive *Staphylococcus aureus* very efficiently. Lately, the FDA shows less enthusiasm towards nanoAg, as a result, we have moved to NPs of ZnO, and CuO as antibacterial agents. They were coated on the above-mentioned fabrics and showed excellent antibacterial properties. The coated textiles were examined for the changes in the mechanical strength of the fabric. A special attention was dedicated to the question whether the NPs are leaching off the fabric when washed repeatedly. The coated ZnO NPs on cotton underwent 65 washing cycles at 92 °C in water in a Hospital washing machine, no NPs were found in the washing solution and the antibacterial behavior was maintained. Recently, an experiment was conducted at PIGOROV Hospital in which one operation room was equipped with antibacterial textiles, namely, bed sheets, pajamas, pillow cover. 22 Patients in this operation room were probed for bacterial infections. Their infection level was compared with 17 control patient that were using regular textiles. The results are demonstrating that a lower infection level is observed for those patient exposed to the antibacterial textiles.

Fabrication and Potential Applications of Novel Poly (Ethylene Glycol) Hydrogel Films and Nanomembranes

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Abstract

Whereas biorepulsive oligo- and poly(ethylene glycols) (OEGs and PEGs) are widely used for different applications, they have not been utilized yet as materials for free-standing nanomembranes. In this context, I discuss fabrication and potential applications of novel PEG hydrogel films and membranes, abbreviated as PHFs and PHMs, respectively. They were prepared by thermally activated crosslinking of amine- and epoxy-terminated, star-branched PEG oligomers and characterized by tunable thicknesses of 4–300 nm. These systems possess a variety of useful properties, including biocompatibility, robustness, and extreme elasticity. They can serve as a basis for hybrid materials, advanced nanofabrication, and lithography, using electron irradiation and ultraviolet light as writing tools. They can also be used as highly sensitive elements in MEMS as well as in humidity sensors and moisture-responsive nanoelectronic devices, relying on optical or resistive transduction technique. In particular, their resistance changes by ca. 5.5 orders of the magnitude upon relative humidity variation from 0 to 100%, which is unprecedented response for homogeneous materials. The PHFs and PHMs are also able to host protein specific receptors, providing, at the same time, protein-repelling and humidity-responsive matrix with a characteristic mesh size up to 8.4 nm. A noticeable grafting density of the test avidin protein, specifically attached to the biotin moieties coupled to the free amine groups in the PHMs, was achieved, whereas non-specific protein adsorption was efficiently suppressed. The engineering of PHMs with biomolecule-specific receptors and their loading with biomolecules are of potential interest for sensor fabrication and biomedical applications, including tissue engineering and regenerative therapy.

Effective Gene Silencing Using Self-Assembled Rosette Nanotubes

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Abstract

In this talk we will introduce the Rosette Nanotubes (RNTs) as a safe, tunable, and effective nanocarrier that can efficiently deliver a therapeutic RNA payload to a target cell. RNTs are biologically inspired nanomaterials created through the self-assembly of a DNA base analog (GAC), exhibiting tunable chemical and physical properties. A defining characteristic and strength of the RNTs as a drug delivery vehicle is the ability to display various functional groups on their surface via self-assembly, conferring to them tunable physical (stability, dimensions), chemical (surface charge and channel properties), and biological (targeting peptides, bioactive molecules) properties. Such exquisite level of control allows to rationally design delivery systems that (a) evade the immune system, (b) encapsulate drugs, (c) actively or passively cross cellular membrane, (d) display bioactive drugs and exert a biological function, (e) display radioactive or photoactive probes to track and kill cancer cells, (f) escape the endosome when functionalized with positively charged amino acids and peptides, and (g) disassemble into innocuous small molecules after delivering their payload. Our multi-modal delivery system uses a multi-pronged approach to penetrate the tumor and deliver therapeutic agents, all with one self-assembled biocompatible nanomaterial construct.

Hierarchical Fabrication of Gold Nanoparticles with Amyloidogenic Protein of Alpha-Synuclein

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Abstract

Fabrication of nanoparticles (NPs) into multi-dimensional structures is crucial for not only maximizing the physical and chemical properties of individual NPs, but also their applications in the development of high-performance nano-devices. Here, NPs have been assembled with an amyloidogenic protein of α -synuclein (α S), the major pathological component of Lewy bodies found in the degenerating neurons of Parkinson's disease. By taking advantage of the unit-assembly process of α S, gold-nanoparticles (AuNPs) coated with α S were assembled into either anisotropic 1-D chain or tightly packed singlelayered 2-D array on chemically diverse substrates. The resulting peapod-type AuNP chains embedded within the amyloid protein nanofibrils were shown to be capable of exhibiting photo conductance with visible-light. The α S-mediated single layered AuNP adsorption was also employed in non-volatile memory development, fuel-cell performance improvement, plasmonic solar-cell enhancement, and photodynamic cell-culture platform fabrication, where the outlying α S has played versatile roles such as

specific ligand interaction, dielectric layer for charge retention, sacrificial layer to expose AuNPs for chemical catalysis, reaction center for bio-silicification, and bio-interface for cell attachment, respectively. In addition, the tightly packed 2-D AuNP array was successfully unleashed from a substrate of polycarbonate in the form of free-floating monolayer film showing unlimited expandability, robustness for patterning, and flexibility leading to conformal contact. Not only these approaches, therefore, offer a facile and general way to fabricate NPs into hierarchical structures, but also the unique properties provided by the protein sheath make the resulting hybrid structures multi-functional photoelectric fusion materials suitable for applications in future nano-bio-technology.

Molecular Machines Operating in Nanoworld: Some General Principles

Igor Goychuk

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Abstract

In nanoworld, fluctuations and noise play generally a constructive rather than destructive role, and molecular machines are almost inevitably stochastic or Brownian machines using noise as a stochastic lubricant. Can a very slowly operating molecular machine arrive at a near to 100% thermodynamic efficiency at ambient temperatures? Can its thermodynamic efficiency at maximum power exceed 50% while operating fast? The correct answer on both questions is YES [1]. Should we minimize friction and/or lower temperature to arrive at such high efficiencies? The right answer is NO [1]. The design is crucial. Unfortunately, some common fallacies continue to plague the literature in this respect and hinder the progress [1]. I will review some general operating principles of isothermal stochastic machines with thermal fluctuation-dissipation theorem serving as cornerstone. It will be explained why a very high efficiency is also possible in very viscous and highly dissipative gel-like environments like cytosol of living cells [2]. This quest for efficiency is intimately related to another problem of whether an almost heatless classical computing is theoretically possible in dissipative environments or the cost of one-bit operation can be essentially lower than one kT, in principle. Some recent experimental work [3] points also into this direction, confirming a theoretical reasoning defeating the Landauer principle.

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Nanoscale Approaches to Study Molecular Mechanism of Alzheimer's Disease

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Abstract

Alzheimer's disease (AD) is a neurodegenerative disease characterized by dementia and memory loss for which no cure or prevention is available. Amyloid toxicity is a result of the non-specific interaction of toxic amyloid oligomers with the plasma membrane.

We studied amyloid aggregation and interaction of amyloid beta (1-42) peptide with lipid membrane using atomic force microscopy (AFM), Kelvin probe force microscopy and surface Plasmon resonance (SPR). Using AFM-based atomic force spectroscopy (AFS) we measured the binding forces between two single amyloid peptide molecules. Using AFM imaging we showed that oligomer and fibril formation is affected by surfaces, presence of metals and inhibitors. We demonstrated that lipid membrane plays an active role in amyloid binding and toxicity. Effect of lipid composition, surface charge and presence of cholesterol or melatonin are discussed. We discovered that membrane cholesterol creates nanoscale electrostatic domains which induce preferential binding of amyloid peptide, while membrane melatonin reduces amyloid-membrane interactions. Using AFS we showed that metals affect binding forces and inhibitors prevent amyloid-amyloid binding on a single molecule level, the first step which leads to the formation of toxic amyloid oligomers. These findings contribute to better understanding of the molecular mechanisms of Alzheimer's disease and aid to the developments of novel strategies for cure and prevention of AD.

Biomimetic Block Copolymer Membranes for Reconstitution of Transmembrane Proteins

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Abstract

Structure and function of many transmembrane proteins are affected by their surrounding environment. In this respect, reconstitution of a membrane protein into a biomimetic polymer membrane can alter its function. To overcome this problem we synthesized new poly(1,4-isoprene-block-ethylene oxide) block copolymers (PIPEO) and studied their self-assembly in aqueous media with respect to the polymer molecular weight, block ratio, polymer concentration in aqueous solution, and the added fraction of phospholipids. The results show, that the amount of isoprene blocks mainly determined the morphology of formed aggregates. Within the prepared samples, block copolymer molecular weight and concentration showed only a minor influence regarding the self-assembly. Mixtures of block copolymers and phospholipids revealed a demixing regime of the amphiphiles, depending on block copolymer molecular weight. To show feasibility of transmembrane protein reconstitution into membranes formed by PIPEO blended with 1,2-diphytanoyl-sn-glycero-3-phosphocholine we used the well characterized outer membrane protein OmpF from *Escherichia coli*. We demonstrate functionality of this protein in biomimetic lipopolymer membranes, independent of the molecular weight of the block copolymers. In line with these experiments, integration of OmpF was also revealed by impedance spectroscopy. Our results indicate that blending of our new synthetic polymer membranes with phospholipids allows reconstitution of transmembrane proteins under preservation of protein function, independent of the membrane thickness.

Osteoblastic Stimulation of MSCs through Nanoscale Inducement: The Conception of a Novel Osteogenic Bioreactor

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Abstract

Introduction: Mesenchymal stem cells (MSCs) have large regenerative potential to replace damaged cells from several tissues along the mesodermal lineage. Controlled differentiation of these cells can be brought about using various physical environmental conditions *in vitro*, we present data demonstrating our ability, in 2D to control these cells at a nano-level, and induce osteoblastogenesis in MSCs using high frequency (1000 Hz, 3000 Hz & 5000 Hz) piezo driven nano-displacements coupled with a nano-topographical (NSq-50) surface and subsequently translate this effect in a 3D collagen matrix.

Results: At a transcriptomic level the high frequencies (5000 Hz) was found to show the most up-regulation of genes related to osteogenesis, without the presence of the nano-topography. However, this was not the case at a proteomic and mineralization level which were closely in line with each other. At a proteomic and mineralization level 1000 Hz proved to be an optimum frequency even without the NSq-50 surface, giving rise to large distinctive Ca₃(PO₄)₂ apatite nodules in 2D. This work was then evolved into a novel 3D bioreactor (conceptualized, designed and built), with Raman and microCT confirming the presence of mineral apatite deposits *in situ*.

Discussion and Conclusions: High frequency nano stimulation is a novel way to induce MSC differentiation into osteoblastic cells, giving rise to a high level of efficacy through focal adhesion manipulation at the nano-scale. Having interrogated an optimum condition in 2D this research has been successfully translated for use in a 3D collagen matrix as a bioreactor capable of scale up, and GMP culturing under sterile conditions. It is envisaged that in the not too distant future this technology may have real world practical application to provide a ready source of autologous osteoblastic cells along with the onset of mineralized bone, providing a potential therapeutic effect for musculoskeletal conditions such as bone fractures or osteoporosis.

Single Cell Imaging with Surface Enhanced Raman Scattering

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Abstract

Surface enhanced Raman scattering (SERS) has been historically considered a tool for physical scientists. Recently however it has emerged as a powerful technique for biomedical applications, and has been demonstrated that SERS tags can aid surgeons in the identification of tumor margins. SERS tags are nanostructured reporter systems comprising a plasmonic nanoparticle for electric field enhancement, a Raman reporter molecule, a capping layer to impart stability and biocompatibility, and a tagging moiety. They serve the role in SERS that fluorescent dyes have in fluorescence microscopy, while outperforming them owing to their insensitivity to photobleaching and sensitive multiplexed identification power.

