

Proceedings of the 3rd NanoWorld Conference (NWC-2018). Part III: Featured Presentations

Nanotechnology and Nanosciences Session (Cancer Nanotechnology)

Targeting of Cancer Cells via Electrically-Charged Superparamagnetic Nanoparticles

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Abstract

In cancer diagnosis and therapeutics, extensive effort has been devoted to identifying cancer cells in terms of oncogenic and pathological characteristics. One of the major approaches has been the development of tumor-specific ligands for cell targeting. However, previous studies have shown that two isogenic cancer cell lines differ only by a few proteins. These commonalities between cancer and normal cells at molecular level have been the fundamental problems in any biomarker-based cancer diagnosis and therapeutics. We have recently discovered that all cancer cells are negatively charged due to the hallmark metabolic pattern associated with glycolysis. We report a close correlation between the lactate acid secreted and a net of negative electrical charges that appears on cancer cell surfaces. Superparamagnetic nanoparticles are rendered electrically charged, via surface functionalization, to strongly bind onto the cancer cells for effective and specific targeting. The charge-based targeting paves a new way for cancer cell capturing and sensitive detection in clinical settings.

Multiplex Detection of Pancreatic Cancer Biomarkers Using a SERS-based Immunoassay

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Abstract

Early diagnosis of pancreatic cancer (PC) is critical to reduce the mortality rate of this disease. Current biological analysis approaches cannot robustly detect several low abundance PC biomarkers in sera, limiting the clinical application of these biomarkers. Enzyme linked immunosorbent assay and radioimmunoassay are two common platforms for detection of biomarkers; however, they suffer from some limitations. This presentation investigates a novel system for multiplex detection of pancreatic biomarkers CA19-9, MMP7, Mesothelin and MUC4 in sera samples with high sensitivity using surface enhanced Raman spectroscopy. Measuring the levels of these biomarkers in PC patients, pancreatitis patients, and healthy individuals reveals the unique expression pattern of these markers in PC patients, suggesting the great potential of using this approach for early diagnostics of PCs. Advantages and feasibility of performing this platform on an integrated microfluidic device also will be discussed.

Novel Biodegradable Second-Generation Oxygen Release Compound in Enhancement of Dissolved Oxygen Concentration

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Abstract

The release rates of H₂O₂ and O₂ from solid peroxides are an important issue to be considered no matter they are used in environmental remediation or biomedical applications (e.g., tissue and scaffold engineering). In the field of environmental applications, solid peroxides have been encapsulated with materials like concrete and alginate. On the other hand, microfibrillated cellulose and poly (lactic-co-glycolic acid) [PLGA] have been used as the encapsulation materials to slow down and extend the period of H₂O₂ and O₂ release in medical applications. However, solid oxygen-releasing compounds still have some disadvantages or limitations in applications. To resolve these problems, a biocompatible and biodegradable nanomaterial designated second-generation oxygen release compound (2G-ORC; Taiwan patent pending) has recently been developed by the present authors. Briefly, 2G-ORC is comprised of sustained-release catalase and high-stability nanoscale sodium percarbonate. Test results showed that under neutral and alkaline pH conditions the catalytic oxygen release ability of H₂O₂ by sustained-release catalase outperformed other oxygen releasing biomaterials reported. By applying 0.17 g of 2G-ORC to 20 mL deionized water, the dissolved oxygen (DO) level was found to maintain at 6.24 mg/L even a test period of seven days has elapsed. Accordingly, being a bio-nanomaterial 2G-ORC has proved to be long-lasting and capable of markedly increasing the DO concentration in aqueous solutions. This feature is considered to be of great use in enhancement of DO concentration not only for *in situ* aerobic bioremediation of organic pollutants, but for various biomedical applications including but not limited to tissue and scaffold engineering.

Development of a Methodology and Ionizing Radiation Device that uses Metallic Nanoparticles for the Detection and Simultaneous Treatment of Cancer

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Abstract

A new methodology for the detection and simultaneous treatment of tumors is presented. The method is based on a 3D scanning by means of convergent X-ray beam irradiating phantom/patient containing targets with biomarker of heavy atomic number nanoparticles in certain concentration levels previously studied by other authors. Confocal detection of the point scanning allows reconstruction of a 3D image aimed at mapping tumor cells, while a second convergent beam scanning slightly out of phase operates in treatment mode to eliminate the tumor. It is proposed that simultaneity between target location and treatment irradiation may avoid the mismatches between actual and practical target. Monte Carlo simulations carried out adapting subroutines in FLUKA and PENELOPE main codes demonstrated the feasibility of the proposed method. Current efforts are devoted to design and build a laboratory prototype to validate the proposed method.

Nanotechnology and Nanosciences Session (Energy & Environment)

Nanocatalyst Development for Fuels from Biomass using Si-Microreactor and Tubular Reactor

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Abstract

The major focus of our NSF-CREST Bioenergy Center at NC A&T is to develop technology for the production of liquid transportation fuels and hydrogen for fuel cell applications. One of our main objectives is to develop robust and stable catalysts for Fischer-Tropsch (F-T) synthesis using Si-microchannel microreactor. Recently, we demonstrated a novel, modified closed channel infiltration (mCCI) method, to produce ~10 μm silica sol-gel coatings containing Ru, Fe and Co- catalysts in the microchannels [1]. While Co/SiO₂ at 250 °C showed highest CO conversion, 90%, with highest deactivation resistance, it was followed by Fe/SiO₂ and Ru/SiO₂ in regard to CO-conversion and stability of the catalyst. To investigate the effect of support,

the Si-microchannels were coated with titania sol-gel containing Ru, Co, Fe catalysts. Preliminary studies exhibited stability and reactivity (150 °C to 300 °C) in the order of 12% Ru-TiO₂ >> 12% Fe-TiO₂ > 12% Co-TiO₂.

The other area of research involves catalyst development for H₂ production from bio-derived alcohols. Our previous studies on steam reforming of methanol with different metals and MCM-41 and TiO₂-supports have shown that the interaction between metal and the support plays a profound role on H₂ production and its selectivity [2]. We have now extended our studies to steam reforming of glycerol (SRG), a byproduct of biodiesel. The SRG studies were carried out with Ni/Co-MCM-41 and Ni/Co-SBA-15 catalysts at 650 °C using a tubular reactor. Both H₂ selectivity (85% vs 78%) and conversion (99% vs 88%) were better at higher glycerol to water feed ratio (1:12) for both catalysts.

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Life Cycle Considerations for Risk Assessment of Nanomaterials

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Abstract

The commercialization of nano-enabled products and their societal acceptance requires the insurability of safety at all stages of the product life cycle. Current uncertainties on the safety of such products need to be carefully addressed to avoid public fears blocking the benefits of nanotechnology. Sound scientific information must be generated to identify potential risks of nano-enabled products on human and ecosystems health and, when considered unacceptable, efficiently mitigate such risks. This has to be done in a holistic manner, taking into consideration all stages of the life cycle of these products, to protect the safety of workers, downstream users and consumers, the ecosystems, and the general population that may be exposed through the environment. Several European projects work in this direction, generating data (physic-chemical, hazard and exposure data) on exposure relevant materials that are released at different stages of nano-enabled products life cycle. This presentation will be focused on the strategy followed in several EU projects (caLIBRATE, NANOFASE, GUIDEnano) to integrate the knowledge and data generated, into risk assessment frameworks, models and tools to provide industry, regulators and society with advanced methods to evaluate the impact of ENM at any stage of their life cycle.

Inorganic, Hybridized and Living Macrocellular Foams: “Out of the Box” Heterogeneous Catalysis

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Abstract

We will show how, when combining chemistry and the physical chemistry of complex fluids, we can trigger the design of highly efficient heterogeneous catalysts. We will thus focus the topic on 3D-macrocellular monolithic foams bearing hierarchical porosities and applications thereof toward heterogeneous catalysis where both activities and mass transport are enhanced. We will first depict the overall synthetic path, focusing on concentrated emulsions and lyotropic mesophases, acting as soft templates at various length. We will see how we can design cellular materials being either, inorganic, carbonaceous, hybridized or living ones where heterogeneous catalysis applications are addressed while considering respectively acidic, metallic, enzymatic or bacterial processes. Along, we will show how the fluid hydrodynamic, the low molecular hindrance and the easiest accessibility occurring within the macrocellular foams are offering advanced “out of the box” heterogeneous catalysis whatever acting in batch, on-line or when dedicated toward cascade-type chemical reactions.

