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Meeting Abstracts

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Proceedings of the First NanoWorld Conference in Boston (NWC-2016). Part III: Featured Presentations

Featured Presentations

Engineered Metallic Nanoparticles: Pro-inflammatory Response and Effects on Integrity of Blood-Brain-Barrier

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Abstract

The purpose of the current studies was to determine what role the microvessel endothelial cells in brain inflammation and neurotoxicity associated with colloidal metallic nanoparticles (NPs). A primary culture of rat brain microvessel endothelial cells (rMVEC) was isolated by enzymatic digestions and differential centrifugation for an *in vitro* model of the BBB. Confluent rMVEC monolayers were treated with various sized Ag, Au or Cu NPs. The cellular accumulation of the NPs was determined spectrophotometrically at various time intervals. The cytotoxicity was evaluated by XTT in rMVEC following 24-hours of NPs exposure. The extracellular concentrations of pro-inflammatory mediators were evaluated by ELISA at various time intervals (0, 2, 4, 6 and 8 hours) following exposure to various sized Ag, Au or Cu NPs. The magnitude of cellular accumulation was size dependent and similar for all NPs over the experimental period. The cytotoxicity of rMVEC following 24-hours of exposure to Ag-NPs and 10 ug/ml (40 and 80 nm) was significantly increased, when compared to Au-NPs whereas Cu-NPs LD50 was approximately 12.5 ug/ml for both sized. Au-NPs above 3 nm in size showed no significant cytotoxic effects. PGE2 release following Ag and Cu NPs exposure was significantly increased when compared to control at the end of the 8-hour experiment. The basal levels of TNF and IL-1B were significantly increased following Ag or Cu NPs, but not with Au-NPs. These data suggest that the brain microvessel endothelial cells may play a significant role in the neurotoxicity associated with Ag, Au or Cu NPs.

A Direct and at Nanometer Scale Study of Electrical Charge Distribution on Membranes of Alive Cells

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Abstract

The presentation is on a new and innovative method to study *in vivo* and at nanometer scale the electrical charge distribution on membranes of alive cells. It relies on a new atomic force microscopy (AFM) mode based on an electro-mechanical coupling effect. It will be illustrated by the study of the cell wall of Gram+ *Rhodococcus wratislaviensis* bacteria, naturally adherent to a glass substrate, under physiological conditions. In addition to classical height and mechanical (as stiffness) data, mapping of local electrical properties, such as bacterial surface charge, was proved to be feasible at a spatial resolution better than a few tens of nanometers. Electrical surface charge was measured and is fully compatible with results from standard macroscopic electrophoretic mobility measurements. Furthermore, an additional electrical signal detected by both the deflection of the AFM cantilever and simultaneous direct current measurements was detected at low scanning rates. It was tentatively attributed to the detection of the current stemming from ionic channels the opening of which might be triggered by local mechanical overpressure generated by AFM contact.

This new method offers an important improvement in local electrical and electrochemical measurements at the solid/liquid interface. It thus opens a new way to directly investigate *in situ* biological electrical surface processes involved in numerous practical applications and fundamental problems such as bacterial adhesion, biofilm formation, microbial fuel cells, etc.

Nanoengineering Stretchable Bio-gel Electronics and Devices

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Abstract

While human tissues are mostly soft, wet and bioactive; machines are commonly hard, dry and biologically inert. Bridging human-machine interfaces is of imminent importance in addressing grand challenges in health, security, sustainability and joy of living faced by our society in the 21st century. However, designing human-machine interfaces is extremely challenging, due to the fundamentally contradictory properties of human and machine. At MIT SAMs Lab, we propose to use tough bioactive hydrogels to bridge human-machine interfaces. On one side, bioactive hydrogels with similar physiological properties as tissues can naturally integrate with human body, playing functions such as scaffolds, catheters, drug reservoirs, and wearable devices. On the other side, the hydrogels embedded with electronic and mechanical components can control and response to external devices and signals. In the talk, I will present a general framework to design bioactive and robust hydrogels as the matrices for human-machine interfaces. I will first discuss the fundamental principles to design tough hydrogels and tough bonding between hydrogels and diverse engineering solids including metals, glass, silicon, ceramics and polymers. I will then discuss large-scale manufacturing strategies to fabricate robust and bioactive hydrogels and their microstructures, including synthetic biology and 3D printing.

In vitro Toxicity of Carbon Nanotubes, Nano-Graphite and Carbon Black: Similar Impacts of Acid Functionalization

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Abstract

We focused on carbon-based nanomaterials with three nanometric dimensions: carbon black (CB), two nanometric dimensions: carbon nanotubes (CNT), and one nanometric dimension: nano-graphite (NG). CNT and NG have demonstrated exciting physicochemical properties promising numerous industrial applications, but whose health impacts are still not understood. It has been shown that CNT and NG have the potential to trigger inflammation, cytotoxicity and oxidative stress. CB is a conventional and widely studied material, used as a pigment or reinforcing phase in tires. CB is either used in toxicity studies as a negative control or a positive control.

The comparison of these three carbon-based nanomaterials is thus of great interest to improve our understanding of their toxicity. An acid functionalization was carried out on CNT, NG and CB so that, after a thorough characterization, their impacts on RAW 264.7 macrophages could be compared for a similar surface chemistry (15 to 120 μg.mL^{-1}, 90 min to 24 h contact). Functionalized nanomaterials triggered a weak cytotoxicity similar to the pristine nanomaterials. Acid functionalization increased the pro-inflammatory response except for CB which did not trigger any TNF-α production before or after functionalization, and seemed to strongly decrease the oxidative stress. The toxicological impact of acid functionalization appeared thus to follow a similar trend whatever the carbon-based nanomaterial. At equivalent dose expressed in surface and equivalent surface chemistry, the toxicological responses from murine macrophages to NG were higher than for CNT and CB. It seemed to correspond to the hypothesis of a platelet and fiber paradigm.

One-Pot Preparation of Graphene Nanomesh and Graphene Quantum Dots in Chitosan Solution with Ultrasonication

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Abstract

We report a facile method to prepare graphene nanomesh (GNM) and graphene quantum dots (GQDs) in one-pot by ultrasonicating graphite dispersions in chitosan (CTS) solution. This method includes exfoliation of graphite by the movement of CTS segments in ultrasonic bath, perforation on graphene sheets by ultrasonication, separation of GNM with centrifuge and dialysis to get GQDs. The lateral size of GNM can be as large as 30 µm, and the diameters of nanopores in GNM can be readily modulated from several to hundreds of nanometers by varying the ultrasonication time. The prepared GNM substrate exhibited efficient gene delivery in a substrate-mediated manner. The as-prepared GQDs with a particle size in the range of 3-7 nm showed a great potential as biological labels for cellular imaging.