During my talk, I will introduce the audience to the concept of SERS tags and their potential in disease diagnosis. Starting from our earlier studies, I will move on to more recent results in which SERS tags have been synthesized starting from gold nanostars. In particular, I will focus on the synthesis and characterization of these nanoparticles, provide a detailed analysis of their plasmonic properties, and show how their cytotoxicity is equal to or lower than that reported for spherical gold nanoparticles, using a multiparametric analysis and four different types of cytotoxicity assay. Compared to fluorescent tags, SERS tags promise to become a much-improved tool in biomedical imaging.

Biomimetic Nanopores Fundamental to Applications

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Abstract

Nanopore design and fabrication are now well controlled, allowing study fundamental biological or physical problems and the development of future biotechnologies and medicine applications. We give some examples about –dynamics in confined medium; proteins unfolding and detection of mutations; high-resolution size and mass discrimination of molecules; cyclodextrin nanotubes insertion into membrane-, using a single molecule method, with an electrical detection. Macromolecule chains, passing through one nanopore submitted to an electric field induce detectable blockades of ionic current, in the presence of salt solution. These blockades, frequency, duration and amplitude, depend on the size, mass, conformation, structure of the passing molecule, concentration and the interaction between the molecule and the nanopore.

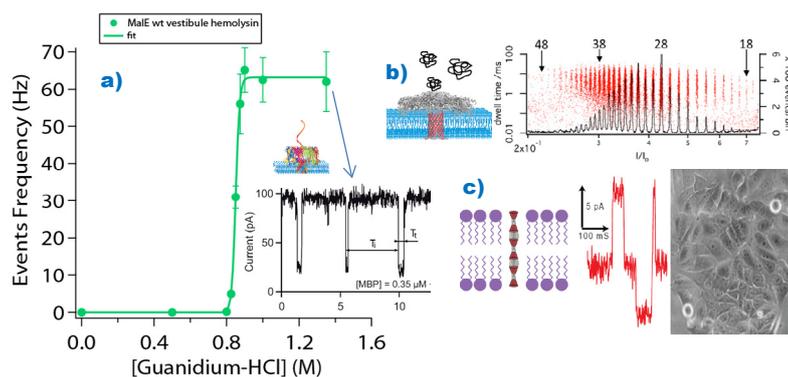


Figure 1: Protein unfolding (A) and single polymer mass spectrometry (B) through a nanopore coupled with an electric detection, cyclodextrin nanotubes insertion into membrane and cytotoxicity assay (C).

Plasmonic Nanoagents for Controlling Chemical Reaction and Biological Systems in Space and Time

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Abstract

One of the key challenges for nanoscience today is the development of nanoscale probes and assemblies that are capable of performing or enabling a specific task or function. Nanomaterials, in this case, are not solely perceived based on their physical properties and small dimensions but start to become enabling reagents, or more descriptively 'nanoagents', that allow for guiding and monitoring complex operations such as running a chemical reaction or a biological process with unprecedented control and efficiency.

In this presentation, I will address the potential of plasmonic nanoparticles as such nanoagents for controlling chemical reactions and to sense and manipulate biological systems such as lipid membranes and living cells in space and time.

Effect of Doxazosin & Amlodipine on Insulin Release

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Abstract

Hypertension is an asymptomatic disease and it is sustained elevation of resting systolic (≥ 140 mmHg) & diastolic (≥ 90 mmHg) BP (Carretero & Operil, 2000). Normal human Blood pressure ranges from 120/80 mmHg to 140/90 mmHg (ISH, 2014). Coronary heart disease (CHD) is more prevalent in diabetic hypertensives' (James et. al, 2000) and CHD is the main cause of deaths worldwide. Anti-hypertensive therapy has reduced the incidence of stroke, heart failure & renal failure, however incidence of CHD is not been decreased to that level, conversely many antihypertensive drugs has diabetogenic effects via suppression of insulin. Objective of the study was to observe effects of Doxazosin & Amlodipine on insulin release by using rat isolated pancreas (Loubatieries et. al, 1972). Diazoxide was used as positive control i.e. known Insulin suppressant drug. Doses used were based on therapeutic peak plasma concentrations. Doxazosin (10 ng/ml) & Amlodipine (5 ng/ml) did not suppress Insulin release significantly. In conclusion, Doxazosin and Amlodipine have no effect on Insulin release.

Nanopore Sensing - Beyond DNA Sequencing

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Abstract

Nanopores (NPs) are single molecule biosensors, which utilize electrokinetic focusing and transport to detect and characterize unlabeled biomolecules. Controlling and tuning the capture rate and the translocation speed of biomolecules through the NP are crucial features to allow sensing of fine biomolecular features within the experimental bandwidth limitations. In the first part of my lecture I will discuss two physical methods to: (i) enhance the *capture rate* of DNA molecules into solid-state using salt gradients to enable sensitive sensing down to a few attomoles, and (ii) slowing down the *translocation speed* of DNA and proteins through NPs using a novel optoelectronic effect that can be switched on or off in a fraction of a millisecond. In the second part of my lecture I will discuss biomedical applications utilizing NPs: (i) barcoding and distinguishing among two highly similar HIV genes using solid-state NPs by incorporation of sequence specific peptide-nucleic acids (PNA) probes; (ii) discrimination among two, unlabeled, Ubiquitin (Ub) protein conformers, which only possess a slightly different 3D structure and having the same amino-acid sequence; (iii) direct and label-free detection of individual transcription-factors bound to DNA; (iv) single molecule sensing of epigenetic bio-markers. The ability to analyze biomolecular complexes, fine features along DNA strands and small proteins in their native folded state at the single molecule level opens up broad opportunities in biomedical research and in biophysics.

Probing Retinal Physiology with Optoelectronic and Microfluidic Platforms

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Abstract

Cell-cell interactions are crucial for the function of neural networks and the behavior of a single cell often differs remarkably from cells in a larger population. In the central nervous system, there are complex interactions between neurons and glial cells that are often spatially regulated, in both healthy and pathological conditions. Interactions in the neural networks are both chemically and electrically regulated. While many approaches can examine single cells of artificial neural networks *in vitro*, these are limited in their ability to extrapolate findings to intact, native neural networks. There are two primary challenges to assessing cell-cell interactions in large neural networks. First, there is a need to chemically isolate and probe components of a large neural network, while preserving the structural integrity of the network as whole. Second, high spatiotemporal resolution and high throughput are necessary for accurate signal detection to map functional connectivity of a neuronal network. Microfluidic techniques provide the capability of implementing spatiotemporal control in local microenvironments. We utilize microfluidic platforms with multiple reagent access points to chemically isolate and probe microenvironments within whole, living retina. To address the challenge of achieving high spatiotemporal resolution and high throughput, we combine graphene field-effect transistors and scanning photocurrent microscopy with microfluidic platforms to map electrical activities of large neuronal networks with single synapse spatial resolution. This method not only provides a way to investigate chemical and electrical processes in whole, living retina, but also offers opportunities to study many other cellular systems involving cell-cell interactions through chemical and electrical signaling.

Polymer Mass Spectrometry with a Single Nanopore

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Abstract

Nanopore sensing is a new single molecule technique which aims to provide rapid real time detection and characterization of molecules. It consists in measuring the flow of ionic current through a single nanopore. The presence of a molecule inside the nanopore affects the current flow inducing a measurable decrease in ionic current that depends on the size and conformation of passing molecules, on the diameter and length of the molecule and on the interaction between the molecule and the nanopore. We discuss here the ability of nanopores to detect and discriminate polymer chains differing by only one repeat unit in length leading thus to construct a mass spectrum resembling to the mass spectra obtained with conventional techniques [1]. We discuss how we can extend the range of polymer size discrimination and how we can generalize this technique for biological polymers [2-4].

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Accumulation of Quantum Dots in Lymphocytes of Human Blood

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Abstract

For biomedical applications, it is important to know, which kinds of blood cells can capture quantum dots (QDs). The maximum accumulation of QDs was found for the monocytes leukocyte fractions, minimum binding of QDs was observed for the lymphocytes. It was found that the accumulation of QDs by lymphocytes depends on the type of coating and the concentration of QDs. In particular, the maximum level of accumulation – 99% was observed for the CdSe/CdZn-MPA in lethal concentration (0.1 mg/ml), after reduction of concentration to DL₅₀ (0.025 mg/ml) was observed a significant reduction of the accumulation level to 20% ($p < 0.05$). At the same time, the QDs with a complex coating CdSe/CdZnS/ ZnS-PTVP-APS practically did not change the accumulation level: only 8% of lymphocytes accumulated CdSe/CdZnS/ ZnS-PTVP-APS in lethal dose (0.1 mg/ml) and 0% level of accumulation was observed for DL₅₀ (0.08 mg/ml) ($p > 0.05$). Thus, the group Si-(CH₂)₃-NH₂ hinders binding and accumulation QDs by lymphocytes.

The significant increase of QDs aggregate was found by dynamic light scattering after incubation with lymphocytes in serum-free medium (in 4 times for CdSe/CdZn-MPA and in 2.8 times for CdSe/CdZnS/ZnS-PTVP-APS).

The Effect of Concurrent Longer Usage of Hypericum perforatum along with Oral Contraceptives leads to Infertility

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Abstract

There is a belief based on the theories, the knowledge, skills and practices that, traditional medicines are inherently safe and without side effects. The herbal drug *Hypericum perforatum* commonly known as St John's wort, frequently used as anti-depressant. It is reported that while used along with oral contraceptives hinders metabolism and therefore considered to be unsafe. This herb changes the pharmacokinetics of oral pills that reduces efficacy, leading to intermenstrual bleeding. The study carried out on local population that is using this herb signifies marked anemic conditions leading to Hormonal dis-balance followed by infertility. There are some concerns as reported in study that this herb might increase the breakdown of estrogen leading to decrease effectiveness of birth control pills which serves the reason for unwanted pregnancies. It is reported that; this herb increases the clearance of fexofenadine by 1.6 fold. It acts as an inducer of CYP3A4, the enzyme responsible for the metabolism of estrogens and progestin found in oral contraceptives. The underlying mechanism for an altered drug effect is a serious issue and yet to be determined on experimental basis to see the potential Herb-drug interactions as a stark reality of today i.e. St. John wort with other drugs. Hence the proper reporting of cases, careful vigilance and counseling, evidence-based judgment and awareness, constantly updated reviews of such herb-drug interactions are very important to facilitate systematic research.

Assembly of Plasmonic Gold Nanoparticle Arrays on Lysozyme Amyloid Scaffolds

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Abstract

Plasmonic nanostructures have attracted special attention due to their outstanding optical, thermal and catalytic properties. Surface plasmon resonance (SPR) property of anisotropic gold nanoparticles with characteristic morphologies has nominated these nanostructures as promising candidates in biosensing, drug delivery, cancer therapy, tissue engineering, etc. Therefore, combination of such nanostructures with biological templates encourages development of a new generation of nanoscaffolds for biomedical application of interest. Herein, gold nanostructures were assembled on lysozyme amyloid fibrils to attain nanowire-like structures. The nanostructures were synthesized according to seed mediated growth protocol. Lysozyme was transformed into amyloid fibril-like structures in acidic environment (0.1% HCL, pH 1.6), incubating a fixed concentration of protein at 60 °C (540 rpm). The scaffold was then mixed with nanostructures, previously treated with Polystyrene sulfonate (PSS). The nanostructures and amyloid fibril scaffolds were characterized by various spectroscopic and microscopy techniques, such as UV-visible, Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICPAES), Dynamic Light Scattering (DLS), Circular

Dichroism (CD), Thioflavin-T (ThT) assay and Transmission Electron Microscopy (TEM). Incubation of gold nanoparticles on the amyloid fibril scaffold lead to formation of ordered arrays and aggregates on the biotemplate. The hybrid system could be further tested for possible enhanced conductivity and application in tissue engineering. Results of this effort encourage possibility of assembling nanoparticles of desired morphology and property on biological Scaffolds, with promising applications in Nanomedicine and Nanobiosensing.