Challenges in the Growth of Vertically Aligned Carbon Nanotubes: Substrate, Catalyst Layer, CVD Conditions and Much More

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Abstract

Potential applications of carbon nanotubes (CNTs) can be significantly widened, in case CNTs form a forest-like, vertically aligned structure (VACNT). The aim of the current work was to develop a cheap and easy method for growing carbon nanotube forests on various substrates (either conductive or non-conductive) with the CCVD (Catalytic Chemical Vapor Deposition) method. However, this growth technique is rather sensitive to synthesis parameters both during catalyst layer formation (substrate; composition; thickness; porosity; etc.) and during CCVD (gas feed – carbon source, carrier, hydrogen, water vapor; reaction temperature; reaction time; etc.). Synthesis parameters might affect not only the outer diameter, the quality and graphitization of carbon nanotubes but also the height and the density of growing forests. A systematic study proved that the catalyst layer's morphology and amount of catalyst during the growth of carbon nanotube forests are able to control mainly the diameter of CNTs. In order to tune the height of vertically aligned carbon nanotube forest several parameters were varied during the both catalyst layer fabrication (e.g. ink concentration, ink composition, dipping speed) and the CCVD synthesis (e.g. gas feeds, reaction time). It was established that no considerable alignment occurs when CNTs are shorter than 10 μm . Above this value the orderliness of CNT forests becomes ostensible more or less independently of either reaction time or catalyst ink concentration. Authors are convinced that simple and cheap methods can open up novel applications in nanotechnology devices.

Generation of Single Molecular Species on Carbon-based Nanomaterials and their Catalytic Applications

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Abstract

Chemical designing on nano-materials in molecular level would be a promising route to create new hybrid materials and to control various properties of nano- and molecular materials. Organometallic compounds have been a center of molecular catalysts with preeminent catalytic activity and selectivity in a wide range of chemical transformations. As carbon-based nanomaterials, such as graphene-based materials, carbon nanotubes, and carbon nitrides, are sterically bulky, and they exhibit a wide spectrum of electrical properties, they can dramatically tune the catalytic behavior of transition metal-based active species. Hybridization of organometallic complexes with graphene-based materials can give rise to enhance catalytic performances. In this presentation, I will discuss my recent research activities on the fundamental chemistry of carbon-based nano-materials as well as catalytic applications.

Structural Functionalization of Polymeric Carbon Nitride for Efficient Photocatalytic Hydrogen Generation

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Abstract

We present a new type of metal-free photocatalyst having a microsphere core of oxygen-containing carbon nitride and self-sensitized surfaces by covalently linked polymeric triazine dyes. These self-sensitized carbon nitride (SSCN) microspheres can be prepared through a simple solvothermal approach, and exhibit high visible-light activities in photocatalytic hydrogen generation with excellent stability for more than 100 hours reaction. Comparing to the traditional $g\text{-C}_3\text{N}_4$ with activities terminated at 450 nm, the polymeric triazine dyes on the carbon nitride microsphere surface allow for effective wide-range visible-light harvesting and extend the hydrogen generation activities up to 600 nm. Further, the solvothermal approach allows for uniformly insertion of boron atoms into the polymeric carbon nitride framework, resulting in B-doped SSCN with reduced band-gap, enhanced charge separation efficiency and promoted surface reactivity for hydrogen generation. This new type of highly stable self-sensitized metal-free structure opens a new direction of future development of low-cost photocatalysts for efficient and long-term solar hydrogen production.

Reservoir Interactions and Chemical Heterogeneity at the Nanoscale: Atomic Force Microscopy for Reservoir Applications

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Abstract

Despite major technological advances toward improving hydrocarbon recovery, significant amounts of oil are still left behind in subsurface reservoirs. Laboratory studies of hydrocarbon recovery, fluid/material transport, and rock properties are traditionally performed on bulk samples which provide valuable information used to inform injection and production decisions. Bulk measurements, however, do not provide nanoscale measurements of parameters such as molecule-rock and nanomaterial-rock interactions at extremely high salinity which are directly relevant for designing reservoir tracers and tracer studies. In addition, when rock composition varies significantly at the nanoscale, as for source rocks, the nanoscale chemical heterogeneities that are essential to understanding the behavior and maturity of source rocks are not explained by bulk studies. Atomic Force Microscopy (AFM) has been used for petroleum applications to provide fundamental understanding of the nanoscale material properties related to molecular adhesion and mechanical properties as well as measure pores. This presentation demonstrates two applications of AFM to study reservoir rock properties. First, we demonstrate the effects of salinity on nanomaterial and molecular adhesion in reservoir fluids and show that the calcium content in these fluids affects the tip-calcite adhesion as surrogate for nanomaterial adhesion to carbonate reservoir rock. Second, we show high-resolution (20 nm/pixel) hyperspectral infrared (IR) characterization of source rocks using photo-induced force microscopy (PiFM), a recent advance in AFM-IR methodology. This technique provides a sensitive, high-resolution, and fast means of detecting nanoscale variations in mineralogy and thermal maturity of source rocks at a resolution previously unattainable by other IR techniques.

Mesomechanics of Pristine and Cross-linked Carbon Nanotube Materials

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Abstract

The behavior of carbon nanotube (CNT) materials subjected to mechanical loading exhibits a number of fascinating effects caused by collective interactions among individual CNTs, such as the collective or coordinate buckling and transition from viscoelastic to plastic behavior. This work is aimed at revealing the microstructural mechanisms of such collective effects and plasticity in CNT films and aerogels based on a recently developed mesoscopic model. In the mesoscopic model, nanotubes are represented in a form of chains of stretchable cylindrical segments. The mesoscopic force field accounts for stretching, bending and buckling of individual nanotubes, as well as non-bonded van-der Waals interaction between CNTs and covalent cross-links between them, and is parameterized based on results of atomistic simulations and experiments. The structures of CNT films and aerogels are found in simulations of self-assembly of initially dispersed CNTs into networks of interconnected bundle and compared with experimental data. Elastic and inelastic mechanical properties of CNT aerogels and films under compressive, tensile, and cycling loading are studied in dynamic mesoscopic simulations. The deformation-induced variations of local structural properties of the CNT materials are analyzed depending on the CNT length, material density, density of cross-links, and strain rate and used to explain the energy dissipation properties of CNT networks. For compressive loading, conditions responsible for the onset of coordinated buckling and wrinkling of CNT films are revealed.

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3D Printing Nanomaterials-based Electrodes for Electrochemical Energy Storage and Conversion

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Abstract

Two-dimensional (2D) nanomaterials, such as graphene and transition metal dichalcogenides, hold extraordinary promise for application in a number of electrochemical technologies. Electrochemical energy storage (EES) devices, such as lithium-ion batteries and supercapacitors, in particular, have seen 2D materials integrated into various components with exciting results. In general, EES devices are emerging as primary power sources for global efforts to shift energy dependence from limited fossil fuels towards sustainable and renewable resources. These EES devices, while renowned for their high energy or power densities, portability, and long cycle life, are still facing significant performance hindrance due to manufacturing limitations. One major obstacle is the ability to engineer macroscopic components with designed and highly resolved microstructures with optimal performance, via controllable and scalable manufacturing techniques. 3D printing covers several additive manufacturing methods that enable well-controlled creation of functional materials with 3D architectures, representing a promising approach for fabrication of next-generation EES devices with high performance. Here, we present recent work in fabricating 3D functional electrodes utilizing 3D printing-based

methodologies. Specifically, 3D printing techniques such as projection microstereolithography and direct ink writing are described, as well as the details of respective feedstock development efforts. Finally, characterization of the 3D-printed electrodes and their performance in various EES applications will be presented and discussed.

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Accelerate your Research Using Nature Research Group's AI Powered Nanotechnology Platform

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Abstract

Growing public and private investment into nanotechnology has led to a significant rise in nanotechnology data generated, with increasing research output and patents over the last decade. Nanotechnology has made a significant impact on a wide range of industries from medicine to aerospace – in developing new products and applications. However, utilizing this rapidly growing data remains a critical challenge. The increasing diversity of nanomaterials, leads to a gap between data generation and data access. Nano.nature.com known as Nano is an artificial intelligence powered research solution under the Nature Research portfolio that aims to provide highly indexed and structured information related to nanomaterials derived from peer-reviewed journals across all major publishers. These include composition, synthesis, properties, characterization methods and application information. This talk will illustrate on the impact of nanoscience around the world and how Nano can aid nanotechnology research communities to obtain fast and precise insight into the wealth of nanotechnology based scholarly knowledge.

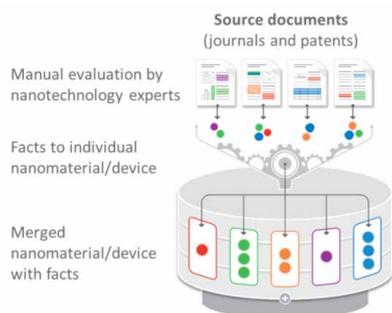


Figure 1: Creation of curated summaries of nanomaterials.

A Novel Approach to Low-temperature Synthesis of Cubic HfO₂ Nanostructures and their Cytotoxicity

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Abstract

The development of a strategy to stabilise the cubic phase of HfO₂ at lower temperatures is necessary for the emergence of unique properties that are not realised in the thermodynamically stable monoclinic phase. A very high temperature (>2600 °C) is required to produce the cubic phase of HfO₂, whereas the monoclinic phase is stable at ambient temperature. Here, a novel rapid synthesis strategy was designed to develop highly crystalline, pure cubic-phase HfO₂ nanoparticles (size <10 nm) using microwave irradiation. Furthermore, the as-prepared nanoparticles were converted to different morphologies (spherical nanoparticles and nanoplates) without compromising the cubic phase by employing a post-hydrothermal treatment in the presence of surface modifiers. The cytotoxicities and proliferative profiles of the synthesised cubic HfO₂ nanostructures were investigated over the MCF-7 breast cancer cell line, along with caspase-3/7 activities. The low-temperature phase stabilisation was significantly attributed to surface imperfections (defects and deformations) induced in the crystal lattice by the desirable presence of Na₂S_xH₂O and NaOH. Our work provides new insight into the stabilisation of nanoscale cubic-phase HfO₂ in

ambient environments; the method could be extended to other challenging phases of nanomaterials.