Investigation of the Three-Dimensional Structural Dynamics and Fluctuations of DNA-Nanogold Conjugates by Individual-Particle Electron Tomography

Gang Ren

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Abstract

DNA base-pairing has been used for many years to direct the arrangement of inorganic nanocrystals into small groupings and arrays with tailored optical and electrical properties. The control of DNA-mediated assembly depends crucially on a better understanding of the three-dimensional (3D) structure of the DNA-nanocrystal hybridized building blocks. Existing techniques do not allow for the structural determination of these flexible and heterogeneous samples. Here, we employed cryo-electron microscopy (cryo-EM) and negative-staining (NS) techniques to investigate the morphology of DNA-nanogold conjugates that were self-assembled from a mixture of an 84-base-pair double-stranded DNA (dsDNA) conjugated with two 5 nm nanogold particles for potential substrates in plasmon coupling experiments. Using NS electron tomography and the individual-particle electron tomography (IPET) reconstruction method, we obtained 3D reconstructed 14 electron density maps at a resolution of ~2 nm from each individual dsDNA-nanogold particle. Using these 3D density maps as constraints, we derived 14 conformations of dsDNA by projected a standard flexible dsDNA model onto the observed EM density maps using Molecular Dynamics (MD) simulations. The variation of the conformations was largely consistent with the variation from liquid solution. Moreover, the IPET approach provides the most complete experimental determination of the flexibility and fluctuation range of these directed nanocrystal assemblies to date. The general features revealed by these experiments can be expected to occur in a broad range of DNA-assembled nanostructures.

Manipulation of Single Proteins with a Nanopore Electrophoretic Trap

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Abstract

The non-covalent manipulation of single molecules has many potential applications in nanotechnology. Current approaches, such as optical tweezers and ABEL traps are able to precisely trap nanoparticles or fluorescent proteins with dimensions down to ~15 nm (~100 kDa). We show that wide range of native proteins can be controllably and reversibly trapped inside the lumen of Cytolysin A (ClyA), a nanopore with an internal constriction of 3.3 nm. Proteins are focused at a potential minimum created by the drop of the electrophoretic field inside the nanopore. The introduction of opposite charged residues at precise positions within the protein allows the precise tuning of the residence of proteins as small as ~3 nm (19 kDa), that is smaller than the constriction of ClyA. Furthermore, the binding of analytes to the nanoconfined proteins is reflected by changes in the nanopore conductance. Remarkably, the binding constant of the protein inside the nanopore are identical to bulk values, indicating that nanoconfinement has negligible effects on the folding and activity of proteins. The controlled electrophoretic trapping of single proteins inside a nanopore can be employed for the manipulating proteins with atomic precision, and will have further applications in real-time single-molecule enzymology or analytes detection.

Three-Dimensional Microstructures of Biodegradable Polymers for Controlled Drug Delivery

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Abstract

The ability to create three-dimensional (3D) biomaterial structures with high resolution and aspect-ratio enables significant biomedical applications. Numerous methods including 3D printing technologies have been developed to fabricate microdevices and particles with well-defined 3D structure. However, these techniques are limited in terms of shape, aspect ratio, scalability, and either require potentially toxic additives or lack the fine resolution demanded for some applications. Here I present a novel method-termed StampEd Assembly of polymer Layers (SEAL)-which can create versatile 3D microstructures of pure biodegradable polymers such as poly-lactic-glycolid acid (PLGA), and use this method to create a robust drug delivery platform with unique release kinetics. SEAL combines computer-chip manufacturing technologies, micromolding, and a layer-by-layer assembly process to fabricate 3D microstructures of biomedically relevant materials without processing additives. We employed SEAL to create PLGA/drug core-shell microparticles for controlled drug delivery applications. These SEAL-fabricated particles exhibited delayed, pulsatile release for up to 2 months, which is particularly exciting to the development of single-injection vaccines. We also demonstrate the use of SEAL for creating particles using an enteric polymer that exhibits pH-dependent release following oral administration for selective colon targeting. Finally, we show that the SEAL method is compatible with sensitive biomacromolecules such as the highly instable inactivated polio vaccine (IPV). As such, SEAL is a powerful method that can supplement 3D printing when high resolution, high-throughput, and biocompatibility are required for proper device function. We anticipate many applications from this platform technology such as the creation of 3D tissue synthetic scaffolds with well-defined microstructure and injectable drug delivery devices with unique targeting or release kinetics based on complex 3D architecture and/or material composition.

Biomimetic Nanomaterials for Drug Delivery and Tissue Engineering

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Abstract

Progress in cancer treatment has been limited by the absence of effective approaches to achieve selective delivery of drugs to the tumor while sparing other tissues. This disconnect is rooted in the inefficient delivery of therapeutic agents to the tumor upon systemic delivery. We engineered nanoparticles that can modulate the function of biological barriers to our advantage by interacting with target tissues and cells through physical and molecular codes, able to regulate cellular pathways and physiologic mechanisms. Our approach for the generation of biomimetic materials for drug delivery has addressed many aspects of particle synthesis and modification (coating and assembly), escape from the lysosomal pathways (intracellular and intercellular trafficking mechanisms, avoidance of RES uptake (reduced opsonization and phagocytosis) and increased endothelial penetration (mimicking of leukocyte function).

Similarly, biomimetic materials hold the promise of improving the outcome of many chronic conditions through advances in tissue engineering. With the advent of nanodelivery platforms and nanostructured scaffolds, the regenerative potential of stem and immune cells can be now harnessed to its full extent. We developed a set of implantable and injectable biomaterials with high regenerative potential and characterized them for their ability to tune the immune response and direct cell differentiation. I will give an overview of our experience in the design of biomimetic scaffolds for musculoskeletal regeneration comparing synthetic vs natural polymers, and assessing the effect of mechanical, chemical and biological properties on the enhancement of stem cell function.

Microengineered Protein-based Hydrogels for Tissue Engineering and Surgical Applications

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Abstract

Tissue engineering is an interdisciplinary field, aimed at maintaining, restoring and enhancing normal tissue and organ functions by using living cells and merging of engineering, biological sciences and medicine. One of the central themes in the field of tissue engineering is to develop tissue constructs, which mimic the native 3D tissue architectures. To date, tissue engineering has been successfully applied to engineer many types of tissues including bone, cartilage, and vasculature systems. Despite the significant progress in this field, many challenges still remain on the way to develop fully functional tissue constructs. Micro- and nanoscale technologies have been shown to be powerful techniques in addressing the current challenges in tissue engineering. These technologies have benefited the fields of experimental biology and medicine immensely through the design of complex biomaterials that can be used for cell-based studies. Our research has been involved in merging micro/nanofabrication techniques with advanced protein-based biomaterials for tissue engineering applications. We produce proteins with unique

physical properties by using recombinant technology and use them as 3D elastic scaffolds for soft tissue regeneration. We also modify these proteins to increase their adhesion to various tissues and use them as sealants and gules for surgical applications. Our work encompasses a wide range of scientific subjects from materials science to biology. In this presentation, I will outline our work in the development of microscale protein-based hydrogels to modulate cell-microenvironment interactions for tissue engineering applications. I will also highlight some of the clinical applications of our engineered biomaterials as tissue adhesive and surgical sealants.