Probing the Nanoscale with a Combination of Microscopy and Theory

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Abstract

Atomic-resolution microscopies (scanning transmission electron microscopy, scanning tunneling microscopy, etc.) combined with quantum mechanical calculations have proven to be a powerful combination to probe the structural, electronic, magnetic, optical, and transport properties of complex nanostructures. This talk will illustrate specific examples of nanostructures based on two-dimensional materials such as graphene and transition-metal dichalcogenides (TMDs) or complex oxides where a combination of theory and microscopy unveiled unique properties and functionality. In particular, we will show that multivacancies (nanovoids) in graphene can be robustly passivated by silicon atoms so that they can be used in multiple applications based on translocation of molecules (e.g., water filtering, DNA sequencing etc.) [1]; we will demonstrate the sculpting of ultrathin conducting nanowires in monolayer TMDs [2]; we will demonstrate a low-thermalbudget method for doping graphene p-type using boron [3]; we will show that memristive behavior can be achieved in polycrystalline oxides where grain boundaries behave as nanovaristors [4]; we will demonstrate a novel “interlaced structure” in nanoparticles that can lead to giant thermoelectric efficiency [5].

Acknowledgements: Collaborators are acknowledged as co-authors in the cited publications. The work was supported in part by U.S. Department of Energy grant DE-FG02-09ER46554 and by the McMinn Endowment at Vanderbilt University.

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Scalable Nanomanufacturing Processes for Materials and Polymeric Structures

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Abstract

Emerging technologies, materials, devices and structures depend on advances in polymer nanomanufacturing processes, such as roll to roll printing or other additive manufacturing approaches. Polymer materials have processing ease, biocompatibility, biodegradability, and flexibility for improved devices. This work will present novel manufacturing approaches for the incorporation of nano/microscale functionality in polymer based materials. For example, nanomanufacturing can be used to create polymer substrates, inks, and fibers for additive manufacturing or flexible electronics by mixing polymers with nanomaterials. Substrate materials can include designer nanocomposites for better barrier, lighter weight, or tunability for antennas, which are prepared using commercially relevant continuous, twin-screw extrusion processes. Multilayer films, with micro or nanolayers can be fabricated using a modified extrusion process for applications in optical films, barrier packaging and substrates. The surface energy of the substrate can be tailored to control ink behavior (wetting) by changing the surface structure and chemistry. Nano or micro-structured surfaces can exhibit superhydrophobicity, omniphobicity, or patterned to control surface energy in different locations. A printing process can be used to assemble polymers or nanoparticles (conducting/nonconducting) (inks) into nanoscale patterns and transferred to a polymer substrate using the roll to roll process. Unique structures for flexible electronic devices, metamaterials, structural nanocomposites, or biomaterial applications can be fabricated.

State of the Art in Nanotechnology Safety by Design

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Abstract

Applications of nanotechnology and nano-enabled products grow daily. The novel properties of some materials at the nanoscale create opportunities for use in consumer, coatings, medical, energy, agriculture industrial and environmental sectors. The requirements for demonstrating safety of new technologies vary according to the application and market. Further, consideration of any nano-specific properties of new forms is also an important consideration. These requirements create drivers for addressing safety upfront, during the research and design phase. An emerging area for chemistry, safety by design for technologies is a cutting edge practice.

This talk will explain the concepts of safety by design, and demonstrate examples in practice, including nanoscale and bio-based technologies. Considerations for inclusion in safety by design assessments such as the product life cycle, hazard properties, alternatives analysis and risk analysis will be described, and methods reviewed. The talk will conclude with practical examples of ways to adopt safety by design in the innovation process.

Roll-2-Roll – Nano – Imprint – Lithography (NIL) – Journey to Seamless, Large Format Functional Film

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Abstract

Functionalization of surfaces by micro- and nanostructures is one of the most exciting market in the near future. PV, OLED-Lighting, LCDs etc. need structures to increase efficiency. Light guiding and shielding of modern buildings with large area nanostructured glass fronts are getting more and more important in the ecological aware society. Antibacterial and antifingerprint surfaces are other application possibilities. In my paper I will present new development for seamless sleeves and latest developments and products in Roll - to - Roll UV-embossing.

Nanomaterials for Sustainable Architecture and Conservation of Cultural Heritage: State of Art and Perspectives

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Abstract

Today the use of nanomaterials in architecture offers new opportunities by improving significantly the behavior of building materials and structures, their energy efficiency, as well as the way buildings relate to the environment. Nanomaterials expand design possibilities for both interior and exterior spaces: surface treatments able to make any surface easy to clean, innovative materials having de-polluting, antibacterial or anti mold properties, self-healing surfaces, new paintings with *ultra-mat* saturated colors or nano-insulating materials, just to highlight some revealing examples. These appear as groundbreaking and promising tools, being able to improve the performance of traditional building materials, like concrete, steel and glass. Moreover, several applications of nanotechnologies in the field of conservation of cultural heritage are currently used, allowing a more reliable and sustainable preservation of artifacts by the use of non-toxic and environmentally friendly treatments.

This contribution aims at presenting the last achievements and the perspectives on the application of nanomaterials to the building construction and cultural heritage sectors as driver to innovation and sustainability. The increased performances, as improved strength and durability of materials are magnified also considering the reduction of the built environment's environmental footprint throughout the efficient use of resources. Lastly, this contribution underlines that, even if these nanomaterials are contributing to a significant change in our life, we must ensure that the potential risks are identified and controlled, through developing new appropriate standards and codes for their application.

Review and Discussion of Recent Regulatory Developments in Europe when it comes to Nanomaterials

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Abstract

A number of recent developments in European regulation of nanomaterials are presented and discussed. In 2013, the new Biocidal Product Regulation came into force representing the first piece of legislation, worldwide, to implement a definition of nanomaterials, to require nanospecific data to be submitted and to require a dedicated risk assessment when a nanoform of a substance is used. Although, the intentions of the BPR are good, implementing them has come with a set of challenges that legislators and registrants of biocides have to face including how to complete material characterization, exposure preparation and delivery of substance to test systems to enable nanospecific risk assessment. When it comes to the European chemical legislation, REACH, only changes in the accompanying annexes are currently being discussed and there are four different proposals on the table for annex revisions. One proposal comes from Swedish competent authorities, two stem from the German competent authorities and finally, a non-paper stems from the European Commission DGs. Each of the proposals has pros and cons and provides annex revisions to varying level of details especially when it comes to requiring characterization of nanomaterials and assessment of the applicability of the tests used when it comes to nanomaterials. It is also interesting to note that some of the challenges what the European Commission is having with revising the REACH annexes stem from the fact that these challenge can only be properly addressed via changes in REACH itself something which the Commissions has so far declined to implement.

Nanocellulose: The Road to Commercialization

Jack Miller

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Abstract

Nanocellulose has been known since the 1950s, but now development of markets and applications has accelerated, driven not only by interest in nanotechnology, but also by growing demand for renewable, recyclable, and bio-based materials. At the same time, paper markets have declined, and paper producers have sought new revenue streams and new uses for forest-based materials. New ventures including CelluForce, American Process, Blue Goose Biorefineries, Melodea, and Nippon Paper have started up pilot or demonstration plants and are working with customers to develop applications. Hundreds of tonnes of material are currently in market applications and hundreds of companies have now tested various cellulose nanomaterials in applications ranging from pulp and paper to cement, oil and gas drilling, composites, adhesives, paints and coatings, and much more.

Why nanocellulose? Why now? What does the future of nanocellulose look like?

Nanocellulose has many of the same properties as other nanomaterials: it is strong and lightweight, with interesting electrical, optical, and rheological properties. But unlike many other nanomaterials, it is renewable, non-toxic, and relatively inexpensive. As a result, there is great excitement about the potential for nanocellulose: the USDA projects 34 million tonnes by 2045 and the Japanese government projects an \$8 billion market by 2030. This presentation will review the types of nanocellulose, and review recent commercial developments and the state of the industry. We will examine the road ahead with special attention to end user perspectives. Finally, we will discuss the challenges yet to be overcome, and provide a forecast to 2025.

Noble Metal Nanoparticles in Matrix for High Efficient Catalyst

Ge Wang

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Abstract

Despite their excellent catalytic properties, applications of noble metal nanoparticles have been hindered by their tendency to coagulate, as well as the difficulty in reusing them. So, generating extra fine noble metal nanoparticles in the matrix to prevent their aggregation and facilitate their separation during retrieval and achieve a higher catalytic efficiency still remains a challenge.

Recently, our group developed a one design many functions strategy to design hollow multiple-Ag-nanoclusters-C-shell nanostructure and double-shelled sea urchin-like yolk-shell $\text{Fe}_3\text{O}_4/\text{anatase}/\text{Au}$ microsphere catalyst. For example, hollow multiple-Ag-nanoclusters-C-shell nanostructures containing stabilized Ag nanocluster and hollow C shell was obtained by a simultaneous synthesis and assembly strategy. The glucose served as mild reducing agent for reducing Ag^+ to Ag and as carbon source for generating C shells, simultaneously. Then, the hollow multiple-Ag-nanoclusters-C-shell nanostructures were fabricated by a redox reaction between the $\text{Ag}@\text{C}$ templates and H_2O_2 . $\text{Fe}_3\text{O}_4/\text{anatase}/\text{Au}$ microspheres began by synthesizing

Fe₃O₄ nanoparticles for the core so that the catalyst could be easily collected using an external magnetic field. Followed is silica and titania coating to obtain the Fe₃O₄/SiO₂/TiO₂ structures. Subsequently, the sacrificial SiO₂ layer guarantees the formation of the double shelled titania urchin structure under hydrothermal condition. Thus, a large number of isolated and dispersed noble metal nanoparticles on the surface of the shell offered numerous interfaces, meanwhile, the channels derived from the shell ensured the accessibility of reactant molecules to the active sites surface. These catalysts exhibit excellent catalytic activity and recyclability for the duction of *p*-nitrophenol.

Structure and Properties of Thin Nanowires Produced by Laser Ablation of Metals in Superfluid Helium

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Abstract

By using the ability of quasi-1D quantized vortices to concentrate in their core any particles introduced into superfluid helium (He II), the ultrathin nanowires can be grown from any metal or alloy. The peculiarities of thermal conductivity in He II leads to the fact that the coagulation of small agglomerates produced firstly molten metal nanoclusters, which then fused to the nanowires. Therefore, the nanowires have not fractal, dense-packing structure. The diameter of the nanowires ranges from 2 nm for refractory metals (as tungsten) up to 8 nm for fusible ones (as indium). In our experiments a metal was introduced into He II by laser ablation of metal targets submerged into liquid. The purity of the resulting nanowires was determined solely by the purity of the metal applied. Using the variety of nanowires such grown, we have studied the size effects: (i) in the electrical conductivity, (ii) in the temperature of the superconducting transitions, (iii) in the thermal stability of the nanowires (a sharp drop in stability for diameters less than 5 nm was observed). The phenomenon of quantum phase slip in thin nanowires of superconducting niobium was found experimentally. The high activity of Au: Cu, Pd, Pt and Nb nanowebs as catalysts in carbon monooxyde oxidation has been discovered and investigated. It was found that the nanoheterostructures suitable for a multitude of goals maybe synthesized under ablation of different alloys.

Towards a Discovery Solution for Nanotechnology – Challenges & Prospects

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Abstract

The exponential growth in nanotechnology has led to vast amounts of information and data being dispersed throughout various journals and patents making the acquisition of this information difficult. Furthermore, the lack of standardized nomenclature for nanomaterials is a huge challenge which makes seeking and transfer of scientific results a difficult task for researchers. There exists, however, a great demand for quick and curated information on nanomaterials, properties and applications. Nano.nature.com known as Nano¹ was launched on 15 June 2016 as a non-journal type product under the Nature Research portfolio. It aims to provide highly indexed and structured information related to nanomaterials derived from peer-reviewed journals. These include composition, synthesis, properties, characterization methods and application information. This talk will illustrate how Nano can aid nanotechnology research communities to obtain fast and precise insight into the wealth of nanotechnology based scholarly knowledge via use case scenarios and provide the latest information for new discoveries and developments.

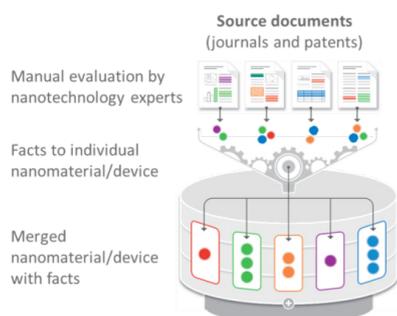


Figure 1: Creation of curated summaries of nanomaterials.