Nanosponge Cyclodextrins and their Modification with Nanomaterials (CNTs, TiO₂ & Ag) for the Removal of Pollutants from Waste Water by Adsorption Process

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Abstract

Water is a worldwide vital resource for sustaining life and due to the pollution of water by different classes of pollutants (inorganic, organic and pathogens), many ongoing studies in water purification remain a critical issue to governments, scientists and industries. The challenge is to develop a water purification technology which will be effective at removing these contaminants simultaneously and reducing their concentrations to ultra-low levels from waste water. This review article serves to give an overview on cyclodextrin nanosponge adsorbents which have already been used for water treatment. The modification of these cyclodextrin nanosponges with existing adsorbent nanomaterials and the factors affecting the adsorption capacity of these nanosorbents are discussed. The nanotoxicity of these engineered nanosorbents material is also addressed since this nanotoxicity is a major concern to the human health and environment. Therefore, having some knowledge on the prevention and detection of the nanotoxicity of these nanomaterials, will play huge role into the future of nanotechnology for sustainable clean and potable water supply.

Electro-spun Si-doped Fe₂O₃ anode Material for Na-ion Rechargeable Batteries

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Abstract

Li-ion batteries currently represent the dominant power source for portable electronic devices, but the restricted availability of Li raw material and its growing consumption represent a serious concern. The larger abundance of Na sources has gathered increasing attention on Na-ion batteries (SIBs). Nonetheless, the development of the SIB technology requires the discovery and the investigation of new electrode materials with reversible Na⁺ intercalation reaction. Several oxides have been considered as electrode materials for SIBs [1-3]. The low conductivity and pulverization are mainly responsible for their unsatisfactory performance. Recently, high porosity and aspect ratio of the active material have been demonstrated to facilitate the electrochemical processes resulting in improved electrode stability and enhanced specific capacity [1, 2]. Electro-spinning is a very simple, cheap and scalable and technique for the growth of highly porous one-dimensional nanostructures [2, 3].

This contribution deals with preparation, characterization and testing as anode material in SIBs of electro-spun iron oxide (Fe₂O₃) fibers. The fiber doping with silicon (Fe₂O₃:Si) is proposed as a strategy to improve the electrochemical material performance. Results of half-cell tests demonstrate that undoped Fe₂O₃ electrodes are able to deliver a reversible specific capacity of 100 (24) mAhg⁻¹ at 0.050 (2) Ag⁻¹. An outstanding improvement is obtained in Fe₂O₃:Si: specific capacity rises up 400 (120) mAhg⁻¹ at 0.050 (2) Ag⁻¹, with Coulombic efficiency close to 100%.

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The Phase Formation for Monodispersed Ultrathin NiPt Hollow Nanospheres

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Abstract

Ultrathin magnetic hollow spheres of NiPt alloy have been synthesized via a mild, green, solvothermal method. The phase formation mechanisms are studied in detail. For ultra-thin shelled hollow nanospheres, with the typical shell thickness of 2~3 nm, the phase formation can be better understood by a theoretical model proposed by Erlebacher et al.[1]. It involves the presence of nano-holes over the outer shell of the nanoparticles, favoring the outflow of atoms from within the particle surface exposed to the surrounding acidic environment. On the other hand, the commonly known Kirkendall effects do not apply in the present work. They are the mechanism to the phase formations of hollow nanospheres in the high temperature reaction, or in the long-time reaction at room temperature [2-4]. The present work lays down an important base to understand the synthesis of ultra-thin shelled nanospheres in nanoscale.

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Vacancies vs. Magnetic Doping for Optoelectronic Properties of Lead-halide Perovskites

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Abstract

Nanostructures of lead-halide perovskite materials exhibit exceptional optoelectronic properties for photovoltaic and light emitting applications. Fabrication procedure can be accompanied by intentional or spontaneous formation of defects and doping. State of the art computational modeling of photo-induced processes in the defected and doped lead halide perovskite materials allows to identify favorable composition and morphologies responsible for optimal performance of perovskite-based devices. The nonadiabatic molecular dynamics is implemented in basis of non-collinear spin density function theory for the account of spin-orbit coupling for the non-radiative dynamics of photo-excited states [1]. The on-the-fly nonadiabatic couplings obtained from the trajectory provide parameters for density matrix equation of motion for electronic degrees of freedom of perovskite nanostructures. The dynamics of electronic degrees of freedom allows to assess range of key observables: rates of charge transfer at perovskite-to-contact nanointerface [2], role of quantum confinement for multi-exciton generation in perovskite quantum dots [3], and suppression of photoluminescence due to defect-induced trap states [4].

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A Facile Route of Making Nanostructures for Fabrication of Broadband Omnidirectional Anti-reflective Surfaces by Self-assembly of High Molecular Weight Block Copolymers

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Abstract

Nanostructured surfaces that engineer the interaction between incident light and an object are a topic of both scientific and manufacturing significance. Nature routinely produces nanostructured surfaces with fascinating properties, such as antireflective moth eyes, self-cleaning lotus leaves, colorful butterfly wings, and water harvesting desert beetles. We now understand such properties and can mimic some of these natural structures in the laboratory. However, these synthetic structures are limited in the real industrial world since they are not easily mass produced over large areas due to the limited scalability of current technologies such as UV-lithography, the high cost of infrastructure and the inability to pattern non-planar surfaces. Here, we report a solution process based on high molecular weight block copolymers (BCP) self-assembly that allows the fabrication of sub-wavelength structures on large areas of optical and curved surfaces with feature sizes and spacings designed to efficiently scatter visible light. Si nanopillars (SiNPs) with diameters of $\sim 115 \pm 19$ nm, periodicity of 180 ± 18 nm and aspect ratio of 2-15 show a reduction in reflectivity by a factor of 100, $< 0.16\%$ between 400-900 nm at AOI 30° . Significantly, the reflectivity remains below 1.75% up to incident angles of 75° . The BCP nano-patterning capabilities avoid previous 'inherent' size limitations, make exceptional surfaces for improved transparency, light focusing, antireflection and for tuning photon absorption for a variety of applications on a wide range of surfaces, materials and non-planar substrates. This technique facilitates fabrication of a high density ordered array of nanopillars with tunable height, which are easily scalable and can be formed at low temperature. Compared to nanocones and other 'black' silicon layers, broadband antireflection coatings may now be possible for flexible PVs, solar cell technologies, and for broadband elimination of reflection of high quality glass optics.

OptiNanoPro: Novel Nanocomposites and Nanocoatings and their Applications in Solar Panel Processing Lines

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Abstract

In terms of solar energy, contributing to the multifunctionality and efficiency of solar panels, nanocomposites and nanocoatings are of relevance either in the photoactive layers, in protective layers, or on the surface of the solar panels. The electro-hydrodynamic processing (EHDP) techniques are of particular interest as an alternative to conventional deposition and coating techniques since the latter ones require a controlled pressure and temperature environments. Compared to other deposition techniques, electrospray deposition (ESD) offers the advantage of a high deposition efficiency (up to 80%) and a reduction of the process steps. The EHDP has been applied in several fields, mostly at a lab or a pilot scale. Although there have been some industrial efforts to scale up the electrospinning process, it has only been more recently that both techniques, i.e., electrospinning and electrospraying, have been scaled up via multinozzle injectors to an industrial level through companies such as Bioinicia S.L. Through OptiNanoPro project nano-enhanced coating has been applied by electrospinning. This technology has been used to obtain both self-cleaning OPVs and product repellent surfaces (with tailored repellence to selected liquids) for easy emptying packaging. Bioinicia S.L. has achieved materials with tailored polarity including super hydrophobic properties but also amphiphobic ones, a quite peculiar behavior that is much less reported in the literature. The process required a novel multistep approach that has been patented by Bioinicia S.L. on how to use electro-hydrodynamic processes for obtaining stable layers with target characteristics.

Interfacial Engineering of Semiconductor Hybrids for Water Oxidation

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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.

Molecular Engineering of Side Chain Architecture of Conjugated Polymers Enhances Performance of Photovoltaics by Tuning Ternary Blend Structures

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Abstract

Here, we adopted a systemic approach of not only using the same donor chemical units in the two donor-acceptor (D/A) conjugated polymers with complementary light absorption (energy band gaps) but also varying the side chains architectures as a means of tuning the packing of these semi-planar conjugated polymers, thereby influencing the carrier transport and optimizing the PCE. We employed linear, branch and mixed linear-and-branch side-chain attached benzooxadiazole (BO) as the acceptor (A) units in poly[benzodithiophene-thiophene-benzooxadiazole] (PBDTTBO) conjugated polymers and monitored their interactions with poly[benzodithiophene-fluorothienothiophene] (PTB7-TH), both of which featured the same benzodithiophene (BDTT) donor (D) units. We found that incorporating a minor amount (10%) of D/A conjugated PBDTTBO with such side chains into the PTB7-TH with a fullerene allowed us to tune the packing of the two polymers and, thereby, enhance the PCEs of corresponding ternary blend devices; the PCE of the ternary blend device incorporating PBDTTBO with two branched-side chains, PTB7-TH, and PC₇₁BM increased to 11.4% from 9.0% for the device incorporating only the binary blend of PTB7-TH and PC₇₁BM—a relative increase of more than 25%. This approach of using side chain engineering to tune the structure of a minor conjugated polymer and, thus, influence the packing of another major conjugated polymer that features the same donor chemical units appears to be an effective means of preparing highly efficient polymer cells.