Single Molecule Protein Sequence Analysis Using Sub-nm Pores

Eamonn Kennedy*, Zhuxin Dong and Gregory Timp

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Abstract

The primary amino-acid (AA) structure of a single protein molecule can be detected using a picopore sputtered through a thin inorganic membrane immersed in electrolyte under an applied electric field. Modulations in the open pore noise characteristic are observed as the protein blockades the electrolytic flow through a sufficiently small pore, which coincide with the number of residues in the protein. The amplitude curve observed duration translocation correlates closely to a model of the volume occluded by 4 AAs in the waist of the picopore. This observation is consistent for 4 different proteins analyzed on the same pore, permitting accurate identification of each protein species from < 10 molecules. Specific details of all necessary experimental protocols along with the benefits and current limitations of the methodology will be discussed in respect of current standards for (DNA) nanopore sequencing. We anticipate that the ability to determine the primary structure of AAs could enable ultra-high efficiency protein sequencing of sub-pM concentration analyses.

Biomimetic Vesicles Derived from Immune Cells: A Proteomic Standpoint

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Abstract

Over the past few decades, bio-inspired nanoparticles have revolutionized the field of nanomedicine by simultaneously evading immune surveillance and negotiating transport across biological barriers. Circulating immune cells provide a valuable basis from which to build injectable carriers. Leukocytes freely circulate in the bloodstream and, thanks to their interaction with inflamed vasculature, accumulate selectively in diseased tissue. We reason that leukocyte membranes can be manipulated and exploited, as a proteolipid material, to formulate a new generation of biomimetic vesicles. Our approach leverages versatile assembly methods used for liposomes (our control) to synthesize stable, highly standardized product. Moreover, it allows us to transfer the plasma membrane's functional properties to synthetic vesicles. These were extensively characterized to elucidate their physical properties using DLS, cryoTEM, AFM, FT-IR, and DSC. In addition, proteomic and flow-cytometry studies were performed to characterize protein composition, status, and orientation on the carrier's surface. Proteomic analysis showed that we transferred over 180 leukocyte membrane-associated proteins to the particle's surface, conserving their orientation, post-transcriptional modifications, functions, and cooperation with other proteins. The protein corona adsorbed on the biomimetic vesicles following incubation in plasma was also evaluated and compared to the one adsorbed on liposomes. Our results revealed that the presence of leukocyte plasma membrane proteins in the vesicle's bilayer strongly affected the number, amount, and type of plasma protein adsorbed, enabling the biomimetic vesicles' altered biological behaviour compared to controls. To the best of our knowledge, this approach represents (i) the first time a complex material, like the plasma membrane proteins, has been incorporated into a lipid vesicle using an established method and (ii) the first time a bioinspired nanoparticle's protein corona has been investigated.

Nanomaterials and Functional Devices for Clean Energy and Smart Sensors

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Abstract

The ability to harness the unique electrical, optical, magnetic, and catalytic properties of materials at the nanoscale dimension is essential for explorations of a wide range of technological applications. This presentation will discuss some of

our recent findings in investigating new strategies in constructing nanoparticles and assemblies for clean energy and smart sensor applications. Selected examples will be discussed, highlighting the importance of nanostructural tuning. One example involves alloying noble metals with non-noble metals in the form of nanoalloys to design low-cost, active and robust catalysts for electrochemical energy production, conversion and storage. Fundamental understanding of how the atomic-scale structures of nanoalloys can be controlled precisely is a key to achieving the catalytic or electrocatalytic properties by design. Another example involves assembling nanoparticles with molecules or biomolecules into discrete ensembles or continuous thin films to create multifunctional properties for chemical sensing or medical diagnostics. Strategies of effective harnessing of the magnetic, electrical, and spectroscopic properties relevant to fuel cell technology and wearable electronics will also be discussed.

Laser Induced Improvement of Photovoltaic Efficiency for Ternary and Quarterly Chalcogenide Nanocrystallites

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Abstract

It was demonstrated a principal possibility of substantial enhancement of photovoltaic susceptibilities of photovoltaic based on ternary and quarterly chalcogenide nanocrystlalites. Among them: $CuInTeSe_2$ and $CuInGeSe_2$, $CuInS_2$ and $CuInSe_2$ and their derivatives. Different methods of their synthesis are presented. The photovoltaic efficiency was improved by appropriate illumination by different kind of laser irradiation. We have used both by single laser pulses as well as combination of different coherent laser pulses. The effect is defined both by the energy gap operation as well as due to changes of carrier mobility through changes of carrier mobility. The role of nanocrystallite sizes, their aggregation, size dispersion is analyzed in details. DFT simulations of the band structure give an answer concerning the principal mechanisms defining the effect. The role of the trapping levels, phonons as well as uncontrolled impurities is discussed. The optimization of the principal laser parameters is done. Among them the laser beam profile, light stability, convergence of the light and its power density are discussed. Particular interest is devoted to role of the photo-thermal effects and light scattering as well as to the multi-photon and nonlinear optical processes. The principal direction of the further laser treatment for the such kind of materials is discussed. The discussion about the possible elimination of the optical losses is presented.

Photoelectrochemical Water Splitting and CO_2 Reduction in Chemically Derivatized Oxide Nanoparticle Films

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Abstract

In Artificial Photosynthesis the goal is solar energy conversion by water splitting into oxygen and hydrogen or reduction of carbon dioxide to carbon-based fuels. In one approach the high band gap properties of mesoscopic nanoparticle semiconductor films of n-type (TiO_2, SnO_2) or p-type (NiO) oxides are combined with light absorption and catalysis by surface-bound molecular assemblies in the dye sensitized photoelectrosynthesis cell (DSPEC). Important advances have been made in electrode architecture in this area by using core/shell structures with thin shells of TiO_2 deposited by atomic layer deposition (ALD) on cores of SnO_2 or a transparent conducting oxide resulting in greatly enhanced efficiencies. The binding of phosphonate-derivatized chromophores, catalysts, and chromophore-catalyst assemblies to oxide surfaces is stabilized by depositing over layers of Al_2O_3 or TiO_2 or organic polymer films. In exploiting the DSPEC concept, metal complex, organic, and porphyrin light absorbers have been used in conjunction with molecular catalysts for water oxidation or CO_2 reduction. Quantitative performance is assessed by a combination of photocurrent, transient absorption, and H_2 and O_2 efficiency measurements.