Reference

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Understanding and Application of Spin-Related Phenomena in Organic Semiconductors

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Abstract

The use of organic semiconductors can lead to revolutionary changes in many areas of device technology due to their unique electronic properties and functionalities. Furthermore, organic semiconductors, which can be easily tailored by chemical synthesis and molecular engineering, provide other advantages such as low production cost, light-weight, and mechanical flexibility. Especially, an emerging research area referred to as organic spintronics has initiated a range of device concepts by taking advantage of spin-related phenomena in organic semiconductors. There are currently two major interests in spin-related phenomena in organic semiconductor device technology. One of them is to understand and manipulate the interaction dynamics of excited spin states in organic semiconductors particularly with magnetic fields for the development and improvement of organic-based devices such as organic light emitting diodes and organic photovoltaics. The other one is to realize the efficient injection/transport/detection of spin polarized carriers in organic semiconductors to develop novel spin-based computing devices. In this presentation, I will discuss difficulties and challenges of realizing electrical spin injection/transport/detection in organic semiconductors and how interface/interlayer engineering can lead to achieving this goal by enabling efficient spin injection/detection. In addition, I will examine the use of magnetic fields to study different kinds of intrinsic spin-related phenomena such as intersystem crossing and singlet fission occurring in organic-based devices and the modification of magnetic field effects (MFEs) by interface engineering.

Plasmonic Nanoresonators to Enhance Diamond Color Center Emission

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Abstract

Plasmonic nanoresonators were designed to enhance the excitation and emission of nitrogen (NV) and silicon (SiV) diamond color centers, which are capable of generating encoded quantum information. Singlets and dimers of nanorod metal core - diamond shell as well as spherical diamond core - metal shell type coupled systems were inspected. The Purcell factor, radiative rate enhancement and quantum efficiency were determined by extracting the power emitted on the whole, radiated into the far-field and absorbed inside the metal. The plasmonic resonator configurations including the composition, nano-object geometry as well as dipole orientation and location were optimized by setting criteria regarding the excitation rate enhancement and quantum efficiency at the excitation and emission wavelength, respectively. Based on the products of the excitation and emission rate enhancements ($P_{\text{xfactor}} = (\text{Purcell factor} \cdot \text{QE})^2$), silver is the most promising candidate in either of convex and concave nanoresonators, while gold, copper and aluminum are less efficient in total fluorescence enhancement. Simultaneous excitation and emission enhancement ($50-7 \cdot 10^3$) corresponding to $\sim 3 \cdot 10^4 P_{\text{xfactor}}$ is achievable via nanorods due to antenna-like resonances. Higher ($50-3 \cdot 10^4$) excitation and emission improvement is possible by nanorod dimers exhibiting $\sim 2 \cdot 10^6 P_{\text{xfactor}}$. Moderate ($1-7 \cdot 10^2$) enhancements are achieved via singlet spherical concave resonators, which have $\sim 7 \cdot 10^2 P_{\text{xfactor}}$ caused by the loss during radiation escaping. Translocation of dipoles outside the singlet spherical concave resonators does not promote the excitation phenomenon, ($< 1-4 \cdot 10^2$) enhancements are achieved corresponding to $\sim 3 \cdot 10^2 P_{\text{xfactor}}$. Doublets of spherical resonators result in ($6 \cdot 10^2-8 \cdot 10^3$) enhancements, which make possible to reach the largest $\sim 5 \cdot 10^6 P_{\text{xfactor}}$.

C₃N₄/TiO₂ Nanocomposite in Treatment of Water Contaminated with Phenol

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Abstract

A nanocomposites (CNTi) of carbon nitride (CN) and TiO₂ nanoparticles (Ti) of different mass ratios were prepared by a hydrothermal treatment method and characterized using X-ray photoelectron spectroscopy (XPS), Brunauer-Emmett-Teller (BET), UV-Vis diffuse reflectance spectroscopy (DRS) and Transmission Electron Spectroscopy (TEM). UV-Vis diffuse spectrum showed that the CNTi composites exhibited absorption in the visible light range. The kinetics of the phenol degradation using the as-prepared nanocomposite photocatalyst compared to the bare TiO₂ nanoparticles was tested using Xenon lamps (mainly a visible light source) as a photoexcitation source in presence and absence of H₂O₂ and/or O₃. The photodegradation of phenol was evaluated using UV spectrophotometer and total organic carbon (TOC). It was revealed that the photocatalytic activity of the CNTi composites significantly higher than TiO₂ nanoparticles. Furthermore, 0.1CNTi composite showed the best phenol degradation when H₂O₂ and O₃ were simultaneously used in which the degradation percentage of phenol was more than 90% within 30 min.

Designing Asymmetry at the Nano Scale by Post-Synthesis Modifications; Self-processing Synthesis and *Ex-situ* Doping

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Abstract

Programmable introduction of heterogeneity at the nanoscale plays a key role in the design of functional building blocks for catalysis, electronic devices, and numerous other applications. Synthetic strategies for attaining well-defined heterogeneity in structure, shape, composition, and modulation of the electronic structure at selected regions of the nano system is therefore highly desired. I will present our research towards two methodologies for post-synthesis modification and symmetry breaking of semiconducting nanostructures using nanowires as the basic building blocks covering two aspects of post-synthesis modification of nanowires:

(I) *Ex-situ* doping of silicon nanowires.

Ex-situ doping enables the transformation of un-doped silicon nanowires into heterogeneously doped building blocks featuring sharp p-i-n junctions across the nanowire. Relying on surface chemistry provides an accurate dose and initial positioning together with fine control over the diffusion processes. The monolayer doping methodologies are valuable for decoupling the doping step from the nanowire synthesis step, resulting in *Ex-situ* doping.

(II) Self-processing synthesis of coinage metal-semiconductor hybrid structures.

The hybrid nanostructures obtained for the coinage metals resemble the morphology of grass flowers, termed Nanofloret hybrid nanostructures consisting of a high aspect ratio SiGe nanowire (NW) with a metallic nanoshell cap. The new class of structures is useful in a variety of applications owing to the unique geometrical aspect ratio and electronic properties of the hybrid systems. The synthesis involves a sequence of selective etch and deposition steps which are self-initiated and self-terminated resulting in the hybrid nanostructures.

The Effect of Starvation on Bacterial Survivability in Sand and Evolution of Biofilms: Multi-Scale Study

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Abstract

Formation of biofilms in soil offers the potential to sustainable solutions for many geotechnical problems such as soil erosion and contamination. However, little is known regarding how bacteria grow as biofilms in soil environments with low nutrient availability. In addition, in processes where a large concentration of bacteria is to be augmented to develop biobarriers, knowing the concentration of nutrients needed to maintain biofilm growth for long periods of time is important and facilitates

the design of effective upscale processes. Here, the effect of nutrients' starvation on the growth and biofilm formation of *Pseudomonas putida* in sand porous medium was investigated at macro- and nano- scales. Bacterial growth kinetics and the quantity of extracellular polymeric substances (EPS) formed by the bacteria in sand columns under rich or poor nutrients' conditions were examined over the course of 60 days. Using atomic force microscopy, bacterial morphology was determined via imaging of cells grown on silicon slides under rich or poor nutrients' conditions. Finally, biological force microscopy was used to determine the adhesion forces acting between biofilms grown under both rich and poor nutrients' conditions and a model surface of sand. Our macroscale results show that under starvation conditions, bacterial cell count and the carbohydrate content of EPS dropped significantly compared to when bacteria were fed with nutrient-rich medium. Our preliminary nanoscale results indicate that starvation increases the adhesion of *P. putida* to the silicon surface as well as elongates cells compared to when they were supplied by a nutrient-rich medium.

Nano-structured Multicomponent Coatings for Cutting Tools

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Abstract

The study presents the results of development of nano-structured multicomponent coatings of enhanced efficiency for deposition on working surfaces of carbide tools used for the processes of continuous (longitudinal turning) and interrupted (face milling) cutting. The study included testing of multilayer coatings based on nitride compounds of metals of Periodic Table Groups IV-VI which accurately maintain the Hagg's rule, resulting in formation of relatively simple structures during synthesis with predominance of Me-Me binders, where N atoms can be considered as inserted into the lattice of metal atoms for nitrides of Group IV (Ti,Zr,Hf). Nitrides of metals of Groups V and VI (Nb,Mo,Cr) form more complex structures with a larger number of phases. The study used three-layer architecture of coatings consisting of outer (wearresistant) layer, transition/barrier layer, and adhesive layer (adjacent to substrate). For the tests, the following coating compositions were selected: Cr-CrN-(TiCrAl)N; Zr-ZrN-(ZrNbCrAl)N; Zr-ZrN-(ZrCrAl)N, and Ti-TiN-(NbZr-Al)N. Their chemical and phase compositions, mechanical properties (hardness, adhesion to substrate) were studied, and metallographic tests were also carried out. The study also included testing of carbide tools for a wide range of changes in cutting conditions in machining of structural steels and nickel-based alloy. The study compared cutting properties of samples of carbide tools without coatings, with commercial coatings TiN, (Ti-Al)N, and developed coatings. The study results allowed finding optimum compositions and architecture of coatings which demonstrated maximum tool life in continuous and interrupted cutting for a wide range of changes in cutting conditions.

The Influence of Sol-Gel Process on the Microstructure of Surface and Nanocrystalline TiO₂ for Ti-Si Binary Oxide

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Abstract

Three different structures of Ti-Si binary oxides powder with 10% SiO₂, silica-supported titania (TS1), intimately mixed silica titania (TS2) and silica-coated titania (TS3), were made by three sol-gel processes and then heated from 773 K to 1273 K. The microstructure of surface in depth and nanocrystalline(nc) TiO₂ were comparatively studied by XRD, XPS, ARXPS, SEM and HRTEM. SEM showed that all samples consisted of 20-50 nm flakes, but these flakes had sintered together for TS1, conglomerated for TS2 and self-assembled to porous structure for TS3. ARXPS showed that the surfaces of all samples enriched in Si and were the mixture of TiO_x, SiO_y, Ti-O-Si, and adsorbed large amount of O and C-containing species. The in depth changes of Ti, Si and O in surface are closely related to its origin structure formed during sol-gel. More sub-valence Ti and Si appeared to the surface of TS1 and TS2, and more adsorbed C and O containing species appeared to the surface of TS3. Besides, the addition of Si greatly inhibited both grain growth and anatase-rutile transformation and TS2 showed the best inhibitory effect. However, the unit cell volumes of nc-TiO₂ anatase in TS2, calculated by the data of XRD, were not the smallest, and which in TS1 showed the smallest and that of TS3 showed the largest among them. Furthermore, many crystal defects of nc-TiO₂ anatase were founded in all samples by HRTEM.

Graphene Supporting Graphitic Carbon Nitride as Novel Electrochemiluminescence Platform and its Application in Ultrasensitive Detection of Chlorinated Phenols

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Abstract

For the first time, a novel one-step electrochemical reduction technology is proposed for the preparation of g-C₃N₄/GR hybrid. And an advanced electrochemiluminescence (ECL) sensor based on g-C₃N₄/GR hybrid has been fabricated for the ultrasensitive, rapid and real-time detection of pentachlorophenol (PCP), which are a typical group of persistent organic pollutants in the environment. The g-C₃N₄/GR shows stable ECL signal in the presence of the self-produced coreactant from oxygen reduction, and the ECL signal can be effectively quenched by PCP, the possible ECL detection mechanism has been proposed in detail. GR can not only significantly enhance the cathodic ECL signal of g-C₃N₄ (~4.7 times), but also serve as immobilization platform for g-C₃N₄. This proposed g-C₃N₄/GR ECL sensor enables the real-time detection of PCP with unprecedented sensitivity reaching 1.0×10^{-11} M concentration in a wide linear range from 1.0×10^{-11} to 1.0×10^{-7} M. The practicability of the sensing platform in real water sample shows ideal recovery rates. Moreover, we also find that the one-step electrodeposition technology might be a good and viable way to make the bulk g-C₃N₄ thinner. Our experiments display the powerful utility of GR to g-C₃N₄ ECL studies and will emerge eximious applications in analytical communities and environmental monitoring.