NIR-Responsive Photocatalytic H₂ Generation over NaYF₄:Yb,Tm/C₃N₄ NTs

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Abstract

The generation of hydrogen from water splitting using sunlight by employing semiconductor photocatalysis is expected to be a solution of global energy and environmental issues. Recently, graphitic carbon nitride nanotubes (C₃N₄ NTs), a fascinating conjugated polymer, has become a new research hotspot and attracted tremendous attentions as a metal-free and visible-light-responsive photocatalyst in the field of solar-energy conversion. How to effectively utilize infrared light is challenging as it occupies about 50 % of solar irradiation. In this work, a new NaYF₄:Yb,Tm/C₃N₄ NTs composite fabricated through a PVP-assisted surface coating was firstly applied in photocatalytic H₂ production under near-infrared (NIR) irradiation.

NaYF₄:Yb,Tm nanoparticles with optimal doping ratio of lanthanide ions was selected based on the light absorbance of C₃N₄ NTs and H₂ generation over C₃N₄ NTs under different monochromatic light. It was revealed that this nanostructure improved the upconversion UV visible energy transfer, thus enhanced H₂ evolution performance. The energy transfer process between NaYF₄:Yb,Tm and C₃N₄ were investigated to explore the nature of NIR-responsive photocatalysis of NaYF₄:Yb,Tm/C₃N₄ NTs. Our discovery highlights the potential of developing NIR-driven structural design of photocatalysts for energy and environmental-related applications.

Photocatalytic Activity of Ce Doped ZnO Films Prepared by Sol Gel Spin Coating Technique

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Abstract

The aim of present study is to enhance the photocatalytic efficiency of Ce doped ZnO films. Herein, different concentrations (1.0 at.wt%, 1.5 at.wt%, 2.0 at.wt%, 2.5 at.wt%) were used as dopants. Ce doped ZnO films were synthesized by sol gel spin coating technique on to the sapphire substrates. The prepared films were annealed at 550 °C for 2.5 hours. The prepared films were characterized by various techniques in term of structural, morphological, optical and photocatalytic properties. The detailed characterization confirmed the excellent crystallinity and revealed that ZnO nanoparticles had a hexagonal wurtzite structure with preferred orientation along (101) plane. Morphology of these films was carried using FESEM images and its rods- shaped morphology has high surface to volume ratio which is related to regular growth of crystalline grains with the grain size in the range of 30-60 nm. Raman peaks indicates the tensile stress existed in Ce-ZnO films. Further, the prepared Ce-doped ZnO films were used as photocatalyst application for photodegradation of methyl orange dye. The percentage degradation of Ce-doped ZnO films were found to be improved with increased Ce concentration from 1.0%-2.0% and further increase in Ce concentration doesn't lead to enhancement in percentage degradation. The optimum concentration is of 2.0 at.wt% exhibited almost complete photodegradation in 60 min under UV illumination. Kinetic studied revealed that all the Ce doped ZnO films follow first order kinetics. The value of pseudo first order constant was found to be maximum 0.05960 (min)⁻¹ for C₃-ZnO.

Nanotechnology and Nanosciences Session (Nano-Electronics)

Anatomy of Spin-Orbit Phenomena in Nanostructures Comprising Ferromagnetic and Nonmagnetic Materials for Advancing Spintronic Applications

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Abstract

Theoretical insights are provided into spin-orbit coupling based phenomena such as perpendicular magnetic anisotropy (PMA) [1-5] and Dzyaloshinskii-Moriya interaction (DMI) [6-9] at interfaces comprising transition metal and insulator, metal or graphene. First, the nature of PMA at Fe|MgO interfaces is unveiled by evaluating the orbital and layer resolved contributions to magnetic anisotropy in Fe/MgO interfaces and MTJs with different interfacial conditions [1-3]. Mechanisms of the optimization of the effective anisotropy as well as of its electric field control are discussed [3-5]. Next, the main features and microscopic mechanisms of DMI behavior are elucidated in Co/Pt and other Co/NM bilayers [6]. Furthermore, several approaches for DMI enhancement and manipulation will be presented including, in particular, physical mechanisms of DMI behavior in Pt/Co/MgO structures [7, 8] allowing observation of room temperature skyrmions [8]. The behavior of PMA and DMI will then be addressed for nanostructures comprising Co/graphene interfaces [4, 9] which may be of strong interest for graphene spintronics [10]. Finally, the mechanisms inducing the magnetism in graphene via magnetic insulators (MIs) proximity effect will be discussed including four cases of different magnetic insulators were studied: EuO, EuS, Cobalt Fe₂O₄ as well as yttrium iron garnet (YIG) [11, 12].

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Plasmonic In₂O₃ Nanocrystals as Multifunctional Materials: The Role of Dopant, Phase, and Electronic Structure

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Abstract

Synthesis, properties, and applications of gold and silver nanostructures with tunable localized surface plasmon resonances (LSPRs) have been a subject of intense investigation over the past decade. The focus on these noble metal plasmonic nanomaterials stems from their facile synthesis, relative stability, and the visible-range LSPR. However, among other drawbacks, these nanostructures are also costly for large-scale applications and exhibit high degree of optical losses due to electronic transitions. Consequently, doped transparent semiconductor and metal oxide nanocrystals have emerged as a new class of unconventional plasmonic materials. In this talk I will present the results of our recent work on colloidal indium oxide-based plasmonic nanocrystals, including structure-dependent plasmonic properties. I will also discuss colloidal synthesis and spectroscopic properties of several new plasmonic nanocrystal systems based on In₂O₃ and comparative investigation of their electronic structure using combined Drude-Lorenz model and density functional theory. Application of these colloidal mid-IR plasmonic nanocrystals will also be discussed. I will specifically focus on our recent results on robust electron polarization in degenerately-doped In₂O₃ nanocrystals, enabled by non-resonant coupling of cyclotron magnetoplasmonic modes with the nanocrystal exciton.

Hydrogenated Graphene for Surface Engineering and Transfer

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Abstract

Chemical functionalization dramatically alters the chemical and physical properties of graphene. For instance, extensive hydrogenation of graphene using a dissolving metal reduction essentially eliminates the material's electronic conductivity, but graphene can be recovered cleanly through either thermal annealing or mild chemical oxidation [1]. Partially hydrogenated graphene exhibits room temperature ferromagnetism by introducing unpaired spin centers onto the lattice [2]. Hydrogenating graphene also weakens the van der Waals force between graphene and substrate; as a result, hydrogenated graphene delaminates cleanly from a substrate, and we have used this feature to transfer chemical and physical properties of the functionalized graphene surface intact from one substrate to another. By combining this delamination with the reversibility of hydrogenation, we have developed a transfer protocol for chemical-vapor deposited (CVD) graphene that avoids polymers and chemical etchants, resulting in an ultraclean graphene surface, as corroborated by spectroscopy and optical and electron microscopy [3].

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Role of Anionic Surface Ligands in Photophysics of Quantum Dots

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Abstract

We present several examples, where calculations based on density functional theory (DFT) succeed in providing insights into photophysical properties of quantum dots (QDs) allowing for explanations of experimental observables sensitive to surface defects and ligand passivation. Thus, our calculations reveal much more complicated exchange mechanism of the native surface ligands of CdSe QDs with phenyl-dithiocarbamates (PTCs) as it was thought before. PTCs decompose during exchange with native ligands, while only a small portion of deprotonated PTCs covalently binds to the Cd-enriched surface. Additionally, the surfaces of CdS and CdSe QDs facilitate deprotonation of thiol ligands to thiolate with proton attached to surface S or Se. However, full deprotonation results in thiolate-localized midgap trap states, while 1:1 mixture of thiols and thiolates/H on the QD surface increase intensity of the lowest energy states. Our calculations also reveal that attachment of the hydride to Se sites results in strong distortions of Cd-Se bounds leading to 'cleaning' out of extra Se ions from the QD surface (in a form of SeH_2 gas) and eliminating Se-associated trap states. On the other hand, adsorption of H^- on Cd, when the surface is enriched by metal ions, results in blue-shifted lower-energy transitions with very high oscillator strength, which likely responsible for experimentally observed emission enhancement of CdSe QDs treated by hydrides. Overall, our calculations provide insights into the surface chemistry of QDs and offering guidance for controlling optical response of nanostructures by means of ligand engineering.