Graphene Photonics: Multiphysics Modeling in Time-Domain

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Abstract

Optimal design of graphene-based high-speed photonic devices is impossible without comprehensive understanding of the carrier dynamics in graphene. The transient evolution of carriers in graphene under ultrafast excitation has been recently studied theoretically and experimentally. Thus far, no computational apparatus for modeling the transient response of graphene elements has been developed. Popular approximations for the graphene surface conductivity including the Kubo formula do not allow for any immediate way to modeling the transient response of the interband part. Although using the surface conductivity of graphene with classical transient modeling is perhaps another approximation; still this approach could be utilized as a first step to understand the experimental data. A technique that we have successfully probed to solve this problem is based on intrinsically causal Padé approximants; it provides robust, broadband, multiphysics simulations in time-domain with material models that simultaneously handle scattering rates, temperature, and chemical potential. Our most recent approach is built on the direct transformation of the Kubo formula into time-domain. Two remarkable results immediately follow; in time-domain, a multivariate model (as a series of physically meaningful oscillators) is achieved, in frequency-domain, the Kubo formula is expressed in an alternative closed form (as two digamma functions) and hence loses its computational complexity. In summary, by comparing both methods we outline how our computational techniques could offer keys to modeling the transient optical responses in graphene photonics.

Nanotechnology: Risks, Benefits and Governance

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Abstract

Recent developments in the design of advanced nanomaterials have resulted in many innovative products. Central to commercialization of these products and technologies is the consideration of the potential environmental, health, and safety (EHS) risks associated with nanomaterials. Risk assessment has been proposed as a primary method to evaluate EHS risk and decision making, where risk assessment practitioners seek to understand what can go wrong, its likelihood of occurrence, and the ultimate consequences if it should arise. However, given the emerging nature of nanomaterials, uncertain threats, exposure and consequence, traditional risk assessment techniques may not be sufficient. Instead, there is a critical need for an integrated approach in which decision analytic techniques are used to assess evidence-based data on risks and benefits of materials and technologies with the values and preferences of stakeholders. This presentation will review recent efforts geared toward risk assessment for nanotechnologies and nanomaterials, and discuss the challenges associated with providing accurate risk information to policymakers and regulators. Decision analytical approaches that provide decision makers with adaptive guidance regarding how to balance risks with technological benefits and costs, communicate those trade-offs, and change nanomaterial design toward sustainable nanotechnology will be discussed.

Novel Large 2D Black Phosphorus Film

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Abstract

Black phosphorus is a stable, semiconducting allotrope of phosphorus that was first discovered by Bridgman in 1914. The crystal structure is composed of corrugated, continuous six-member rings forming sheets of covalently bonded phosphorus atoms. Different layers are held together by weakly attracting van der Waals forces. In this work, we reported some fundamental aspects a novel family of 2D materials, phosphene, a monolayer material generated from black phosphorus. We will report a level of control to fabricate large phosphene (greater than 1 x 1 mm^2) for practical applications in the future. Simple analysis with bright-field microscopy shows apparent color change with various thicknesses on the substrates. Because of the electron-rich character and unique bandgap, the conductivity of phosphene is much higher than that of graphene, which makes phosphene competitive for many applications.

A Greener and Cleaner Cavitation Technique for the Functionalisation and Generation of Nanomaterials for Diverse Technological Applications

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Abstract

An increasing number of newly developed drugs are sparingly soluble in water and are often also insoluble in organic solvents, consequently the formulation of these drugs is a major obstacle to their clinical applications. Owing to their extremely low solubility, these drugs usually possess poor bioavailability. The immediate formulation then aims for the reduction in the particle size of these drugs so that the specific surface area increases which ultimately enhances the bioavailability. Common ways of solving this problem include the use of solubilizers, cyclodextrins, and mixtures of solvents. But to overcome the shortcomings existing with these strategies, alternative attempts have been made to formulate the drugs as nanoemulsions. Continuous search is on to find out the techniques by which these nanoemulsions could be generated and which can make positive differences over the conventional techniques. Generation of nanoemulsions using cavitation approach is highly energy efficient and also flexible control of droplet size are possible over other conventional mechanical and high-pressure emulsification techniques. At appropriate energy density levels, ultrasound can well achieve a mean droplet sizes well below 1 μm. Efficiently generating the emulsion property of ultrasonic cavitation has been exploited for the preparation of a number of nanopharmaceutical emulsions as well as suspensions incorporated with a wide variety of drugs/natural products that have intense potential.

Hierarchical Self-Assembly of Nanomaterials for High Activity and High Stability

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Abstract

Self-assembly is emerging as an elegant, "bottom-up" method for fabricating nanostructured materials, which are formed from interatomic and intermolecular interactions. The most significant problems with the applications of self-assembled nanomaterials have been property changes over time because of poor stability. Recently advances in self-assembly technique enabled precise control synthesis of nanomaterials with various structures, which has significant impacts in the development of self-assembled nanomaterials. Herein, we show our recent work on design of a series of self-assembled materials with hierarchical nanostructure, which can greatly improve their activity and stability. Firstly, hierarchical micro-meso-macroporous materials with zeolite architectures have been designed and fabricated by using self-assembly method. These materials exhibit high activity and high stability in catalysis, which can be ascribed to the unique and stable hierarchically porous structure. Then, hierarchical metal nanocrystals@mesocullular foam with a unique hierarchical "one particle@one cell" structure have been fabricated by the viscosity-adjusting method. Metal nanocrystals in mesocellular foam exhibit high activity, high stability and high durability for oxygen reduction reaction. Furthermore, we also succeed to use self-assembly method for cell protection. Hierarchical living cells with nanoporous biohybrid shells can be rational designed. The self-assembled biohybrid shells endow the cells with enhanced stability and extra functionalities. It is believed that our methods could be useful for the preparation and stabilization of nanostructured materials with multiple functionality.

Nano-advantage for Designing Advanced Bipolar Rechargeable Power Sources for Internet of Things (IOT) Augmented Devices

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Abstract

Internet of Things (IOT) is a buzz word facilitating machine to machine (M2M) talking. IOT is a gist of wireless evolution connecting millions of devices through wireless via cloud space imparting convenience to human kind in a variety of domains dealt with wirelessly connected wearable devices, Communication modules, wireless sensor nodes, implantable devices, control systems, smart phones, etc. These gadgets aimed at establishing connectivity across devices via M2M protocol namely IOT. Hence, the portable rechargeable batteries must be efficient enough to power these wirelessly connected devices through various wireless protocols such as Bluetooth, Ethernet, CAN, LIN, I2C etc. The connectivity through such devices demands more battery life and such power hunger devices required long standby time, elapsed shelf life, high capacity (mAh) and power density (Wkg^{-1}). The talk

focuses on the ways to create such batteries namely a hybrid capattery, an encompassed version of bipolar Lithium Ion battery and Supercapacitors. The bipolar power source is made of novel nanomaterials such as $Li(FeMnNi)_{1/3}PO_4$, $Li_4Ti_5O_{12}$, and nanoporous carbonaceous materials. We have designed such hybrid bipolar devices using our proprietary processes. These nanomaterials are synthesized and characterized for its single phase structure and particle-particle nanowire carbon connectivity. Such connectivity is expected to enhance the electron transport across single nanograin and effectively enhances the electrode-active characteristics in turn to deliver good rechargeable capacity. Feasibility tests on how these materials behaves the purpose stated when assembled as battery/supercapacitor hybrid and how this will help enhance the performance of IOT applications.