Batch and Continuous Photocatalytic Degradation of 4-chlorophenol using Ag Core -TiO₂ Shell Structured Nanoparticles

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Abstract

Chlorophenol has been put up under priority pollutants by U.S. Environmental Protection Agency due to its high toxicity, carcinogenicity and persistence. It is necessary to treat chlorophenol contaminated wastewater from industries prior to its discharge into water bodies. Nano-photocatalysis has been adopted in the present study for degradation of 4-Chlorophenol(4-CP). Ag core-TiO₂ shell (Ag@TiO₂) nanoparticles were synthesized by one pot synthesis method with post calcination. These nanoparticles were tested for their photocatalytic efficacy in degradation of 4-CP both in free and immobilized form under UV light irradiation through batch experiments. Ag@TiO₂ nanoparticles were found to be the effective photocatalysts for UV photocatalytic degradation of chlorophenol. The factors such as pH, initial 4-CP concentration and catalyst loading were optimized to maximize the chlorophenol degradation. The complete degradation of 30mg/L, 4-CP could be achieved within 5hours of irradiation under UV light with 0.5g/L of catalyst loading. The efficacy of the nanoparticles immobilized on cellulose acetate film was inferior to that of suspended nanoparticles due to light penetration problem and diffusional limitations. The photocatalysis of 4-CP by suspended and immobilized Ag@TiO₂ nanoparticles followed the first order kinetics. The performance of fluidized bed photocatalytic reactor operated under batch with recycle mode was evaluated with immobilized Ag@TiO₂ nanoparticles and it was found that 1 L of 30 mg/L 4-CP was degraded to around 75% in 5 h. Thus, the potential of fluidized bed reactor in batch with recycle mode for application in large scale wastewater treatment by photocatalysis was demonstrated.

Using Nanostructures to Tailor Thermal and Solar Radiation

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Abstract

This talk will present some of our recent work on using nanostructures to tailor thermal and solar radiation with applications including incandescent lighting, energy saving fabrics, electricity generation, and clean water. By designing nanostructures to reflect infrared radiation back to its emitting source, we can improve the efficiency of converting thermally-radiated photons into electricity via thermophotovoltaic devices and the efficiency of incandescent light bulbs. With properly chosen fiber diameters, we design fabrics so that they are opaque to visible light and yet allow thermal radiation from human body to escape to environment for passively cooling. Nanostructures can also be used to improve the efficiency and reduce the cost of solar to electricity energy conversion. In one example, we use nanostructures to capture efficiently the sunlight in 10 micron thick single-

crystalline silicon photovoltaic cells, achieving 15.7% solar-to-electricity energy conversion efficiency. In another example, we use optically transparent aerogels to allow sunlight to be concentrated into a heat absorber, and yet thermally insulating it from the ambient to reduce heat loss. This approach can potential allow concentrated solar-thermal systems operating without vacuum, leading to cost reduction.

Directing Charge Transfer in Nanoparticle Assemblies

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Abstract

We are exploring nanoparticle-based materials for solar to electrical energy transduction. Nanoparticle devices promise to provide a systematic and modular approach to creating supramolecular assemblies of linked nanoparticles that function as charge transfer elements. I will report on recent work in which we explore how to engineer nanoparticle/nanoparticle interfaces and nanoparticle/conjugated polymer interfaces to enhance charge separation and inhibit charge recombination. Particular foci of our effort are aimed at understanding the importance of energy-level gradients, built-in electrostatic potentials, and symmetry/chirality properties to improve the charge-separation efficiency in inorganic-organic hybrid structures.

New Aspects on Nanostructured Colloid-Interface Engineering

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Abstract

We need innovations for construction of sustainable society on the basis of colloid and interface science on environmentally friendly materials such as nanostructured carbon materials of outstanding properties. This paper introduces new type of colloid and interface studies on in-pore super high pressure effect for new materials production, highly compressed ionic states (supercompressed ionic state) in carbon pores, and fabrication of carbon materials for new engineering using carbon nanotube. Confinement of sulfur in the tube spaces of single wall carbon nanotube (SWCNT) and double wall carbon nanotube (DWCNT) below an ambient pressure gives atomically 1D sulfur chain crystals of metallic property. This in pore super high pressure effect can be widely contribute to science and technology. The super high pressure effect provides specially ordered structure of organic solution in the carbon nanopore spaces which is associated with fundamentals of super capacitor technology. The structure of organic electrolytic solution in slit-shaped pores sensitively depends on the pore width. We succeeded to evidence that the ions of the same charge can form a more compressed structure due to an additional stabilization effect through the image potential in the carbon wall, giving a great potential for the higher density storage of electric charges. Also unique apparent hydrophobic-hydrophilic transformation is induced for water adsorption in carbon nanopores with the aid of cluster-growth of water molecules. We developed highly concentrated carbon nanotube ink with Zn-Al sol-gel agent to prepare carbon nanotube fabrics having excellent functions. We can apply the ink to produce highly stretchable electrodes.

Plasmonic and Perovskite Nanostructures for Advanced Optoelectronic Devices

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Abstract

Plasmonics have also been recognized as promising platform that may premise the enhanced performance of nextgeneration photovoltaic devices. Plasmonic effects have been proposed as a solution to overcome the limited light absorption of thin film photovoltaic devices and diverse types of plasmonic solar cells have been developed. Recently, we made a comprehensive overview of the state-of-the-art progress on the design and fabrication of plasmonic solar cells as well as the understanding of the enhancement mechanism. In this presentation, we propose a few strategies to develop viable plasmonic DSSCs and OPVs based on metal-graphene oxide core-shell nanostructures or lithographically-induced plasmonic nanopatterns.

Very recently metal halide perovskites have been attractive as solar energy harvesters due to efficient ambipolar transport and strong light absorption. They have rapidly advanced thin film photovoltaic performance; as a result, the observed instabilities urgently require a solution. We report the reduced-dimensionality (quasi-2D) perovskite films that exhibit improved stability in solar cell performance while retaining the high performance of conventional three-dimensional perovskites. We achieve the

first certified hysteresis-free solar power conversion in a planar perovskite solar cell, obtaining a 15.3% PCE, and observe greatly improved performance longevity. The quasi-2D perovskites were also employed to develop limiting emitting diodes with the most bright and highest EQE.

Soft Matter Based Hypersonic Phononic Structures

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Abstract

Phononic structures, i.e. composite materials in which a periodic distribution of elastic parameters facilitates control of the propagation of phonons, hold the promise to enable transformative material technologies in areas ranging from acoustic and thermal cloaking to thermoelectric devices. Realizing these opportunities requires strategies to deliberately 'engineer' the phononic band structure of materials in the frequency range of interest. Phononics, the acoustic equivalents of the photonics, are controlled by a larger number of material parameters, as phonon cannot propagate in vacuum. The study of hypersonic phononic crystals imposes substantial demand on fabrication and characterization techniques. Colloid and polymer science offer methods to create novel materials that possess periodic variations of density and elastic properties at mesoscopic length scales commensurate with the wave length of hypersonic phonons and hence photons of the visible light. The key quantity is the dispersion $\omega(k)$ of high frequency (GHz) acoustic excitations with wave vector k which is measured by the noninvasive high resolution spontaneous Brillouin light scattering. The typical approach involves the exploitation of Bragg-type phononic band gaps (BGs) that result from the destructive interference of waves in periodic media. However, the sensitivity of BG formation to structural disorder limits the application of self-assembly methods that are generally susceptible to defect formation. Phononic hybridization gaps, originating from the anti-crossing between local resonant and propagating modes, are robust to structural disorder and occur at wavelengths much larger than the size of the resonant unit. Here, examples based on hierarchical structures will be highlighted.

Design of New Flat Nanomaterials Based on Carbon

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Abstract

Optimal searching for new, stable atomic arrangements of two-dimensional graphene-like carbon lattices using a hybrid algorithm is presented. The hybrid algorithm combines the parallel evolutionary algorithm and the classical conjugated gradient minimization of the total potential energy of the optimized atomic cluster. The behavior and the potential energy of carbon atoms are determined using the Adaptive Intermolecular Reactive Empirical Bond Order (AIREBO) potential [1]. In order to validate the model and verify its accuracy, certain arrangements of carbon atoms already known from literature (including the supergraphene and the graphyne) are examined, Next the proposed optimization algorithm is applied to searching for new stable configurations of a given number of carbon atoms in a unit cell of prescribed size and periodic boundaries. New stable flat graphene-like materials named X and Y have been obtained [2]. The atomic structures with orthotropic elastic material properties are also taken into account. In this case the objective function depends on the norm of differences between a vector of prescribed and computed elastic properties for the nanostructure. Mechanical properties of the obtained new nanomaterials are evaluated by means of computer simulation of the tensile tests using molecular dynamics.

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Electrochemical Synthesis of Energy Related Materials

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Abstract

It is the aim of our project to carry out fundamental studies on designing and synthesizing novel functionalized foam and ordered structures for potential applications in electrochemical energy storage. We combine electrochemical synthesis with structural studies on different length scales including transmission electron microscopy. Templates are directly grown by electrodeposition, either by hydrogen bubble formation or by utilization of ordered structures formed by anodic electrochemical oxidation [1-3]. By this we are breaking new grounds and achieve innovative aspects to design electrode materials with both, high performance and stability over a long term. To reach our goals we are using complementary methods to synthesize and electrochemically characterize the novel electrode nanomaterials. In the case of synthesized NiCoFe foams the catalytic activity is strongly enhanced for both, the cathodic reduction of oxygen and the anodic evolution of oxygen and shows a good reversibility [1]. In the case of fabrication of nanodendritic Ag simultaneously grown with porous anodic aluminium oxide we accomplished well anchored dendritic Ag nanostructures [2] of long-term stability [3].

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Metal Sulfide@Graphene@Nickel Foam Nanocomposites for Supercapacitor Electrodes

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Abstract

Various metal sulfide (or oxide)@graphene@nickel foam nanocomposites have been developed for supercapacitor electrodes. Electrochemical performance of the graphene-based metal sulfides (or oxides) nanocomposites has been improved due to the synergistic effect of excellent conductivities and mechanical properties of graphene sheets and to the high pseudocapacitance of metal oxides and metal sulfides. Most metal oxides and sulfides are low costs and doping of graphene with metal oxide or sulfide nanoparticles enhances the energy density remarkably, resulting in an excellent performance as an electrode material for supercapacitors. Recently, metal foam has been getting tremendous attention as it provides a large surface area and large pores that enables electrolytes and charges penetrates freely. However, to meet the demands of industry for higher capacitance, energy density and power density, a new approach is required.

Various metal oxides and sulfides will be compared. The benefits of using graphene will also be discussed. In the synthesis of these materials, a cleaner technology has been employed. Nanocomposites that show high surface areas, high conductivities, and remarkable electrochemical properties will be introduced.

A Dissolution-Recrystallization-Assisted Electrospinning Method to Improve Lithium-Ion Storage Performance of Zn₂GeO₄

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Abstract

We have prepared the uniform 1D porous Zn₂GeO₄ nanofibers (abbreviated as p-ZGONFs) and flexible Zn₂GeO₄/C composite (ZGO/C-P) via the dissolution-recrystallization-assisted electrospinning technology. The precursor of Zn₂GeO₄ nanorods (ZGONRs) was firstly synthesized by a common hydrothermal method and then dispersed uniformly into the polyacrylic acid (PAA) aqueous solution. Subsequently, CA was added slowly into the above-obtained dispersion until all

ZGONRs were dissolved completely. The resulting viscous solution can be easily electrospun into well-defined nanofibers due to the absence of any solid-state precipitates in the precursor solution. Finally, p-ZGONFs were obtained after annealing the as-obtained fibre precursors in air at 700 °C for 4 hours. Furthermore, flexible Zn₂GeO₄/C composite (ZGO/C-P) can also be obtained by annealing the as-obtained fiber precursors in N₂ atmosphere. Electrochemical tests demonstrate that the as-prepared p-ZGONFs and ZGO/C-P exhibit superior Li-storage properties in terms of the high reversible capacity and excellent high-rate capabilities. More significantly, all these Li-storage properties are much better than those of Zn₂GeO₄ nanorods (ZGONRs) prepared by a commonly employed hydrothermal process.