Preparation of New Core-shell Type $\text{cLiYF}_4: \text{Yb}^{3+}/\text{Er}^{3+}/\text{Ho}^{3+}/\text{Tm}^{3+}@\text{LiYF}_4: \text{Yb}^{3+}$ Upconversion Nanoparticles for Biomedical Applications

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Abstract

In this study, the new core/shell type of the upconversion nanoparticles (UCNPs) $\text{LiYF}_4: \text{Yb}^{3+}, \text{Er}^{3+}, \text{Tm}^{3+}, \text{Ho}^{3+}@\text{LiYF}_4: \text{Yb}^{3+}$ were successfully synthesized. By varying the composition and concentration of the activators (including Er^{3+} , Ho^{3+} , Tm^{3+}) and the concentration of the sensitizer Yb^{3+} in the shell, the effect of the intensity of luminescence with the activators and the sensitizer could be compared. Dynamic light scattering (DLS) measurement exhibited that the particle sizes before coated with the shell was about 60-70 nm, and the size was about 90-100 nm after coated with the shell. Photoswitch tests revealed that the spiropyran molecules were successfully coordinated to the oleic acid-coated UCNPs. After irradiated with UV light, spiropyran was converted to merocyanine. It was found that the absorption band around 580 nm of merocyanine overlapped with the 540 nm emission band of the UCNPs. Photoluminescence (PL) measurements confirmed that the merocyanine form located on UCNPs could quench the green-light emission of the UCNPs through the Fluorescence Resonance Energy Transfer (FRET). In the biosensing test of the UCNPs, it was found that the fluorescence intensity of the UCNPs was quenched by the formation of electron-holes on the surface of UCNPs, hence the fluorescence intensity of the UCNPs decreased with the increase of the concentration of Hg^{2+} . After adding glutathione (GSH) to the above solution, the S- Hg^{2+} complexes were formed, and the concentration of Hg^{2+} was reduced. Therefore, the intensity of the fluorescence increased with the increase of the concentration of GSH.

Applications of Four-dimensional Electron Microscopy in Nanomaterials

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Abstract

Using 4D electron microscopy by combining the nanometer spatial resolution of electron microscopy with the femtosecond temporal resolution of fs laser pulses and electron pulses we have investigated ultrafast phenomena of nanomaterials. Our goals are to elucidate their structures, dynamics and novel physical properties for potential applications in solving important energy, environment and biomedicine related issues. In one of our Science papers, we applied ultrafast scanning electron microscopy (USEM) to study photoinduced carrier dynamics across semiconductor p-n junctions. We observed fast charge separation of electrons and holes at the p-n junction and their extremely fast ballistic dynamics, contrary to the familiar diffusive carrier transport. We attributed such observed phenomena to slow electron-phonon collision time on the surface and also to polarity-dependent gating mechanism at the junction. In our other Science and also Science Advances papers, we demonstrated novel applications of ultrafast transmission electron microscopy (UTEM) of nanoparticles in liquid solution. We have discovered

very fast anomalous Brownian motion of gold nanoparticles upon fs laser excitation. Unlike the well-known Einstein's theory of Brownian motion with linear time dependence for the mean square displacement, the observed dynamics exhibits several kinds of power time dependence, covering ballistic, super-diffusion as well as the normal diffusion regimes. Moreover, the corresponding diffusion constant is four orders of magnitude greater than same nanoparticles in the absence of laser excitation. We elucidated the impulsive driving forces on gold nanoparticles as caused by water vapor nanobubbles generated by pulsed laser heating. In another work published recently in *Angew. Chem Int.* we applied the PINEM (photon-induced near field electron microscopy) technique to investigate human cancer cells. We could unfold the protein receptor conformations on the surface of cancer cell membranes which are characteristically different from the normal cells. We have also used 4D electron diffraction, published much earlier in *Nature Comm.*, we demonstrated that the whole crystallization processes of a TiO₂ thin film, from melt, via nucleation to crystal formation, could be visualized and investigated during the crystal growth.

Glucose Sensing and Bioenergy Harnessing

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Abstract

We describe herein the construction of a glucose biosensor system that senses glucose without the use of potentiostat and harness usable electrical energy from glucose to power a digital electronic device simultaneously. This system is powered by a single enzymatic glucose biofuel cell comprising a highly dense mesh network of multi-walled carbon nanotubes and enzymes that results in the immobilization and direct electrical connection of the enzymes. The bioanode is functionalized with pyroloquinoline quinone glucose dehydrogenase, while the biocathode is functionalized with bilirubin oxidase. The glucose biofuel cell assembly and its performance were investigated under physiological conditions (pH 7.4 and 37 °C) at which a maximum open circuit voltage of 548.2 mV, short circuit current density of 7.19 mA/cm² and peak power density of 1.475 mA/cm² were obtained in 20 mM glucose. The nominal electrical power generated from the single glucose biofuel cell (~ 548 mV) was amplified to 3.2 V using a two stage electrical power amplification circuit and a capacitive element functioning as a glucose transducer. The self-powered glucose biosensor exhibited a linear dynamic range of 1 mM to 45 mM and a high sensitivity of 92.51 Hz/cm².mM when simultaneously sensing glucose and powering a glucometer. Additionally, the system demonstrated excellent operational stability over a 53-day period.

Sub-20 nm Corner Lithography Based on Digital Etching of a-Si

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Abstract

Corner lithography is an emerging 3D-nanopatterning technique, with demonstrated use in the wafer-scale fabrication of nanofluidic devices (e.g., fluidic probes for SPM, particle and cell traps, micro-mixers) [1-4], and potential use in NEMS, nanoelectronics and energy storage and conversion devices. In its most basic form it consists of a combination of conformal deposition and isotropic thinning of the deposited layer, leaving residues in sharp concave corners. These residues can be used as structural material, or as mask material in a subsequent etching or LOCOS based inversion step. In a self-multiplying fabrication scheme it has been used for the fabrication of octahedral 3D-fractal structures [5].

Here we introduce a procedure to scale down corner lithography to the 10 nm level, based on the LPCVD of amorphous silicon (a-Si), followed by an accurate and uniform procedure for isotropic thinning based on repeated oxidation and HF etching. The rationale behind the use of a-Si in combination with "digital etching" [6] is the need for high uniformity in composition and thickness of the deposited layer as well as its isotropic thinning. It is shown that due to the self-stopping nature of both the wet-chemical oxidation (in 69% HNO₃ solution at 95 °C) and subsequent 1 % HF etching of the silicon oxide formed, the thinning of the a-Si layer is uniform and well controlled, with an effective thinning of around 0.5 nm per cycle. Sub-20 nm a-Si patches created by corner lithography are used to pattern an underlying silicon nitride layer.

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The Synthesis and Application of Highly Sensitive Fluorescent Probes

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Abstract

Fluorescent probes have attracted great attentions for merits of photostability, biocompatibility and selectivity. To further improve the sensitivity of fluorescent probes, we constructed series of core-shell nanostructures for biosensing and bioimaging. With the strategy of plasmon-enhanced fluorescence (PEF), fluorescence emission can be highly enhanced owing to the larger and stronger electromagnetic fields at sharp tips of nanostructures. The nanostructures we constructed include the cores of nanorods, nanobipyramids, nanoprisms, and nanocubes, etc., with different “hot spots”, and applied them to the detection of pyrophosphate, microRNA, single nucleotide polymorphisms, and real-time monitoring of polymerase chain reaction products [1-3]. Besides, we developed a PEF-based single-molecule probe to avoid the limitation of the average effect and reflected the single molecular message directly [4]. Moreover, we explored a molecular beacon sensor based on plasmonic-enhanced single molecular fluorescence and realized in situ imaging of intracellular telomerase. To develop environmentally friendly fluorescent probes, we also studied DNA-sequence-dependent fluorescent copper nanoparticles and designed a smart DNA three-way junction to achieve fast, direct, label-free, enzyme-free and versatile detection of SNPs at room temperature [5]. The highly sensitive fluorescent probes we synthesized show potentials in biological detections.

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A High-integration Sensor Array Sensitive to Oxynitride Mixture

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Abstract

There are many methods to detect mixed gas components at present, including metal oxide semiconductor sensor arrays, nanomaterial based adsorptive sensor arrays, gas chromatographs, and spectrometers and so on, but they are limited by high operating temperature, low integration, slow response and serious overlap of characteristic absorption spectrum of different components. Here, we report on a high-integration carbon nanotubes sensor array with two different electrode separations. The array is comprised of a large carbon nanotube array cathode, two extracting electrodes and two collecting electrodes and worked at non-self-sustaining discharge state, which was determined by the study on current-voltage characteristic of a double-electrode structure sensor. Through studying the relationship between gas concentration of oxynitride mixture and discharge currents at 1 atm, we obtained the distinct sensitivities of a binary mixture in the concentration ranges of 0–1166 ppm NO and 0–712 ppm NO₂ using the array at low operating voltages and 60 °C. Collecting currents of the two sensors decreased with increasing NO and NO₂

concentration in the gas mixture. The repeatable characteristics and dynamical response tests of the sensors were also conducted. The proposed sensor array has potential for the direct detection of a mixture without separating the mixed gases.