Field Emission Properties of ZnO Nanostructures

Bing Wang

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Abstract

ZnO is an excellent metal-oxide semiconductor material because of its wide direct band gap of 3.37 eV and large exciton binding energy of 60 meV at room temperature. ZnO has been widely used in different applications, such as dye-sensitized solar cells, ultraviolet photodetectors, gas sensors, optical resonator and field emission cathodes. Field emission is one of the most fascinating properties of semiconductor nanomaterials and has been extensively studied due to its importance in view of the field emission flat display, x-ray sources, and microwave devices. One-dimensional nanostructured ZnO has the better characteristics of physical and chemical properties due to the high aspect ratio, which means that it could be a good candidate for use in field emission applications. ZnO nanostructures are fabricated on silicon substrate using thermal chemical vapor transport. The field emission property of ZnO nanostructures is characterized. The low turn-on electronic field and the high current density are achieved with ZnO nanostructures as the emitters. It is suggested that the special morphology of ZnO nanostructures play a crucial role for its excellent field emission property, and the ZnO nanostructures can be a promising candidate for an emitter. The growth mechanism of ZnO nanostructures can be explained by the combination of vapor–solid (VS) and secondary nucleation processes.

Cellulose Nanomaterials: Production, Properties, Applications and Future Prospects

Mehdi Tajvidi

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Abstract

Cellulose nanomaterials mainly cellulose nanofibrils (CNF) and cellulose nanocrystals (CNC) are known as the nanomaterials of future because of the promise to provide an alternative to synthetic nanomaterials that is bio-based, eco-friendly, non-toxic and offers a wide window of applications in various industries. This presentation will provide an overview of cellulose nanomaterials production, properties, applications and future prospects with a focus on opportunities as well as challenges in the way of commercialization of these materials. Applications in food/packaging, composite materials, cement and concrete, flexible electronics and other industries will be reviewed. Key physical and mechanical properties that justify research in target applications will be discussed and current efforts in the United States to commercialize these applications will be introduced.

A New Theoretical Approach to LENR Using the BSM-SG Atomic Models

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Abstract

The Basic Structures of Matter Supergravitation Unified Theory (BSM-SG) reveals the existence of space micro-curvature around superdense nuclei. This makes the near field of space fabrics non-linear. In the far field the energy levels are consistent with quantum mechanical models, while the physical dimensions appear heavily distorted. This is valid also for single protons and neutrons. The re-examination of scattering experiments from this point of view reveals a complex three-dimensional nuclear structure with a much larger overall size. Therefore, the Coulomb barrier is not as strong as considered by the quantum mechanical models based on the Bohr model of hydrogen. The arrangement of the protons and neutrons in the nuclear structure according to the BSM-SG models matches perfectly the pattern of the Periodic Table with clearly identifiable valences and angular directions of the possible chemical bonds. The nuclear magnetic resonance obtains a clear classical explanation. It also carries a signature of

the nuclear configuration. From the point of view of BSM-SG models, LENR are theoretically feasible. By proper selection of involved elements, it is possible to predict an energy efficient cold fusion reaction with minimal or no radioactive waste.

Fabrication of Alumina and Silica Zeolite Nanofibers Using Electrospinning Technique

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Abstract

In today's world, one of the major areas where catalysis is of key importance is the crude oil refining process, where maximizing the product yield and quality while minimizing the process cost and energy consumption are key challenges. This requirement calls for an optimum chemical composition and systematic physical hierarchy of different phases inside a catalyst for enhanced chemical activity and hence higher throughput. One effective and practical solution that takes advantage of the nanoscale is to shape the catalyst in a linear one-dimensional fashion with greater length scale while confining the lateral dimension in nanometer range, thus forming a catalyst in the nanofiber shape. Electrospinning (ES) offers a fast, scalable, and economical route to shape materials in the form of nanofibers. It uses electric charge to draw fine fibers from a solution droplet. While this technique has been widely studied to produce micro to nano size polymeric fibers, the use of this technique to produce zeolite fibers are scarce. To produce zeolite fibers using this technique, pre-made zeolite micro or nanoparticles were mixed with polymeric solution and electrospun to form a zeolite-polymer composite fiber. After calcination, the organic polymer burnt off leaving behind the zeolite particles aligned in the form of fibers. To improve the mechanical stability of the zeolite fibers, a thermal resistant inorganic phase such as alumina was added. The presence of alumina derived from decomposition of AlC_3 improved the mechanical stability of the zeolite fibers.

Biological Systems as Targets for Study of New Properties Induced by Nanomaterials: the Case of Silver Nanoparticles

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Abstract

The convergence of nanotechnology and medicine has generated a new expectation in the field of pharmaceutical therapy. The silver nanoparticles (AgNPs) are widely used in medicine and chemistry industry due to their antimicrobial properties. However, there is a lack of information about their new biophysical properties, functions and effects at different levels of biological organization, and their impact on human health. The aim of the current presentation is to show the recent advances that our laboratory has been investigated, related with the effects that confer the AgNPs at different biological targets, and their potential toxic or beneficial implications in the cardiovascular (CVS), respiratory (RS) and the central nervous (CNS) systems. In blood vessels AgNPs induced dual effects, at low concentrations, induced vasoconstriction; at high concentrations, stimulated vasodilation mediated by the activation of endothelial nitric oxide synthase (eNOS), which produces low concentrations of nitric oxide (NO), an important vasodilator and antihypertensive agent. However, in the RS; in trachea, we shown that AgNPs, hyperreactivity, in presence of acetylcholine (ACh) mediated by the inducible nitric oxide synthase (iNOS), promoting large amounts of NO related with allergic mechanisms. In addition, in the CNS the AgNPs promoted a selective effect that permit survive astrocytes and promote necrosis in the C6 glioma cells, the altered form of astrocytes. These data suggest that specific/selective mechanisms of action induced by AgNPS depends on the biological target. Further studies are needed to elucidate the signaling pathways responsible to promote their toxic or beneficial effects in the CVS, RS and CNS.

Novel Core-shell Fluorescent Nano-materials for Biochemical Applications

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Abstract

Fluorescent nano-materials attract great attention for their merits of excellent photostability, good selectivity and biocompatibility as bio-probes. Recently, our group has focused our study on fluorescent nanoprobes for sensing and imaging by using novel core-shell plasmon-enhanced fluorescence (PEF) materials, upconversion nanoparticles (UCNP) and aggregation-induced emission (AIE) nanomaterials. The core shell gold nanorods as a near-IR sensor realized highly sensitive detection of pyrophosphate in living cells. In addition, core-shell UCNPs@SiO_2@photosensitizers-FA nanomaterials possess advantages of high photosensitivity, good photostability and selectivity, they realize down-converting imaging, targeting and photodynamic therapy for tumor cells. We also developed AIE nanoparticles into ratiometric fluorescent sensor and stains, for the detection of Hg^{2+} and melamine in living cells, and staining protein markers in polyacrylamide gel electrophoresis, respectively. Our studies demonstrated the successful applications of novel nanomaterials in biosensors and biological probes. The high sensitivity, selectivity and biocompatibility make fluorescent nano-materials potential in clinical and biological analysis.