Sub-100 nm Semiconductor Tubular Architectures for Efficient Solar Fuel Generation

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Abstract

Significant enhancement in the performance of solar energy conversion devices have historically been achieved through optimized device scaling. Scaling trends will be extremely difficult to maintain unless new materials and device structures are discovered. Herein, sub-100 nm TiO₂ tubular architectures were synthesized, for the first time, via galvanostatic anodization. The fabricated nanotubes are partially crystalline with high photoactivity towards water splitting and solar-to-electric conversion. Mott-Schottky, transient photocurrent, incident photon-to-current efficiency (IPCE), and electron transfer time constants analyses indicate faster electron transfer at the nanotubes/electrolyte interface. The sub-100 nm tubes showed remarkable efficiency upon their use in solar fuel cell devices. The concept of short nanotubes should be useful for the future use of the material in various applications.

Highly Active Electrocatalysts with Novel Nanostructures

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Abstract

Electrocatalysts are widely employed in energy conversion systems, such as water electrolysis and fuel cells. In general, several approaches are taken to maximize the activity: improve the activity per unit site, increase the number of active sites, enhance the mass transport, and reduce the electrical resistance. In this talk, I will present our recent efforts on high performance electrocatalysts for three typical reactions: hydrogen evolution and oxygen evolution during water electrolysis, and methanol oxidation. For water electrolysis, our materials are loaded on high surface area nickel foams; for methanol oxidation, we fabricate gold meshes with numerous active sites. By taking the above approaches on both noble and nonnoble metal based electrocatalysts, our materials are superior to many state-of-the-art electrocatalysts.

Investigation of Surface and Interface Properties in Photoelectrodes for Solar Fuels

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Abstract

Sunlight is a clean, renewable and abundant energy source on the earth. Its conversion to hydrogen has been considered an ideal solution to counter the depletion and environmental problems of fossil fuels. Photoelectrochemical (PEC) water splitting is an ideal technology for the purpose, since H₂ could be produced directly from abundant and renewable water and solar light from the process. The key to the technology is photoelectrodes made of small band gap semiconductors of photocatalytic properties. The materials should have high efficiency, high stability, and low cost. In addition of the discovery of new materials, the structure and morphology of the known materials could be controlled to enhance the performance of the photoelectrodes. In this talk, the concepts of materials design and their examples will be proposed for efficient photoelectrodes of PEC cells for visible light water splitting. Particularly, we will discuss the material designs including i) p-n heterojunction photoanodes for effective electron-hole separation, ii) electron highway to facilitate interparticle electron transfer, iii) metal or anion doping to improve conductivity of the semiconductor and to extend the range of light absorption, iv) one-dimensional nanomaterials to secure a short hole diffusion distance and vectoral electron transfer, and v) loading co-catalysts for facile charge separation.

2D Nanomaterials for Energy Conversion

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Abstract

Layered transition metal di chalcogenide (TMDs) provide intriguing opportunities to develop low cost, light and wavelength tunable stimuli responsive systems that are not possible with their conventional macroscopic counterparts. TMDs are stack of triple layers with transition metal layer between two chalcogen layers. While the atoms within the layers are chemically bonded using covalent bonds, the triple layers can be mechanically/chemically exfoliated due to weak van der Waals bonding between the layers. Due to the large optical absorption ($\sim 10^7 \text{ m}^{-1}$) in these materials, they are already being exploited for photocatalytic, photoluminescence, photo-transistors and solar cell applications. In this talk, I will present our recent results on direct optical to mechanical motion in 2D nanomaterial composites. This intriguing phenomenon opens up new avenues of energy conversion based on 2D nanomaterial semiconductors.

Hybrid Glass-fiber/Epoxy Composites with Graphene or Carbon Nanotubes as Radar Absorbing Materials

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Abstract

The use of micro- and/or nano-fillers to optimize the properties of epoxy resins has become common practice. Carbon nanotubes (CNT) and graphene nanoplatelets (GNP) are considered excellent fillers because of their unique properties, such as strength and stiffness, thermal conductivity and stability, electrical capacity, along with electromagnetic wave absorption capability in the microwave range. This talk will focus on the development of three-component composites based on glass-fiber/epoxy resin with either GNP or CNT for radar absorbing application. A novel procedure to disperse and deposit nanofillers onto glass fiber fabrics has been developed to reach high overall content of CNT in the hybrid composite (up to 4.15 wt.%), which were later produced by unconventional resin transfer molding (RTM) and characterized using mechanical, dynamic-mechanical, electrical conductivity and reflectivity analyses. The mechanical properties were not significantly affected by the nanofillers although storage modulus increased with the incorporation of CNT, especially when they had also been added to the epoxy. Nevertheless, the response of the composites to electromagnetic radiation has shown an increasing trend for higher CNT content (up to 2 wt.%), reaching up to -18.3 dB (98.5% of absorption). For GNP, conductivity increased sharply and reflectivity showed excellent attenuation values (up to 99.9%) in the 8-12 GHz frequency range. These attenuation levels were obtained even at low concentrations of GNP nanoparticles, indicating the possibility of producing composites with low cost and easy processing for advanced application as radar absorbing materials.

Nanocrystalline and Metastable AA' Graphite

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Abstract

Over the history of carbon, Bernal AB stacking of the sp² carbon layers is known to be the unique crystalline form of graphite. The universal graphite structure is synthesized at 2,600-3,000 °C and exhibits a micro-polycrystalline feature. In this lecture, we introduce another form of graphite with an AA' structure where graphene planes are horizontally translated by half the hexagon width from zigzag AA stacking. The non-Bernal AA' allotrope of graphite is metastable, and is synthesized by the thermal- and plasma-treatment of graphene nanopowders at $\sim 1,500 \text{ °C}$ [1]. The formation of AA' bilayer graphene nuclei facilitates the preferred texture growth and results in 1-dimensional (1D) nanoribbon structures. Kinetically controlled AA' graphite shows quasi-linear behavior near the K-point of the electronic band structure resulting in anomalous optical and acoustic phonon behavior, and exhibits semiconducting nature where the bandgap is $\sim 0.35 \text{ eV}$ (0.00 and 0.50 eV for AB and AA stacking, respectively). AA' graphite reveals unique XRD pattern for textured AA' graphite (lacking several peaks for AB graphite, but revealing two peaks at $2\theta = 42.4^\circ$ and $2\theta = 77.6^\circ$) with the interlayer spacing of around 3.44 Å. We also show that MWNTs are a type of AA' graphite resulted from spiral growth of AA' stacked graphene nanoribbons. Lastly, we discuss availability of 1D nanocrystalline AA' graphite as energy materials.

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Free-standing and Flexible MnO₂/Carbonized Cotton Textile Electrode with Tunable Morphology and Electrochemical Property for Supercapacitors

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Abstract

Due to the increasing demand of low-cost, flexible, stable, and environmental-friendly power sources for emerging wearable electronic equipment, supercapacitor electrodes based on natural cotton textile have been developed. After a simple carbonization/activation process, the carbonized cotton textile with hierarchical meso/microporous structure served as 3D scaffolds to anchor MnO₂ nanostructures, which was realized via a simple in situ redox replacement reaction between potassium permanganate and cotton cloth. The morphology of MnO₂ nanostructures was adjusted from curled sheet-like, sheet-like, rod-like to particle-like. Electrochemical measurements showed that curled sheet-like MnO₂ had a specific capacitance of 465 F g⁻¹ at 0.1 A g⁻¹, and exhibited an excellent cyclic stability with specific capacitance retention ratio of 96% after 3000 cycles. Due to the flexible nature of cotton textile with porous as well as curled morphology of MnO₂, the hybrid electrodes could be bent freely, and the capacitance and cyclability almost remained unchanged even at a bending angle of 150 degrees. Such flexible and stable electrodes from low-cost and environmental-friendly biomass offer new development potentials for energy storage and wearable electronics.

Charge Separation and Transport in Functional Heterojunctions Based on Solution-Grown TiO₂ Nanotube & Nanowire Arrays

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Abstract

TiO₂ nanotube arrays (TNTAs) are vertically aligned, polycrystalline, hollow nanocylinders grown by electrochemical anodization, and are composed of either the anatase or rutile phase of titania or contain both. TiO₂ nanowire arrays (TNWAs), on the other hand, are vertically oriented single crystal nano-pillars composed exclusively of the rutile phase and grown by a solvothermal process. Heterojunctions in which TiO₂ nanotubes or nanowires constitute the *n*-type component, have been used to demonstrate a range of high performance devices involving interactions with and utilization of, photons. For instance, the most efficient photocatalysts for the sunlight-driven transformation of CO₂ into methane are heterojunctions of TNTAs/TNWAs with noble metal nanoparticles [1-3]. Likewise, 18 % efficiency TNWA-based perovskite solar cells have been reported. In addition, extremely sensitive photodetectors and optochemical sensors have also been demonstrated.

In spite of these advances, studies of charge transfer and charge transport in TNTA- and TNWA-based heterojunctions have been rudimentary and rather indirect. Our fundamental studies of charge separation and charge transport in TNTA- and TNWA-based heterojunctions point the way to significant further improvements in device performance and functionality. In particular, our studies suggest that photocatalytic reaction pathways need to be separated into ones based on accumulation- type and depletion-type band alignments at TiO₂-noble metal interfaces. We also found the reactivities of both free and trapped electrons and holes with each other in TNWAs to be extremely weak, thus enabling nearly quantitative collection of charge carriers in pulsed charge injection experiments.

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Combining Solar Steam Processing and Solar Distillation for Off-grid Production of Cellulosic Bioethanol

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Abstract

Conventional bioethanol for transportation fuel typically consumes agricultural feedstocks also suitable for human consumption and requires large amounts of energy for conversion of feedstock to fuel. Alternative feedstocks, optimally those not also in demand for human consumption, and off-grid energy sources for processing, would both contribute to making bioethanol far more sustainable than current practices. Cellulosic bioethanol production involves three steps: the extraction of sugars from cellulosic feedstock, the fermentation of sugars to produce ethanol, and the purification of ethanol through distillation. Traditional production methods for extraction and distillation are energy intensive and therefore costly, limiting the advancement of this approach. Here we report an initial demonstration of the conversion of cellulosic feedstock into ethanol by completely off-grid solar processing steps. Our approach is based on nanoparticle-enabled solar steam generation, where high-efficiency steam can be produced by illuminating light-absorbing nanoparticles dispersed in H₂O with sunlight. We used solar-generated steam to successfully hydrolyze feedstock into sugars, then used solar steam distillation to purify ethanol in the final processing step. Coastal hay, a grass grown for livestock feed across the southern U. S., and sugar cane as a control, are successfully converted to ethanol in this proof-of-concept study. This entirely off-grid solar production method has the potential to realize the long-dreamed-of goal of sustainable cellulosic bioethanol production.

Nanoparticle-embedded Nanofibers in Highly Permselective Osmotic Membranes for Sustainable Water and Energy

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Abstract

To address global problems associated with water scarcity, new effective methods of producing water at low energetic and environmental costs are essential. Forward osmosis has recently gained increasing attention due to its various advantages in sustainable water, resource and energy production. Developing robust membranes with effective and controlled structures for osmotic transport is imperative for widespread adoption of this technology platform. Here we report a scalable approach to fabricate osmotic membranes with high permselectivity based on nanocomposite of mesoporous silica nanoparticles and nanofibers by electrospinning. Transmission electron microscopy (TEM) images provide visualization of dispersed and clustered nanoparticles embedding within or at the surface of nanofibers. Energy-dispersive X-ray (EDX) point analysis confirms the chemical identity of the nanocomposite structure. Brunauer-Emmett-Teller (BET) analyses show a 75-fold increase in specific surface area when 15% of silica nanoparticles were integrated into polyacrylonitrile nanofibrous mats. Mechanical strength tests show that even at high load of silica nanoparticles, e.g. 15 wt%, the mechanical integrity of the membranes was maintained. Incorporating nanoparticles into nanofibrous mats enhanced their water uptake up to two times. In osmotic transport studies, we observed an outstanding permselectivity of our membranes compared to ones reported in literature. Our membranes show a remarkable 7-fold and 3.5-fold enhancements in osmotic water permeability and water/sodium chloride selectivity, respectively, compared to standard commercial forward osmosis membranes. These results suggest a pathway to develop scalable, high performance osmotic membranes and to further study the predominant mechanism governing transport behaviors of water and solute across nanomaterials interfaces.