Innovation of Magnetic Properties Using Au Nanoparticles

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Abstract

An enhancement of magneto-optical (MO) characteristics in the magnetic materials is one of the promising ways to develop novel physical applications in functional materials. In this study, our target material is TbFeCo magnetic thin film, which is known to be one of the conventional MO materials. By utilizing self-organized Au nanoparticles as an underlayer of TbFeCo thin film, we attempted to enhance MO characteristics of TbFeCo. We confirmed that self-organized Au nanoparticles exhibit localized surface plasmon resonance (LSPR) phenomena, such that an increase in the electric field in the vicinity of each Au particle can be expected. As a consequence, enhancement of MO characteristics of TbFeCo could be possible due to strong electric field between TbFeCo/Au interfaces.

We formed self-organized Au nanoparticles on Si substrates. Afterward, TbFeCo thin film was prepared on the Au nanoparticles. The samples were prepared through the magnetron-sputtering technique. In the present study, we formed Si₃N₄ (10 nm: capping layer)/TbFeCo (various thickness: MO layer)/self-organized Au nanoparticles (5 to 10 nm in diameter: LSPR layer)/Si substrate structures.

The magnetic properties and polar-Kerr characteristics were compared concerning the samples with/without Au nanoparticle underlayers. The properties were largely affected by Au nanoparticle underlayers. Coercivity of TbFeCo thin film was decreased when the Au nanoparticles were used as an underlayer of TbFeCo, whereas MO angle was drastically increased. Magnetic domain structures of the samples with/without Au nanoparticle underlayers were different. We consider that these results are owing to interaction between TbFeCo magnetic thin film and self-organized Au nanoparticles.

Graphene/Half-metallic Heusler Alloy: A New Heterostructure towards High-performance Graphene Spintronic Devices

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Abstract

Due to the extraordinary properties such as high carrier mobility, weak spin-orbit coupling and unique band structure of graphene, graphene-based spin transistor, magnetic random access memory and magnetic field sensor were proposed for ultrafast, low-power consumption spintronic devices for next generation. In those reported graphene-spintronic device, conventional ferromagnet such as Ni, Co, Fe with low spin polarization have been used due to the well-established synthesis method of graphene on them. However, the low spin signal and tiny magnetoresistance effect reported in those system are very disappointing and makes the graphene still far from being considered for real spintronic device application. Adopting highly spin-polarized material such as half-metal can be the most effective way to improve the performance of graphene spintronics device, the experimental demonstration, however, is still lacking.

This study, for the first time, presents a successful synthesis of graphene by high-vacuum chemical vapor deposition on a half-metallic Co₂FeGe_{0.5}Ga_{0.5} (CFGG) Heusler alloy whose half-metallicity has been confirmed experimentally. We confirmed the high-quality epitaxial growth of single layer graphene directly on CFGG. Strikingly, a detail investigation of the electronic structure of the graphene/CFGG heterostructure reveals the physical nature of the interface between graphene and CFGG, which makes the graphene/Co₂FeGe_{0.5}Ga_{0.5} heterostructure unique from other graphene/ferromagnet (Ni, Co, Fe, Permalloy) heterostructure with a chemical interface bonding so far. The features of high spin polarization of CFGG Heusler alloy together with the quasi-freestanding nature of graphene make the graphene/CFGG heterostructure extremely promising for high-performance spintronic devices.

A Discrete Resistance Change in the 3D Nanostructured Metal Oxide due to the Nano-confinement Effect

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Abstract

Functional oxides with strongly correlated electron system, such as vanadium dioxide, manganite, and so on show first-order metal-insulator phase transition (MIT) with a change in conductivity by several orders magnitude. Since a discovery of the phase separation during MIT process, many researchers have been trying to capture a nanoscale electric domain and investigate its exotic properties. To understand exotic nanoscale electronic domain properties and utilize their superior properties as device functionalities, the three-dimensional (3D) nano-structuring is one of the most effective approaches. We report the construction of the well-defined 3D metal oxide nanowall wire (nw), which allows the direct investigation of its insulator-metal transition (IMT) at the single domain scale. A single electronic nanodomain exhibited an intrinsic first-order IMT with an unusually steep single-step change in its magnetoresistance and temperature-induced resistance. The special confinement effect is discussed in terms of the reduction in the number of elements due to an IMT.

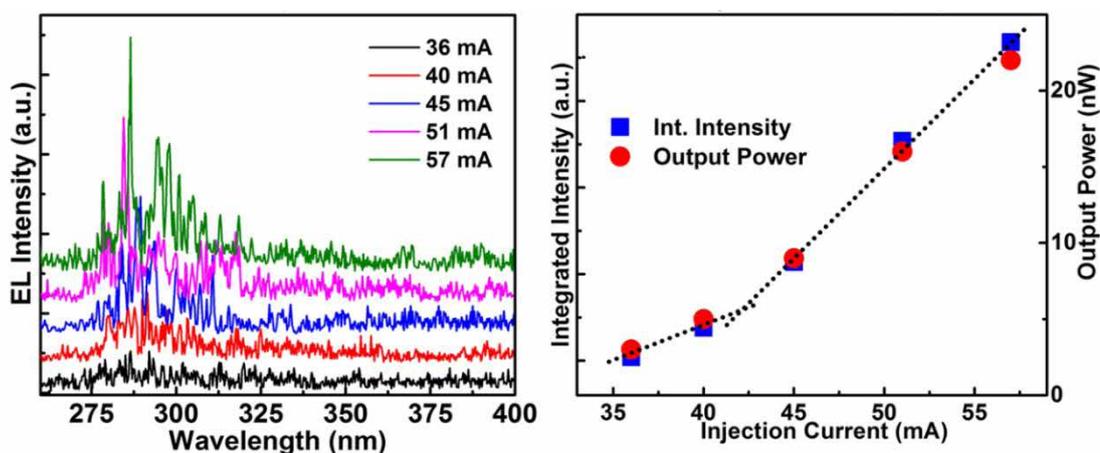
ZnO-based Low Dimensional Structures for Ultraviolet Photodetectors and Light Emitting Devices

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Abstract

Low dimensional ZnO structures, such as nano/micro-wires and quantum dots, have been paid considerable attentions during last decades due to their facile preparation processes, abundant morphologies and superior photoelectronic properties. Here, we report the fabrication and characterization of UV photodetectors and light emitting devices based on ZnO low dimensional structures. Self-powered UV photodetectors was fabricated through combining ZnO nano/micro-wires with p-Te microwire or p-PANI. Heterojunctions were formed and then contributed to the separation of photogenerated electron-hole pairs under 0 bias. Thanks to the heterojunction, the self-power device shows fast response speed with rise time < 0.1 ms and decay time < 1 ms, which is much faster than that of ZnO based photoconductive one. In additionally, deep UV random lasers were realized based on MgZnO nano-crystals. The grain sizes are in the range of 130~300 nm. This kind of morphology facilitates effective light scattering for the formation of random laser cavities. The lasers are operated with continuous current mode at room temperature and the shortest wavelength reaches 284 nm with very low threshold current densities of 33 A/cm². Our results demonstrate that ZnO low dimensional structures have promising applications in UV optoelectronic devices.



Nanotechnology and Nanosciences Session (Life Sciences & Medicine)

Acoustic Nanofluidics

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Abstract

Acoustic waves have found new utility in microfluidics in recent years, providing an enormously powerful ability to manipulate fluids and suspended particles in open and closed fluid systems. In this talk, we cover some fundamental and powerful concepts of acoustic wave generation and propagation often overlooked in the literature and follow it with exploration of new phenomena observed at the nanoscale, terming it acoustic nanofluidics. The utility of acoustic waves at the micro-scale is even more compelling at the nano-scale, in many ways not predicted by classical theory. Particle deagglomeration, fluid pumping, pattern formation, and other curious physical phenomena will be shown in the context of potentially useful nanoscale applications. Along the way, the fascinating underlying physics tying together the acoustics, fluid dynamics, and broader physical phenomena appearing in these systems will be described.

Alzheimer's Disease and Nanotechnology. Novel Drug Treatment Strategies

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Abstract

Alzheimer's disease (AD) inflicts more than 5 million Americans for which no suitable therapeutic strategy is available till today. Recent evidences show that neprilysin (NPL), the rate-limiting enzyme for amyloid-beta peptide (AbP) play key roles in the pathogenesis of AD. In this investigation we explored the role mesenchymal stem cells (MSCs) and cerebrolysin (CBL, a combination of neurotrophic factors and active peptide fragments) in relation with NPL in AD. We used TiO₂-nanowired of MSCs and CBL on NPL content and brain pathology in AD using a rat model comprising intraventricular (i.c.v.) administration of AbP (1-40) in the left lateral ventricle (250 ng/10 µl, once daily) for 4 weeks. Co-administration of TiO₂ nanowired MSCs (106 cells) with 2.5 ml/kg CBL (i.v.) once daily for 1 week after 2 weeks of AbP infusion significantly increased the NPL in hippocampus (400 pg/g) from untreated control group (120 pg/g; Control 420 ± 8 pg/g brain) along with significant decrease in the AbP deposition (45 pg/g from untreated control 75 pg/g; saline control 40 ± 4 pg/g). Neuronal damages, gliosis and myelin vesiculation were also markedly reduced by the combined treatment of TiO₂, MSCs and CBL in AD. However, these changes were significantly less evident with MSCs or CBL treatment given alone. These observations suggest that co-administration of TiO₂-nanowired CBL and MSCs induces superior neuroprotection in AD through increasing the brain NPL level effectively. Further studies are needed to explore clinical value of these findings.