Illuminating the Molecule Pattern of Phosphoinositides in the Plasma Membrane Using Single Molecular Localization Microscopy

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Abstract

Phosphoinositides (PIs) play essential roles in cell physiology and signaling. However, their molecular pattern in the plasma membrane remains elusive at nano-scale levels. Both PI4P and PI(4,5)P2 are independent plasma membrane (PM) determinant lipids that are essential for multiple cellular functions. We developed a novel imaging approach using single-molecule super-resolution microscopy and newly engineered fluorescence probes based on the different PH-domains that specifically recognize phosphatidylinositides. We reported that the PI(4,5)P2 probes exhibited a remarkably uniform distribution in the major regions of the PM of insulin-secreting INS-1 cells. In some regions, we observed sparse PI(4,5)P2 enriched membrane patches/domains of diverse sizes (383 ± 14 nm in average). Quantitative analysis revealed a modest concentration gradient which was much less steep than previously thought, and no densely packed PI(4,5)P2 nano-domains were observed. Live-cell super-resolution imaging demonstrated the dynamic structural changes of those domains in the flat PM and membrane protrusions. A few other PIs, including PI4P and PI(3,4,5)P3, showed the similar spatial distributions as PI(4,5)P2. These data reveal the nanoscale landscape of key inositol phospholipids in the native PM, implying a structural base for local cellular signaling and lipid-protein interactions at molecular levels.

Nanoparticle-based System for Harvesting Low Molecular Weight Biomarkers

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Abstract

The untapped bank of information residing within the LMW proteomic fraction of human serum "peptidome" is one of the most promising means for detecting cancer. Tumor cells excrete low molecular weight (LMW) bio-markers (< 10 kDa) that are specific to the tumor type, and at a rate proportional to the tumor stage. The major obstacles in harvesting LMW biomarkers are their low abundance and concentration in serum. Deficiencies in traditional methods have stimulated pursuits for alternative detection and diagnostic approaches. Here we offer the usage of tailor-fitted coated nanoparticles (NPs) as a potential, selective biomarker harvesting platform.

Anodizing of Aluminum for Solar Cell Application

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Abstract

The aim of this research is to use the porosity property in anodic alumina to produce well-ordered silicon Nanowires for solar cell applications. The study uses a single step anodizing process as a main process in the experiments. Samples produced from a 99.97% purity Aluminum (AL) foil, and others produced from AL-silicon wafers coated by an AL film with different AL thicknesses are used in the study. The study investigates the effects of varying the anodizing conditions (voltage, acid concentration, electrolyte type, and time) on the parameters of the AL Anodizing Operation (AAO) including pore diameter and interpore distance. Samples were characterized using scanning electron microscope (SEM). Results show a stable performance of both AL foils and AL-silicon wafers in growing silicon Nanowires for solar cell applications.

Fabrication of Multifunctional Fluorescent Magnetic Carbon Dot for Enhanced MRI, Fluorescent Cell Imaging, and Chemotherapy

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Abstract

Designing a multifunctional nanomedicine for integration of early diagnosis and effective therapy of cancer is desirable but remains a great challenge. Imaging and imaging-guided therapies have become a new platform in the present development of cancer theranostics. Herein, we synthesized paramagnetic fluorescent Gd@Carbon dots (Gd@C-dot). Nanocomposite via one-pot microwave method in 10 min. These multifunctional Gd@CQDs have been conjugated with, a molecular marker folic acid (FA) and utilizing dual modal fluorescence/magnetic resonance (MR) imaging is demonstrated *in vitro* using HeLa cancer cells and also applied *in vivo* using zebrafish as an animal model. On the other hand, hydrophilic anticancer drug, doxorubicin, is also incorporated into the nanocomposite, forming an FA-Gd@C dot-DOX complex, which enables novel imaging guided and pH dependent targeted drug delivery. Our work provides a platform to synthesize a nanocomposite system with highly integrated functionalities for dual modal biomedical imaging and cancer chemotherapy.

Natural Cellulose Nanofibers as Sustainable Enhancers in Construction Cement

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Abstract

High durability and low cost make cement one of the most widely used construction materials in the world. Cement, however, suffers from brittle fracture and facile initiation of cracks. Though researchers have addressed these drawbacks by incorporating a variety of polymer, carbon, and glass fibers, the high cost and environmental impact are unattractive. Renewable cellulose, the reinforcing component in natural hierarchical composites such as wood, exhibits properties comparable to other engineering fibers. Nanocellulose with higher aspect ratios can form a network to block crack propagation and improve toughness of composite materials. Here, we integrate relatively low weight fractions of cellulose nanofibers (CNFs) into cement composites and measured the effect of CNFs on the mechanical properties, degree of hydration (DOH), and microstructure of cement pastes. An increase of 15% and 20% in the flexural and compressive strengths of cement pastes was observed with the addition of 0.15 wt% CNFs. The increase in mechanical strength can be ascribed to the high DOH and dense microstructure of cement pastes with the modest addition of CNFs. Hence, CNFs show promising potential for manufacturing light-weight but high strength composites.

Synthesis and Applications of Detonation Nanodiamonds

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Abstract

The NS3E laboratory synthesizes detonation nanodiamonds by detonation of explosives since many years. These very small nanoparticles (i.e. 5 nm) can be used for a wide variety of applications in many fields such as sensing, medicine, pyrotechnics, optics.

We developed a novel approach to synthesize detonation nanodiamonds by using nanostructured explosives. Using this kind of explosive has never been experimented elsewhere in the world as we are the only one laboratory to be able to produce enough quantities to achieve explosive charges. This new synthesis method leads to novel results in the control of the size and the properties of the synthesized nanodiamonds, but also in the understanding of the nanodiamond synthesis and the detonation mechanisms.

The nanodiamond chemistry, functionalization, deposition and doping have been intensively studied. Detonation nanodiamonds possess oxygenated surface functional groups which allow the functionalization of these particles by various molecules. Suspensions of individual nanodiamond particles can be prepared and deposits of very dense monolayers can be achieved on substrate of different nature. The nanodiamonds can be modified by introducing foreign elements in the diamond crystal in order to modify their properties such as photoluminescence and electrical conductivity.

Facet-dependent Photovoltaic Efficiency Variations in Single Perovskite Grains and Spatially and Temporally Varying Nano PL Heterogeneity in Single Pervoskite Crystals

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Abstract

Photovoltaics based on hybrid perovskite materials have exceeded 20% efficiency in only a few years of optimization, for reasons generally ascribed to large charge carrier mobilities and lifetimes. Although functional properties, such as mobilities, photocurrent generation, and open circuit voltage are influenced by the microscopic structure and orientation of the perovskite crystals, these properties are difficult to quantify on the intragrain length scale and are often treated as homogenous within the active layer.