Reduction of Coliforms Presents in Domestic Residual Waters by Air-Ozone Micro-Nanobubbles in Carhuaz City, Peru

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Abstract

Peru generates approximately 2,217,946 m³ per day of wastewater discharged to the sewage system and only 32% receive treatment. The rest of the waters are discharged to the rivers, which have presence of fecal coliforms. Preliminary analyzes of the domestic wastewater of the Carhuaz district were carried out, with total coliforms (at 35 °C) of 240,000 NMP/100 mL and thermotolerant coliforms (at 44.5 °C) of 130,000 NMP/100 mL at pH 7, 17 exceeding the environmental standard values. The treatments were carried out with the air-ozone micro-nanobubbles generator with a water flow rate of 4.67 L/min and a pressure of the air-ozone mixture of 90 PSI, achieving a reduction of total coliforms up to 100 NMP/100 mL (99.01%) and fecal coliforms up to 100 NMP/100 mL (99.58%).

Assessment of the Optical and Solid State Properties of Manganese Sulphide (MnS) Thin Film; Theoretical Approach

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Abstract

Assessment of the optical and Solid State properties of MgS thin film using theoretical approach of beam propagation technique in which a scalar wave is propagated through the material thin film deposited on a substrate with the assumption that the dielectric medium has homogenous reference dielectric constant term, ϵ_{ref} and a perturbed dielectric term, $\Delta\epsilon_p(r)$ representing the deposited thin film medium is presented in this work. These two terms, constituted arbitrary complex dielectric function that describes dielectric perturbation imposed by the medium of for the system. This is substituted into a defined scalar wave equation in which the appropriate Green's Function was defined on it and solved using series solution technique in conjunction with Born approximation method in order to obtain a model equation of wave propagating through the thin film. This was used in computing the propagated field for different input regions of field wavelength such as ultraviolet, visible and infrared region respectively during which the influence of the dielectric constants of the thin film on the propagating field were considered. The results obtained from the computed field were used in turn to compute the band gaps, solid state and optical properties of the thin film such as reflectance, Transmittance and reflectance. The electrical and optical conductance was also computed.

Nanotechnology in Detection of Cancer Biomarkers

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Abstract

The detection of cancer biomarkers represents an important theranostic pathway for early screening of cancer. Nanotechnology plays an intriguing role in amplification of optical and electrical detection signals. This presentation will discuss recent development of nanotechnology in two areas of cancer biomarker detection. One area involves coupling magnetic and plasmonic properties of functional nanoparticles in a microfluidic platform for surface enhanced Raman scattering detection of cancer biomarkers such as carcinoembryonic antigen. The other area involves constructing nanoparticle-assembled arrays in a chemiresistive sensor for detecting volatile organic compounds from human breaths as biomarkers characteristic of cancer. The advancements in these two areas have provided some promising leads to the development of point-of-care devices for early screening of cancer.

Nanostructured Electrochemical Sensors: Direct Current vs. Alternating Current Strategies for the Detection of Molecules in Biomedical Applications

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Abstract

Electroanalytical methods are widely used in several industries, including medical devices, pharmaceuticals and food production. Electrochemical sensors are easy to use and economical in comparison with other traditional techniques. In the last two decades, the use of nanomaterials has improved the figures of merit (sensitivity, lineal range and stability) for most sensors. A representative case is the development of nickel sensors, based on the seminal work of Prof. Martin Fleischmann half a century ago. A variety of nanostructures have been evaluated, including nickel nanoparticles, nanosheets, nanowires, and their combination with carbon nanotubes and graphene, for the detection of ethanol, acetaldehyde, dopamine, serotonin, acetylcholine, formaldehyde, and other molecules of biomedical interest. Most of these sensors operate at positive potentials with respect to the nickel hydroxide electrode, with the organic compounds under analysis reducing the NiOOH being formed by oxidation of Ni(OH)₂. The anodic electrical current thus generated is found to be proportional to the concentration of the organic. This traditional direct current amperometric technique, however, presents some drawbacks, such as the need of calibrating with standards, and interference between different compounds in solution. In our group, we developed an alternating current (AC) method based on the analysis of oscillations of the anodic current. With this method, we evaluated the response of several organic compounds (ethanol, acetaldehyde, acetylcholine, glucose) and their mixtures, resolving them by deconvolution of the AC signal, also gaining better understanding of the mechanisms involved.

Electrical Properties and Sensor Applications of a Tube-in-a-Tube Nanostructure

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Abstract

Atomically-thin materials such as single-walled carbon nanotubes (SWCNT) and graphene are prone to chemical attack because all of the constituent atoms are exposed. In this talk, we will present the synthetic creation of a tube-in-a-tube (Tube²) semiconductor and their implications on biochemical sensing. A Tube² is equivalent to a pristine SWCNT nested within a chemically tailored, impermeable, and atomically-thick functional shell. Compared with SWCNTs and graphene, electrical sensors created using Tube² can be readily tailored with robust covalent chemistries to enable chemical selectivity while maintaining exceptional SWCNT-like sensitivity. Recent progress from our lab as well as some of the challenges and opportunities in this area will be discussed.

Scalable Synthesis of Next Generation Magnetic Lipid Nanoparticles

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Abstract

Lipid nanoparticles (LNP) are very promising vehicles for drug and gene delivery. The main challenge to LNP or liposomal delivery systems is designing a stable and long-circulating vector *in vivo*, which can still facilitate significant drug release at the target site. Liposomes or LNPs can lose a significant portion of their cargo in the circulation, and release at the disease site can be too slow to have an adequate therapeutic effect. MRI contrast agents such as iron oxide nanoparticles (IONP), which generate thermal energy by an external AC magnetic field, can be effectively used to induce localized hyperthermia or heat-triggered drug release when co-encapsulated with drugs in LNP. LNP-based magnetic hybrid structures could potentially make LNP efficient tracers for MRI and effective mediators for hyperthermia-activated ondemand drug release at the desired site, which will solve the lack of controlled cargo release from LNP. Thus, bio-imageable nanoparticles that can be activated and controlled through external stimuli represent the next generation multifunctional theranostics (therapeutics + diagnostics). Unfortunately, current methods of synthesizing IONP encapsulated LNPs suffer from poor size control, lack of reproducibility and poor scale-up potential. We have developed a reproducible and scalable formulation technology to design well defined and

size controllable (from 30 nm to 150 nm) magnetic nanohybrid systems that consist of either hydrophobic or hydrophilic IONP encapsulated in various lipid components. We herein present their synthesis and biophysical characterization, as well as their application as *in vivo* MRI contrast agent and triggered drug delivery systems.

Pharmacological and Toxicological Studies of Azathioprine Loaded Chitosan Based Nanoparticles

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Abstract

The Azathioprine loaded chitosan nanoparticle was synthesized, characterized, evaluated for pharmacokinetic parameters, acute oral toxicity study and for the repeated dose 28-day oral toxicity in rats. The drug free CS nanoparticles were in size distribution range of 39.4 to 59.4 nm in diameter, drug loaded CS nanoparticles was in the range of 700 to 806 nm. The zeta potential of the chitosan nanoparticles was 42.7 mV, while zeta potential of the azathioprine loaded chitosan nanoparticles was 50.6 mV. The drug loading capacity of azathioprine loaded chitosan nanoparticles was 32.2%. The relative bioavailability of azathioprine loaded chitosan nanoparticle was 113.74%. In acute toxicity study, there were deaths and clinical signs in the tested groups. Hence LD₅₀ cut off value for azathioprine and azathioprine encapsulated chitosan nanoparticles rats were 500 and 1000 mg/kg, respectively. In repeated dose 28-day oral toxicity, the doses administered orally were control, 300 mg/kg of azathioprine, 200, 350 and 600 mg/kg of azathioprine encapsulated chitosan nanoparticles for a period of 28 days. Biochemical parameters such as AST, ALT, BUN and creatinine showed significant changes in azathioprine and high dose nanoparticle group. Haematological parameters such as TEC, TLC, PCV and Hb concentration showed significant changes in azathioprine and high dose nanoparticle group. Significant decrease ($P < 0.05$) in feed consumption and body weight gain. There were no gross changes but histopathology showed changes in liver. This indicates that azathioprine encapsulated chitosan nanoparticles showed slight improvement in bioavailability and toxic at high dose.

Bio-toxic Effects of Widely Applied Metal Oxide Nanoparticles and their Underlying Mechanisms

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Abstract

Nanomaterials have attracted considerable interest owing to their unique physicochemical properties. The wide application of nanomaterials has raised many concerns about their potential risks to human health and the environment. Metal oxide nanoparticles (MONPs), one of the main members of nanomaterials, have been applied in various fields, such as food, medicine, cosmetics, and sensors. Our work focus on the bio-toxic effects of widely applied MONPs (titanium oxide (TiO₂) NPs, zinc oxide (ZnO) NPs, and iron oxide (IO) NPs) and their underlying mechanisms. Two main underlying toxicity mechanisms, reactive oxygen species (ROS)- and non-ROS-mediated toxicities, of MONPs have been widely accepted. ROS activates oxidative stress, which leads to lipid peroxidation and cell membrane damage. Non-ROS-mediated toxicity mechanism includes the effect of released ions, excessive accumulation of NPs on the cell surface, and combination of NPs with specific death receptors. Furthermore, we studied the combined toxicity of MONPs in the complex system. We find that the toxicity of some MONPs dramatically changed when they are used in a combined system because the characteristics of NPs that play a key role in their toxicity such as size, surface properties, and chemical nature in the complex system are different from the pristine NPs. Hence, we should pay more attention to the effect of combined toxicity. Our work aims at improving the performance of MONP application in various fields and reducing their potential hazard.

Nanocarbon-bio Hybrid Materials: Chemistry and Applications

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Abstract

Controlled assembly of biopolymers, minerals, and carbon nanostructures, specifically graphene, carbon nanotube (CNT), and their chemical derivatives, can lead to nanocarbon-bio hybrids that not only impart specific bio-functionalities but also possess extraordinary physical and chemical properties. CNT and graphene are among the most frequently investigated nanomaterials in the past decade, and yet both continue to offer exciting opportunities for the discovery of new science and applications. In this talk, I will present our recent progress in the creation of advanced materials and devices through hierarchical organization of

nanocarbon-bio hybrids. Examples include CNT and graphene oxide nano-porous membranes, sp²-C incorporated 3D tissue scaffolds, and various C/inorganic hybrid architectures. Our main interests are to develop new material and surface chemistries for material synthesis, to pursue fundamental studies on interface dictated phenomena, and to explore potential applications, especially in biosensing and tissue engineering.

Novel Methods (Microwave and Sonochemistry) for Converting Biomass to Biofuels

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Abstract

I will report on the full conversion (~100%) of oils to biodiesel. This was accomplished by the transesterification of pristine (soybean) oil and restaurants cooked vegetable oil to biodiesel, based on microwave dielectric irradiation as a driving force for the transesterification reaction, and SrO as a solid basic catalyst. This combination has demonstrated excellent catalytic activity and stability. According to ¹H NMR spectroscopy and TLC, this new combination accelerates the reaction, so that the reaction was completed in 10 seconds when stirred, and 40 seconds when unstirred, maintaining a very high conversion (99%) and high efficiency. The catalyst was reused for 10 times and showed the same catalytic power.

We will also demonstrate the direct conversion of as-harvested *Nannochloropsis* algae into biodiesel without separating the lipidic phase using the SrO and microwave radiation. Full conversion to biodiesel was achieved in 5 minutes.

Fermentation of glucose was carried out using *Saccharomyces cerevisiae* under continuous mild ultrasonication conditions. The kinetics of the fermentation reaction was monitored by ¹³C NMR and weight loss measurements of the fermentation broth. The reaction rate constant was enhanced by 2.5 at 20. compared to stirred control experiments, and 10 times faster than the non-stirred fermentation. The acceleration in the fermentation of glucose is observed both at 20 and 40% concentrations of glucose.