The Forthcoming Renaissance for Calcium Phosphate Nanoparticles in Biomedicine

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Abstract

Calcium phosphate was selected throughout the evolution for the mineral component of the vertebrate skeleton. Its comprising the foundations of our bodies has served as an invaluable inspiration for materials scientists who have attempted to discover in this material more potential than meets the eye. Efforts are currently being made to expand the application repertoire of calcium phosphates beyond their use as traditional bone fillers or tissue engineering construct components that impart osteoconductivity and high compressive strength. The application of calcium phosphates for sustained drug delivery, gene and anticancer therapies, antibiofilm coatings and hard tissue regeneration has been intensely explored recently. In this talk I will show that calcium phosphate nanoparticles could be chemically designed to take on the role of bone growth factors, antibiotics for prophylactic or anti-infective purposes, bisphosphonates as antiresorptive compounds, viral vectors to enable the intracellular delivery of therapeutics, and magnetic hyperthermia agents. Correspondingly, nanoparticulate calcium phosphates could: (a) produce tunable drug release profiles; (b) take the form of viscous and injectable, self-setting pastes; (c) be naturally osteoinductive and inhibitory for osteoclastogenesis; (d) intracellularly deliver bioactive compounds; (e) accommodate an array of functional ions; (f) be processed into macroporous constructs for tissue engineering; and (g) be naturally antimicrobial. All in all, calcium phosphates possess a protean nature whose therapeutic potentials have been barely tapped into.

Nanomaterials: From Fiction to Reality. Examples of Liposomes as Drug Nanocarriers and Polymer based Nanocomposites

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Abstract

The fast and large developments of nanotechnology over the last three decades, have led to: production of nanomaterials that are now being used in different fields. Indeed; the new approach to materials science, i.e.: the “bottom-up” approach and the development of new synthesis pathways and techniques, allowed production of “tailor-made” molecules that could be designed for specific applications. These nanomaterials spread out to many scientific and technologic fields, notably in materials science, in catalysis and in medicine. The examples of two types of nanomaterials based on polymers will be discussed:

1-smart nanocarriers used for drugs delivery and targeting. These nanocarriers ranging from liposomes, to polymeric nanospheres and micelles, are now used for cancer treatment. These drugs nanocarriers helped the emergence of what is now called “Nanomedicine”. Polymeric materials are suitable for the design of many drug nanocarriers because of the ease of their synthesis; the versatility of their particle forms, and the soft conditions of their processing. Typical polymer examples will be presented to illustrate this type of nanomaterials.

2-polymer nanocomposites are now industrially produced and used for high performance applications. Carbon nanotubes and clay nanoparticles are widely used as reinforcing agents to enhance mechanical and thermal properties of polymer composites. For instance, It has been found that a load of 5% /wt. of clay, will induce an increase of 50 °C of the melting temperature of some polyolefin based composites (such as Polyamide and Polypropylene). Other examples of polymer nanocomposites will be presented.

Impact of Cerium Oxide Nanoparticles Shape on their *in vitro* Cellular Toxicity

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Abstract

Cerium oxides (CeO₂) nanoparticles, also referred to as nanoceria, are extensively used with a wide range of applications. However, their impact on human health and on the environment is not fully elucidated. The aim of this study was to investigate the influence of the CeO₂ nanoparticles morphology on their *in vitro* toxicity. CeO₂ nanoparticles of similar chemical composition and crystallinity were synthesized, only the shape varied (rods or octahedrons/cubes). Macrophages from the RAW 264.7 cell line were exposed to these different samples and the toxicity was evaluated in terms of lactate dehydrogenase (LDH) release, Tumor Necrosis Factor alpha (TNF-α) production and reactive oxygen species (ROS) generation. Results

showed no ROS production, whatever the nanoparticle shape. The LDH release and the TNF- α production were significantly and dose-dependently enhanced by rod-like nanoparticles, whereas they did not vary with cubic/octahedral nanoparticles. In conclusion, a strong impact of CeO₂ nanoparticle morphology on their *in vitro* toxicity was clearly demonstrated, underscoring that nanoceria shape should be carefully taken in consideration, especially in a “safer by design” context.

Clickable' Recombinant Spider Silk and its Healthcare Applications

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Abstract

Spider silk including recombinant forms is a biomaterial of significant interest for medical and other applications due to both its mechanical properties (tensile strength and toughness) and its biocompatibility. We have recently reported the preparation of antibiotic and fluorophore functionalized silk fibres self-assembled from the miniaturized major spidroin protein 4RepCT derived from the dragline silk of the South African nursery web spider, *Euprosthenoops australis* [1]. This has been achieved through the site-specific incorporation of the un-natural, bio-orthogonally functionalized amino acids L-azido-homoalanine (Aha) and L-homopropargylglycine (Hpg) in the mini spidroins. The Aha residues can be selectively and efficiently modified with ligands bearing alkyne groups using either a copper (I) catalysed azide alkyne cycloaddition (CuAAC) or strain promoted azide alkyne cycloaddition (SPAAC) 'click' reaction.

We have demonstrated that we can functionalize the silk proteins with fluorophores, pep-tides and with the broad spectrum antibiotic levofloxacin. The antibiotic has been attached via a glycerol ester that is cleaved either through a drop in pH or by esterases released by *E. coli* as they grow. The 4RepCT3Aha proteins can be modified either prior to or after silk fibre assembly and the tensile strength of the resulting fibres is unaffected. This has allowed fibres decorated with two or more different ligands in defined ratios to be prepared. The antibiotic functionalized silk fibres prevent *E. coli* growth for at least 5 days demonstrating good potential for future use in medical dressings. Additional applications of the functionalized silks in re-generative medicine will also be presented.

Reference

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Multifunctional Scaffold Based on Hydrogel-incorporated Nanofiber

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Abstract

In this study, we describe a simple method for fabricating micropatterned three-dimensional polymeric fibrous scaffolds that are capable of controlling the spatial positioning of mammalian cells and proteins. Photopatterning of poly(ethylene glycol)(PEG) hydrogel on the electrospun nanofibers produced micropatterned nanofiber matrices made of hydrogel microwells filled with a nanofibrous region, which is capable of generating cell and protein micropatterns due to the different interactions that cells and proteins have with PEG hydrogels and nanofibers. Different proteins and could be immobilized onto resultant micropatterned nanofiber scaffold, carrying out cell patterning, metabolite.

Nanomaterial Based Drug Delivery Systems for Local Immunomodulation in Pancreatic Cells Transplantation

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Abstract

We aim to deliver immunomodulatory drugs locally and in a sustained manner in pancreatic islet grafts to target

macrophages and cytotoxic T cells and improve graft outcomes. We previously developed amphiphilic block copolymers made of poly (ethylene glycol)-poly (propylene sulfide) (PEG-PPS) and poly (ethylene glycol)-oligo (ethylene sulfide) (PEG-OES) that self-assemble into micelles and nanofibers able of loading hydrophobic drugs without chemical conjugation. Here, we are applying those nanomaterials as drug delivery systems (nDDS) to improve solubility, stability, and absorption of the antiinflammatory dexamethasone (Dexa) and of the immunosuppressant cyclosporine A (CsA). We found that PEG44-PPS20 micelles and PEG44-OES5 nanofibers can load both CsA and Dexa allowing controlled drug release with an efficiency and at a rate that is dependent on the chemical composition and on the density of the nDDS hydrophobic cores. Dexa can be released over a period of 6-8 hours, while CsA can be released within 7-14 days. Furthermore, we found that nDDS/Dexa and nDDS/CsA decrease macrophage viability (and cytokine production) and cytotoxic T cell activation, respectively without affecting islet viability and glucose-stimulated insulin secretion. Tunable drug release demonstrates the versatility of our nanomaterials as drug delivery systems for decreasing macrophage-mediated inflammation in the first hours after cell transplantation and for dampening T cell activation and proliferation during the first 7-14 days after islet transplantation, when T-cell mediated rejection occurs. Therefore, our nDDS platform can address the current challenges of islet transplantation in type 1 diabetes by providing local immunomodulation that could reduce the need of chronic immunosuppression and improve graft outcome.

Plasmonic Nanogaps: Sensing Metabolites as Signatures of Biological Processes

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Abstract

Nanoparticles from colloidal solution – with controlled composition, size, and shape – serve as excellent building blocks for plasmonic devices and metasurfaces. However, understanding hierarchical driving forces affecting geometry of oligomers and interparticle gap spacings is still needed to fabricate high density architectures over large areas. Here, I will present how electrohydrodynamic (EHD) flow is used as a long-range driving force to enable carbodiimide crosslinking between nanospheres yielding control of gap spacing in oligomers with sub-nanometer precision over mm² areas. Plasmonic nanogaps produce uniform surface enhanced Raman scattering (SERS) response with billion-fold enhancements at low integration times and laser power.