In this work, we mapped the local short circuit photocurrent, open circuit photovoltage, and dark drift current in state-of-the-art methylammonium lead iodide solar cells with sub 30 nm spatial resolution using photoconductive atomic force microscopy. We find, within individual grains, spatially-correlated heterogeneity in short circuit current of up to an order of magnitude and in the open circuit voltage up to 0.6 V. These variations are related to different crystal facets and have a direct impact on the macroscopic power conversion efficiency of these materials. We attribute this heterogeneity to a facet-dependent density of trap states. These results imply that controlling crystal grain and facet orientation will enable a systematic optimization of polycrystalline and single crystal devices for photovoltaic and lighting applications.

Near field microscopy nano photo luminescence (PL) maps reveal again a facet dependent PL efficiency, supporting the hypothesis of crystal facet dependent trap state densities that modify the local opto electronic processes. Surprisingly, single crystalline perovskite micro crystals with well defined facets, exhibit PL hotspots, which are three times brighter than the rest of the crystal and move around over time. This dynamic PL heterogeneity might provide insight into domain wall movements and ion mobility.

Molecular Dynamics Simulation of Carbon Nanotube Stabilization in an Epoxy Resin Using a Cationic Surfactant

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Abstract

In this fundamental work, we investigated the effect of a cationic surfactant on stabilizing carbon nanotubes (CNTs) in a model liquid epoxy resin. To fully utilize the reinforcing and/or thermal/electrical potential of CNTs in polymers for structural and multifunctional applications, it is of utmost importance that the CNTs are uniformly dispersed in the matrix to maximize the matrix-nanoreinforcement contact surface area. CNTs are known to form bundles that are very difficult to break and often, a mechanical shearing action is needed to physically break the CNT bundles. However, once dispersed in the matrix, the individual CNTs tend to re-bundle during nanocomposite processing and, therefore, the use of surfactants might be warranted to stabilize the CNTs in the polymer matrix. In this work, we used molecular dynamics (MD) simulation to investigate the effect of hexadecyltrimethylammonium (cetrimonium) bromide (CTAB) (a cationic surfactant) on the CNT stabilization in a model uncured liquid epoxy resin. For this purpose, we generated the potential of mean force (PMF) between two (6,6) CNTs (10 Å long) in the resin containing different surfactant concentrations (0%, 16%, 27%, and 43%) at room temperature (298 K) and 1 atm. All simulations were run in the open-source LAMMPS software using the pcff force field and the NPT ensemble. In this presentation, we will compare the PMFs for different systems and discuss whether 1) adding the cationic surfactant to an epoxy resin improves the CNT stabilization and 2) whether surfactant concentration is a major factor in the effectiveness of the CNT stabilization.

Nanomaterial and Infrequent Fields from Particle Physics to Health and Energy

Khashayar Ghandi

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Abstract

Several of our recent works on nanomaterials synthesis and applications will be described. The synthesis is along the lines of green chemistry and the applications cover energy production, detection of pathogens and potential applications in radiation therapy and nuclear industry. The characterization techniques cover both conventional lab based techniques and unconventional particle physics based techniques with very high sensitivity.

The Universal Technique for Thin Nanowires Production in Superfluid Helium

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Abstract

The quasi-1D quantized vortices that have nucleated under the liquid superfluid helium (He II) perturbation can serve as a universal template imposes the growth of any guest particles coagulation product exclusively along vortices axis. By introducing the metal nanoparticles into the He II by laser ablation of targets immersed in liquid, we have implemented the method for the production of nanowires made of any metal and alloy. Because of the sharp dependence of the He II thermal conductivity from the heat flow the precursors of nanowire are molten nanoclusters; thus the nanowires have a perfect shape and dense-packing structure. The wire diameters, dependent on the thermodynamic characteristics of the metal, are ranged from 1.6 nm for tungsten to 8 nm for indium. Together with parent vortices the nanowires prefer to pin to the tips of the needlelike electrodes intentionally introduced into the reactor, thus closing the electrical circuit and allowing carrying out electrical measurements inside the cryostat. In general the condensation product is the nanoweb consisted of cross-linked nanowires. The total surface of nanowires is sufficient for using the nanoweb as a catalyst of chemical reactions in a standard flow reactor.

The nanowires made of more than 20 metals and alloys were grown and studied. By metals space separation under alloy coagulation and by using an electrochemical post-coating of nanoweb the nano-heterostructures as well as the core-shell structures may be produced. The promises for the nanowires application in the quantum devices and in catalysis will be outlined.

Transition Metal Oxide - Multiwalled Carbon Nanotubes Nanocomposites for High Energy Density Supercapacitors

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Abstract

Hydrous RuO_2, α-MnO_2 and β-$Ni(OH)_2$ and their nanocomposites with MWCNTs were synthesized by wet chemical process and characterized by various analytical techniques such as XRD, FT-IR, Raman, SEM-EDS, TEM and BET surface area to understand their structural and morphological properties. The characterization results revealed the formation of pure spherical h-RuO_2, bristle like α-MnO_2 and hexagonal β-$Ni(OH)_2$ in their nanocomposites. The electrochemical performances of h-RuO_2, α-MnO_2 and β-$Ni(OH)_2$ were found to be enhanced in the presence of MWCNTs which is attributed to their structural and morphological properties. Further, asymmetric supercapacitor devices were fabricated separately using these nanocomposites as positive electrode and inexpensive activated carbon as negative electrode. The fabricated ASD was tested by CV, CP, AC impedance technique and life cycle test. β-$Ni(OH)_2$/MWCNTs//AC device was used as power source for lighting different colored LEDs and a mini fan.

A Novel Implementation of Nano-Technology on Modified Asphalt Binder and Mixture

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Abstract

Recently, increased traffic levels, larger and heavier trucks with new axle designs, and higher tire pressures have aggravated the severity of the conditions upon the highway system, resulting in rutting, stripping, fatigue cracking, and reflective cracking. Using enhanced asphalt binder has played an important role in minimizing pavement distresses while improving long-term performance of asphalt pavements. This research presents and discusses benefits of nano engineering in asphalt binder and asphalt mixture; mainly the performances of polymer, nanoclay and nanocomposite-engineered asphalt mixtures were evaluated. A 58-10 PG, conventional asphalt as a base binder, was modified separately with a linear SBS polymer and nanoclay in different proportions. As a result, three modified binders: nano modified asphalt, polymer modified asphalt (PMA), and nanocomposite modified asphalt were made. These modified binders were used to prepare asphalt mixtures. A laboratory study included characterization of physical, mechanical, and rheological properties and behaviors of the modified binders and the asphalt mixtures were performed. Asphalt binder tests were used for the modified binders while performance tests such as tensile strength, resilient modulus, and rutting tests were employed for the asphalt mixtures. Test results have shown that nanoclay can enhance physical and rheological properties of the PMA binder as well as its storage stability. With these enhanced binder characteristics, the asphalt concrete specimens showed an increase in tensile strength and resilient modulus and also improved rutting resistance over conventional asphalt concrete.