Ulva Rigida, a microalgae were converted to bioethanol in a one-step SSF process.

A novel instrument for the solar-aided conversion of glucose and biomass solutions to bioethanol in a flow system will be introduced.

Electrochemically Exfoliated Graphene Materials: Scalable Synthesis and High Performances

Junzhong Wang*, Junying Wang and Congwei Wang

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Abstract

Hummers' and CVD methods are popular to prepare graphene with different properties for different fields. Here, I would like to introduce another promising approach of electrochemical exfoliation of graphite into graphene. Tunable sizes, layers, defects, pores and hybridization of graphene can be also realized. Graphene and its composites exhibit excellent properties in thermal management, energy storage, catalysis, photodetector and biosensor. The large literal sheets of 1-2 layer graphene flakes can be used to fabricate robust, flexible and free-standing graphene films with excellent properties of high thermal diffusivity and high supercapacity. Small graphene microsheets directly synthesized from natural microcrystalline graphite minerals exhibit good dispersion and reversible specific capacity as an anode material for a Li-ion battery. The electrochemically exfoliated graphene flakes can survive strong basic conditions at high temperature and stimulate cellulose activation to synthesize hierarchical porous graphene-carbon framework. These new porous graphene-carbon materials can reach high supercapacities of > 300 F/g in aqueous solution and of 200 F/g (3.5V) in ionic liquid and high energy density of > 60 Wh/kg at high discharge rate of 6 A/g. In addition, the carbon material can be further filled with sulfur and applied to lithium sulfur batteries with high performance of ~800 mAh/g reversible specific capacity and 1000-cycle stability. Isolated iron atoms onto porous graphene flakes show robust superior oxygen reduction electrocatalytic activity. Graphene/zeolite nanohybrids exhibit superior acidic catalytic activity for some bulky molecules. Our study demonstrates electrochemical approach for graphene materials is scalable and valuable.

All Carbon Nanotubes and Carbon Nanotube - Si Hybrid Solar Cells

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Abstract

This presentation describes our recent results in the field of carbon nanotube (CNT) based photovoltaics (PV) focusing on advantages of semiconducting carbon nanotubes over other organic materials used in organic and organic-inorganic composite photosensing materials. Special attention paid to all carbon nanotube solar cells statistically created in the contact area between two macroscopic films of single-walled CNTs at the junction of semiconducting and quasi-metallic bundles consisting of several tubes. Another aspect is related to CNT-Silicon heterojunction formed at the interface between CNTs and crystalline and amorphous Si. Possible mechanisms of charge photogeneration at CNT-Si interface and charge transport are discussed.

Perspectives and future trends in research of this novel class of PV nanohybrids are presented as well.

Variation of the Raman Scattering Spectra of Monolayer Graphene Samples Subjected to Irradiation by Heavy and Light Ions, Ageing and Annealing

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Abstract

Modification of graphene is essential for its electronic application. Ion irradiation is used for this aim due to ability to control the ion energy and irradiation dose with high accuracy. Irradiation of pristine graphene results in increase of disorder due to introduced structural defects. Usually, measurements of the Raman scattering spectra (RS) are considered as an effective tool for probing the structure of disordered graphene and density of introduced defects. In this work, RS spectra were measured in two series of monolayer graphene samples on SiO₂/Si substrate and irradiated by different doses Φ of heavy (Xe⁺) and light (C⁺) ions. It is shown that dependences of the main RS line on Φ are merged when plotted as a function of the density of defects ND = k Φ , introduced by irradiation. At ND = 5x10¹³ cm⁻², RS lines disappear because the mean distance between defects LD = (ND)^{-1/2} \approx 1.5 nm becomes smaller than the Raman relaxation length. The main results of the long-term ageing are explained by an increase of the radius of the "activated" area around structural defects. The irradiated samples were annealed at different temperatures up to 1000 °C in high vacuum and in forming gas atmosphere. It is shown that two methods of annealing have different influence on the amplitude and peak position (blue shift) of all RS lines. The blue shift is caused by unintentional doping and the lattice strain due to mismatch of the thermal expansion coefficient of graphene and the SiO₂ substrate.

Hybrid Nanomaterials for Electrodes of Supercapacitors

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Abstract

Composites based on graphene, carbon nanotubes, conjugated polymers and ionic liquids can be used to improve electrochemical properties of supercapacitors. The devices resulting from these nanomaterials exhibit greater electrochemical performance, such as high specific capacitance, better cycling stability, power, and energy densities [1]. For this contribution we propose to discuss two devices made from different materials: i) electrodes made of hybrid films of conjugated polymers and carbon nanomaterials [2]; and ii) electrodes made of nanotube/graphene composites and electrolytes based on ionic liquids [3]. We investigated the hybrid structure of carbon nanomaterials through Raman and XPS spectroscopies, thermogravimetry and electrochemical methods. The 2D and 3D morphology of electrodes and supercapacitors of different compositions was characterized through scanning electron microscopy. Furthermore, cyclic voltammetry, galvanostatic charge/discharge and electrochemical impedance spectroscopy were used to study the performance of the materials and devices. Electrodes based on hybrid composites with tailored morphologies lead to capacitance increases two to three times higher than one component electrodes. The enhanced performance can be traced back to the hybrid materials' electrochemical properties, porosity and wettability by the electrolyte.

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From Shearable Carbon Nanotube Films to Torsionable Supercapacitors

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Abstract

To bestow intelligent functions upon clothing textiles, wearable electronics must be able to accommodate complex deformations. Both stretchable and bendable building blocks have previously been demonstrated, but torsionable components are still missing. Here we report a shearable carbon nanotube film, which is capable of withstanding torsion levels up to 20000 rad/m with little resistance change. As a result, fiber-shaped supercapacitors fabricated from such film electrodes show highly stable performance during torsional deformation, with a small capacitance variation around its average value ($< \pm 2\%$) even under severe twisting. Such torsionable energy devices will advance the true independent operation of interactive textiles.

Micro-magnetic Properties of Nano-magnetites by Using Magnetic Force Microscopy

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Abstract

The microscopic magnetic properties of granular, rod, and tubular nano-magnetites were studied. All crystal types showed a cubic structure via X-ray diffraction method (XRD). Based on X-ray photoelectron spectroscopy (XPS), both the Fe(II) and Fe(III) species were clearly observed in the nano-magnetites. The crystals of the nanoparticles were granular, and the particle sizes were in the range of 45–85 nm. The nanorods were acicular; the widths and lengths of their crystals were in the ranges of 50–100 nm and 250–350 nm, respectively. The nanotubes were tube shaped; their crystals had inner and outer radii in the ranges of 40–85 nm and 80–110 nm, respectively, and lengths in the range of 150–300 nm. A magnetic force microscope (MFM) was used to observe the microscopic magnetic structures; the nanoparticle belonged to pseudo-single domain, and the others were magnetic in multiple domains, but the form and distribution of these domains were different. This indicated that the crystal morphology had a significant effect on magnetic properties of these nano-magnetites owing to their different magnetic-domain structures. MFM can be used to detect minute magnetic-properties and it is a tool with potential development in magnetic structures.

Phenomena of Interfacial Spontaneous Chemical Reactions – The Way to Improve the Diamond Tools Performance

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Abstract

Diamond tools with metal binders are widely used to machine the most difficult-to-work with materials, such as reinforced concrete, stone and ceramics. The working layer of the tool contains diamond grains embedded in a metal matrix (binder). The role of the matrix is to retain the diamond grains until they are completely worn out. The retention strength depends on the strengths of the matrix and its interface with diamond, which is influenced by chemical interactions between them. Ni, Co, and Fe are usually added to the binder to increase its mechanical properties. However, these metals have a negative effect, as they catalyze the diamond-graphite transition. As a result, a low-strength graphite layer is formed on the diamond surface, which causes diamonds to prematurely chip off the matrix.

Influence of functional nanosized additives on the graphitization mechanism of diamonds in metal-matrix composites was studied. It was shown that Mo and ZrO₂ additives intensified graphitization, while the addition of WC suppressed the graphitization by 25–30%. Moreover, the phenomena of spontaneous reactions of WC-based interfacial layer formation on diamond surface during the sintering in presence of WC(O) nanoparticles was observed. Interfacial layer was found to form via gas-phase transport mechanism resulted in chemisorption of volatile WO₃ onto diamond surface followed by WO₃ reduction and WC formation. The simultaneous enhancement of mechanical properties of the binder and formation of a protective WC-based layer on diamond crystals facilitate a synergistic effect, which results in increased productivity and cutting speed of diamond tools.

Engineering DNA Nanodynamics to Measure Sub-picoNewton Forces

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Abstract

The ability to self-assemble nanodevices with programmed structural dynamics could enable transformative applications in fields including molecular robotics, nanomanufacturing and nanomedicine. While DNA nanotechnology has enabled engineering of nanostructures with unprecedented geometric complexity with specific chemical functionalities, current design paradigms have focused on the development of static or more recently reconfigurable structures driven by external inputs. However, many natural biomolecular functions including the regulation of DNA accessibility within chromatin, kinetic proof reading, and G protein signal transduction rely on thermally driven conformational changes that occur when energy barriers are comparable to thermal energy, $k_B T = 4.1$ pN·nm. Here, we mimic these natural systems by programing inherent nanoscale structural dynamics (nanodynamics) into a DNA device and establish entropic design principles to control its equilibrium and kinetic properties. We use single molecule Forster Resonance Energy Transfer (smFRET) measurements to show these nanodynamics properties are sensitive to femtonewton scale forces and can be tuned to control device measurement range and sensitivity. We anticipate that this new class of nanodynamic DNA devices will enable molecular-scale systems that sense and respond to their local environment with extremely high sensitivity.

Multifunctional Multicomponent Nanowires for Energy Conversion and Storage

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Abstract

Composites of functional materials have long been synthesized for achieving enhanced physical and chemical properties. Composite properties are achieved through many methods such as physical mixing of its components, chemical methods such as core/shell, hierarchical structures, nanoparticle-decorated nanowires, carbon structured reinforced porous materials and so on. In this era of energy intensive electronics and automobiles, and simultaneously having alarm from global atmospheric changes, generating electrical energy from renewable sources and storing them for further use are of extreme importance.

One-dimensional nanostructures such as nanowires, nanorods, and nanobelts offer many advantages in energy conversion and storage devices such as channeled electron transport, anisotropic charge assembly, improved surface to volume ratio and so on. Many materials have screened in the past for high performance in energy conversion and storage devices; however, achievements in one of the properties has always been at the expense of another. If the composite materials are synthesized as one-dimensional materials, many properties could be assembled in a single material architecture. We have synthesized materials of unique advantages in a single nanowire or nanobelts and evaluated their usefulness in energy conversion and storage devices. Many bottlenecks in energy conversion and storage devices have been overcome using this protocol, the lecture would detail these developments.

Topological Materials

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Abstract

Topological materials host various novel quantum phases of electrons which are characterized by band topology and topologically protected surface/edge states. Despite recent progress, intense world-wide research activity in search of new classes of topological materials is continuing unabated. This interest is driven by the need for materials with greater structural flexibility and tunability to enable viable applications in spintronics and quantum computing. We have used first principles band theory computations to successfully predict many new classes of 3D topologically interesting materials, including Bi_2Se_3 series,

the ternary half-Heusler compounds, TlBiSe_2 family, Li_2AgSb -class, and GeBi_2Te_4 family as well as topological crystalline insulator (TCI) SnTe family and Weyl semimetals TaAs , SrSi_2 , $(\text{Mo,W})\text{Te}_2$, Ta_3S_2 , and LaAlGe family. I will also highlight our recent work on 2D topological materials. These include Bi/Sb honeycombs for TCI, gated silicene for spintronics applications, and hydrogenated III-V thin films as robust topological insulators with large band gaps. Support by the Singapore National Research Foundation under NRF Award No. NRF-NRFF2013-03 is acknowledged.

Citation: Proceedings of the 2nd NanoWorld Conference in Boston (NWC-2017). Part III: Featured Presentations. *NanoWorld J* 3(Suppl 1): S13-S48.

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Received: June 13, 2017 Accepted: July 06, 2017 Published: July 10, 2017