This enables incorporation of nanogaps into in-line microfluidic devices for early detection of bacterial biofilms. During biofilm formation, density-dependent gene expression is regulated; a mechanism called quorum sensing (QS). Once developed, bacterial biofilms often exhibit resistance mechanisms such as efflux pumps, which specifically pump out antibacterial molecules and can withstand up to 1000 times higher doses of antibiotics than their free floating planktonic counterparts. While new antimicrobial strategies are being developed to combat antibiotic resistance, here we investigate a promising parallel strategy, sensing QS molecules for early detection of biofilm formation at a stage where antibiotic treatment has higher efficacy. Here we show that by analyzing SERS response with machine learning algorithms, we are able to differentiate bacterial metabolites in the complex soup of biological media at concentrations down to pg/mL and detect the presence of pyocyanin in supernatant from *Pseudomonas aeruginosa* cultures as early as three hours after seeding due to high signal enhancements by plasmonic nanogaps. Surface-attached bacteria exposed to a bactericidal antibiotic were differentially less susceptible after 10 h of growth, indicating that these devices may be useful for early intervention of bacterial infections.

Nanodelivery of Drugs and Antibodies for the Novel Treatment Strategies of Parkinson's Disease

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Abstract

Parkinson's disease (PD) induced afflicts more than several million Americans for which no suitable therapeutic strategies has emerged so far. Intraperitoneal injections of 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridin (MPTP, 20 mg/kg) daily within 2 h intervals for 5 days in mice induce PD-like symptoms on the 8th da showing significant decrease in dopamine (DA), 3,4-dihydroxyphenylacetic acid (DOPAC) and homovanillic acid (HVA) as well as decrease in tyrosine hydroxylase (TH) positive cells in the Substantia Nigra Pars Compacta (SNpc) and striatum (STr) is seen. We used timed release of cerebrolysin CBL-a well-balanced composition of several neurotrophic factors and active peptide fragments) with titanate nanospheres (TiNS) together with antibodies of alpha synuclein (a-SNL) for treating PD in mouse model. TiNS-CBL (3 ml/kg, i.v.) given after 2-days of MPTP administration for 5 days resulted in a marked increase in TH-positive cells in the SNpc and STr and enhanced DA, DOPAC and HVA levels in SNpc and STr. This effect was further potentiated when co-administration of TiNS-CBL and antibodies to a-SNL (1:20, 25 µg in 50 µl) was given together indicating its therapeutic value in clinics.

Chitosan/imipenem based Nano-constructs to Combat Resistant Clinical ISOLATES: Fabrication and *In-vitro* Study

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Abstract

The global emergence of metallo-β-lactamase (MBL) producing bacterial pathogens has rendered the current therapeutic options ineffective. This perturbing situation requires an inventive strategy to stop the dissemination of MBL producers and their associated infections. The present investigation reports the fabrication and evaluation of bio-based nano-carrier system carrying imipenem, a carbapenem representative, as a therapeutic tool against resistant pathogens. Empty chitosan nanoparticles (CSNPs) and drug loaded CSNPs were generated by ionic gelation method. Both nano-dispersions had mean particle size of less than 100 nm as confirmed by Atomic Force Microscopy (AFM) based analyses. The stability of nano-colloidal system was affirmed by positive zeta potential of more than +50 mV. Encapsulation efficiency of imipenem varied from 45–64% as a function of drug concentration at the time of ionic gelation. FTIR studies confirmed that the drug was entrapped inside CSNPs by simple electrostatic interactions between active molecule and polymer. The imipenem loaded CSNPs displayed a significant activity *in vitro* against the MBL producing pathogens including *Escherichia coli*, *Klebsiella pneumonia* and *Pseudomonas aeruginosa* for at least five days, whereas the ordinary drug fails to control them.

Fluorescence Lifetime Imaging Microscopy (FLIM) for Monitoring Mitochondrial Protein Localization and Shuttling with Sub-diffraction Resolution

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Abstract

Cellular metabolism is highly compartmentalized. This prevents interference of opposing biochemical pathways and therefore enables the maintenance of specific physicochemical environments. Especially mitochondria, placed center stage in many aspects of cell biology and medicine, provide numerous microcompartments. Trafficking of proteins in response to specific stimuli is essential for mitochondrial function and hence for cellular vitality. For instance, the quality control enzyme PTEN induced putative kinase 1 (PINK1) shuttles between the cytosol as well as the outer mitochondrial (OMM) and inner mitochondrial membrane (IMM). However, due to the small size of mitochondria (0.5–1 µm), protein localization in different mitochondrial microcompartments, as well as protein translocation over time, is not accessible by conventional microscopy. Here, we demonstrate that time-correlated single-photon counting (TCSPC) fluorescence lifetime-imaging microscopy (FLIM) of monomeric fluorescent proteins (FPs) classifies not only mitochondria but protein localization in different mitochondrial and cellular compartments. We found that membrane-associated FPs have a shorter fluorescence lifetime than soluble forms. In mitochondria, localization of mCitrine in the matrix as well as in the OMM and IMM could be distinguished by

significant differences in fluorescence lifetime τ . The method was sensitive enough to monitor shifts in protein location between mitochondrial microcompartments. We suggest that FLIM is a versatile and non-invasive method to monitor spatiotemporal events in mitochondria. Time domain sensitivity allows for gaining substantial information about sub-mitochondrial localization overcoming diffraction limitation.

Enhancing Immunity and Disease Resistance in Fish by Chitosan-Selenium Nanoparticles

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Abstract

Selenium nanomaterials are attracting increasing attention due to unique bioactivity and low toxicity compared with traditional selenium species. In this work, chitosan stabilized selenium nanoparticles (CTS-SeNPs) was developed using controlled reduction of sodium selenite at room temperature with food grade materials. Suitability of CTS-SeNPs as an immunostimulant was explored. Zebrafish (*Danio rerio*) were exposed to 0, 2, 5, 10 and 20 $\mu\text{g/g}$ of dietary CTS-SeNPs for 9 days. Their immune response and resistance to bacterial infection were determined. At 5 $\mu\text{g/g}$ and 10 $\mu\text{g/g}$ CTS-SeNPs, these fish showed improved survivorship when challenged by a common aquaculture pathogen *Aeromonas hydrophila*. Moreover, lysozyme activity (1.8-fold) and respiratory burst (2.4-fold) were all significantly enhanced at 10 $\mu\text{g/g}$ CTS-SeNPs. In term of adaptive immune responses, lymphocyte (T cell and B cell) proliferation and immunoglobulin M expression were also improved at 10 $\mu\text{g/g}$ CTS-SeNPs. CTS-SeNPs showed better immunostimulant properties than chitosan and selenite. These results showed that CTS-SeNP is a good immunostimulant for fish species.

Novel fibroin-based Nanoparticles for Cancer Chemotherapy: Development and Characterization

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Abstract

Fibroin, a silk human-biocompatible protein, has demonstrated remarkable properties including toughness, elasticity, as well as biodegradability. Taking these advantages, we conducted a study to formulate and determine the properties of novel fibroin nanoparticles (FNP) as a potential drug delivery system for cancer chemotherapy. Using coacervation method, with the addition of the crosslinker 1-ethyl-3-(3-dimethylaminopropyl) carbodiimide (EDC), three FNP formulations namely FNP, FNP-EDC_{low} and FNP-EDC_{high} were fabricated by varying the content of EDC. Interestingly, all formulations showed nanosize spherical particles of approximately 300 nm, with the charge ranging from -15 mV, FNP and FNP-EDC_{low} to +30 mV as the amount of EDC increased, FNP-EDC_{high}. Using transmission electron microscope, the FNP-EDC_{high} particles were tighter packed due to extensive crosslink reactions as compared to the FNP-EDC_{low}. Also, FNP with no EDC demonstrated some aggregation between particles. In addition, utilizing FT-IR, the shift of characterized amide I peak at 1646 cm^{-1} in raw fibroin to 1622 cm^{-1} was observed in all formulations, suggesting a transformation from silk I (random coils and α -helices amorphous structure) to silk II structures (anti-parallel β -sheet crystalline structure). The results from DSC and XRD methods were in agreement with FT-IR. In addition, the degree of crystallinity was increased as follows; FNP < FNP-EDC_{low} < FNP-EDC_{high}. Finally, combine all data, the possible structures of the novel nanoparticles have been proposed.

Nanoscale Vesicles and Microspheres Derived from the Self-assembly of a Water-soluble Polyamides

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Abstract

Water-soluble polyamides is a kind of eco-friendly materials and has a natural advantage in packaging materials, water-based

coating and drug carrier fields etc. In this work, a novel water-soluble polyamides were synthesized via melt- polycondensation with glutaric and bis (2-aminopropyl ether). The chemical structures of the polyamides were ascertained by FTIR and H-NMR. The thermal properties were measured by TGA and DSC, all the polyamides do not crystallize which contributes to water solubility. According to POM, TEM, SEM and PST, it was found that one kind of the polyamides can self-assemble into nano-size vesicles, which is very suitable in drug deliver applications. In addition, another polyamide can self-assemble into micron solid spheres, and this spheres display a unique pH stimulation response characteristic, which is attributed to the hydrogen-bonded ether bonds. The solid spheres is very promising in intelligent devices applications.

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