X-ray Spatial Frequency Heterodyne Imaging of Aqueous Phase Transitions Inside Multi-walled Carbon Nanotubes

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Abstract

The evaporation and condensation of water on multi-walled carbon nanotube (MWCNT) surfaces was studied as a function of temperature, time and chemical functionalization using X-ray Spatial Frequency Heterodyne Imaging (SFHI). SFHI permits the generation of absorption and scatter images from a single exposure. Differences exhibited in the temporal scatter intensity profiles recorded during evaporation and condensation revealed the existence of an adsorption-desorption hysteresis. Chemical functionalization of the MWCNT walls by thermal oxidation altered the evaporation event time scale and increased the temperature at which condensation could take place. Theoretical calculations were used to correlate the shape of the observed scatter profiles during condensation to changes in MWCNT cross section geometry and configuration of the contained water volume. The qualitative agreement between the theoretical calculations and the recorded scatter profiles as well as the coincidence between the boiling point for the confined water predicted by the Kelvin equation and the change in evaporation time scales with temperature both indicate that thermodynamic equations hold predictive power over water confined to dimensions of less than 10 nanometers. To the author's knowledge this is the first data set demonstrating the tentative applicability of thermodynamic expressions to water confined to this size regime.

Multifunctional Colloidal Nanofiber Composites from Water Dispersion Blends of PVP/Dextran/ODA-MMT/FA/NaOH Nanocomposites by Green Electrospinning as Electro-active Platforms

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Abstract

Recently, attention of many researchers was focused on fabrication of synthetic and natural polymer nanofibers from solution blends of various polymers and/or polymer nanocomposites as a binary multifunctional matrix/partner polymer system rather than fabricating nanofiber structures from one polymer. The nanofibers obtained from a broad range of polymers such as engineering plastics, biopolymers, conducting polymers, block and graft copolymers and matrix-partner polymer blend nanocomposites with a very high continuous surface area compared with other polymer materials. Polymer e-spun nanofibers are preferred because of their unique properties, such as high surface area-to-volume ratio, thin films and coatings, nanoscale fiber diameter and nanoporous surface morphology, as well as their widely medical applications. This work presents the fabrication and characterization of novel colloidal multifunctional polymer nanofiber composites (NFCs) from water dispersion blends of the intercalated silicate layered nanocomposites of poly(2-vinyl-N-pyrrolidone)/octadecyl amine-montmorillonite (PVP/ODA-MMT) and Dextran/ODA-MMT as matrix and partner polymers (Figure 1), as well as their folic acid (FA) conjugated composites by green reactive electrospinning nanotechnology (Figure 1). The chemical and physical structures, surface morphology, electrical properties and bioactivity of fabricated NFCs were investigated. The effects of matrix/polymer volume ratios, composition, organoclay and FA on the main important parameters such as conductivity, resistance, and bioactivity were evaluated. There was observed that addition of FA and doping agent significantly improved electrical parameter of nanofiber mats as bio- and electro-active platforms.

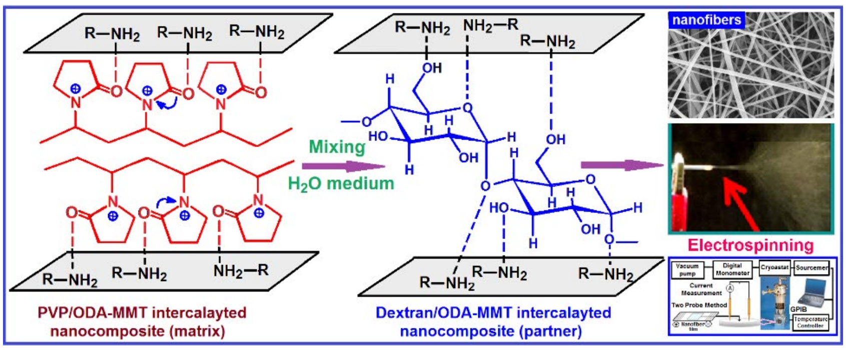

Figure 1: The structures of intercalated matrix/partner polymer nanocomposites and their e-spun nanofiber mats and morphology as effective bio- and electro-active platforms.

Advanced Polymer Nanocomposite Effects for Oil and Gas Engineering

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Abstract

High-performance and functional polymer nanocomposite materials for oil & gas engineering have emerged as a new field. Several polymer nanocomposites are prepared using special intercalation compositing methods. Their structure designs and positive nanoeffects in petroleum engineering are reported.

Polymer (polyamide, polyester) nanocomposite materials are achieved with montmorillonite (MMT) intermediate intercalation process. They greatly enhanced the tensile strength, temperature tolerance, anti-friction and corrosion resistance comparing to their pure counterparts. The obviously enhanced heat distortion temperature (HDT) occurs to polyethylene terephthalate (PET), polybutylene terephathalate (PBT) and Nylon 6 base nanocomposite samples. Their net HDT enhancements of 50 to 90 °C over pure polymer matrix are achieved within 5.0% MMT load. The obvious nanocomposite effects of the nanolayer dispersion, normal distribution, exfoliation-transfer-assemble patterns on their service properties are measured and evaluated. The high effective nanolayer nucleation model and nanoparticle repairing mechanism are proposed to understand the advanced nanocomposite thermal and wear behaviors. The nanocomposite structure and property lay foundation for oil & gas engineering applicable standards. The nanocomposite additives in barrier film against water, plugging particles and short fibers, wear tools (lining or oil pipes, casings), and parts (bearings, and gears) are briefly presented.

A Flexible, Biocompatible and Biodegradable Hybrid Solar and Mechanical Energy Harvester Fabricated from Nanostructured DNA-Mediated PVDF Film

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Abstract

Polymer based energy harvesters are making significant scientific grounds due to their flexibility, compatibility, light weight, durability and low cost for portable and low energy based devices. However, biocompatibility is not properly addressed in polymer based devices. The solution could be found in deoxyribonucleic acid (DNA)-mediated Poly(vinylidene fluoride) (PVDF) based hybrid-energy harvester, capable of operating as a solar cell and mechanical energy harvester. It is well known that PVDF films show piezoelectric properties when the electroactive phases (β- and γ- phases) are induced which require high electric field. Alternatively, we have been able to induce β-phase in PVDF film by the introducing DNA without electrical poling. Single Strand DNA condensates as nanostructures on the PVDF surface with size 30-50 nm inducing the β-phase. The device is capable of harvesting piezoelectric potential up to 20 V by the application of mechanical stress (~63 kPa) with high efficiency (~2.7%). There have been reports of organic solar cells fabricated with DNA with high efficiencies. This is attributed by the fact that DNA based solar cells can show large band gaps and high dielectric constant, playing an important role in enhancing light capture. We have fabricated hybrid DNA-mediated device that can harvest both solar energy and mechanical vibration simultaneously, useful as an all-weather energy generator. This DNA-based thin film device can be molded into any shape suitable in any portable electronic devices and is fully biocompatible and biodegradable. The device would be ideal for biomedical implants and sensors which can operate without storage energy.

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