MAT
(Advanced Materials and Nanotechnology)
3D Indefinite Metamaterial Nano-Cavities with Anomalous Scaling Law

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SUMMARY
We report the first experimental demonstration of nanoscale optical cavity based on indefinite metamaterial structure with anomalous scaling law.

I. INTRODUCTION
Metamaterials allow for extraordinary electromagnetic properties not attainable in nature. In particular, indefinite medium with unique dispersion finds its intriguing applications such as sub-diffraction optical imaging. On another hand, emerging optical micro cavity plays a key role in modern optoelectronics. Miniaturization of optical cavities effectively increases the photon density of states and therefore enhances light-matter interactions, which is critical for ultrafast optical modulators and low power light sources. However, scaling down of optical cavity is not only limited to the diffraction limit, but more importantly, the quality factor rapidly vanishes with its size.

II. RESULTS
Here we experimentally demonstrate a 3D nanoscale optical cavity made of indefinite metamaterial confining electromagnetic field into an extremely small space. The experiments revealed indefinite cavities possess unprecedented properties with anomalous scaling law, for example, cavities with different sizes can resonant at the same frequency and a higher order resonance mode oscillates at a lower frequency in a given cavity. In contrast to conventional cavities, we observed the quality factor of indefinite cavities increases as the size shrinks. We further found a universal 4th power dependence of the quality factor of the cavity on the wave vector. The optical cavity with size down to $\lambda/12$ is realized and unnaturally high refractive index of 17.4 is experimentally obtained which are far beyond that of naturally occurring materials and of critical importance for applications such as optical imaging, slow light, photolithography, and transformation optics.

Figure 1: a. SEM image of the perspective view of indefinite optical cavities array with the cavity size of (170,150) nm. b. SEM pictures of three different cavities with sizes of (135, 100) nm, (170, 150) nm, and (200, 200) nm. c. FTIR measured transmission spectra through the indefinite optical cavities array with 5% cavity area filling ratio for cavities with different size (width, height) combinations.

III. CONCLUSION
Such 3D indefinite cavities of nano-scale open a new possibility for exciting applications in cavity quantum electrodynamics, optical nonlinearities, biosensing and optical communications.

REFERENCES
SUMMARY
Graphite nanoplatelets (GNP) as received and after an oxidation treatment were added as second phase particles to an epoxy resin with the use of a mechanical mixer. A series of these epoxy composite samples were fabricated ranging from 0 to 5 wt% GNP. Compression tests were applied to quantitatively determine the strength of the material. Also, the samples’ damage and microstructure were analyzed using tomography and SEM.

I. INTRODUCTION
For structural applications, epoxy resins provide useful mechanical properties, such as the following: a high modulus, high mechanical strength, low creep, and good performance at elevated temperatures. However, epoxy resins by itself also possess limitations due to their brittle behavior. As a result, the addition of GNP in the epoxy resin is meant to increase the sample’s toughness and alleviate some of these brittle behavior issues.

II. EXPERIMENTAL
A. Samples Manufacturing
In this research, the GNP used were tested with one set as received and another set experiencing an oxidation treatment. The epoxy composites were fabricated by mixing a 1.7 to 1 ratio of the mixing Epon 828 (resin) with Epikure 3055 (curing agent). In addition, GNP was added to fabricate samples possessing 0.1 wt% GNP, 1.0 wt% GNP and 5.0 wt% GNP. Once mixed, the samples were left to cure for 16 to 18 hours at room temperature and an additional 2 hours at 95°C.

B. Compression Test
Three cylindrical samples were prepared for each composition. The samples’ height would be grinded to the diameter size (approximately 11.5 mm) using silicon carbide papers of grit ANSI 200 and ANSI 400. Compression tests were conducted in an Instron 4411 machine at a crosshead speed of 1 mm/min.

C. X-Ray Micro-tomography and SEM
The equipment used was a Desktop Micro CT-System (Skyscan 1072), run at the high resolution mode with projections from 0.1° to 180°. The reconstruction was obtained using the Skyscan-NRecon Software. Also, a JEOL JSM 6700R in a high vacuum mode was used for SEM. A gold layer was added using a Hummer 6.2 system.

III. RESULTS
Table 1 displays the mean compressive strength for each composition tested. The overall trends from the compression tests displayed that the highest compression strengths occurred at 0.1 wt% and 1.0 wt% with a decrease at 5 wt. From x-ray micro-tomography, the structural damage reduced as the GNP content increased. Also, the fracture modes were relatively the same when comparing the as-received GNP samples with the oxidized GNP samples.

<table>
<thead>
<tr>
<th>Sample (GNPs contents)</th>
<th>Mean compressive strength (MPa)</th>
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<tbody>
<tr>
<td>Ref</td>
<td>130 ± 5</td>
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<tr>
<td>0.1% GNP</td>
<td>140 ± 5</td>
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<tr>
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<td>120 ± 5</td>
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<td>5.0% Ox GNP</td>
<td>70 ± 5</td>
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REFERENCES
Analysis and Application of carbon nanotube resonator

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SUMMARY
In this study, we investigate the CNT-based angular-velocimeter for measuring angular velocity via classical molecular dynamics (MD) simulations and the classical continuum theory.

I. INTRODUCTION
The properties of CNTs under axial strains have been intensively investigated via quantum mechanics, classical MD simulations and continuum theory [1]. The proposed CNT-based angular-velocimeter is based on the frequency change of the CNT-resonator due to the rotation-induced centrifugal force.

II. ANALYSIS METHOD
Therefore, we plot the frequency shift (Δf) as a function of the angular velocity for the different inner CNTs as symbols in Fig. 1. The solid line curves of different CNTs, optimized by using analytical calculations, are in excellent agreement with the results obtained from the MD simulations. The resonance frequency shifts linearly decreased with the compressive axial strains, and that such a property could be applied to a pressure sensing. This study shows that the resonance frequency shifts increase with increasing the tensile axial strains, and that this property gives a possible application of the angular-velocimeter. All cases, except for the (8, 2) CNT, are found in the same trend curves. This exceptional result of the (8, 2) CNT can be understood by the axial strain-induced torsion of the (8, 2) CNT that is coupling between the axial strain and torsion strain.

REFERENCES

Fig. 1 The frequency shift (Δf) as a function of the angular velocity of different inner CNTs.
Development of Environmentally Benign Deep Silicon Etching Using C₄F₆ Plasmas in the Deposition Step of the Bosch Process

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Dry etching of high aspect ratio features of silicon is a key process in the fabrication of silicon-based microelectromechanical systems (MEMS) devices. The Bosch process, which is also known as a gas-chopping etching or time-multiplexed deep etching, is widely used to realize deep silicon etching. The Bosch process is a cyclic process, consisting of alternating etching and deposition steps.

SF₆ and C₄F₈ are mainly used in the etching and deposition steps of the Bosch process, respectively. However, C₄F₆ (octafluorocyclobutane) is perfluoro carbon (PFC), which is considered to be problematic from an environmental point of view because of its long atmospheric lifetime, high global warming potential, and strong infrared absorption.

Originally, PFCs have been extensively used as etchants for silicon and silicon dioxide in microelectronics industries. Due to the Kyoto protocol, the PFC emission reduction is much more strongly required. This forces the microelectronics industries to investigate environmentally benign chemistries as alternatives to PFCs including unsaturated fluorocarbons (UFCs) such as hexafluoro-propene (C₃F₆, CF₂=CF-CF₃), hexafluoro-1,3-butadiene (C₄F₆, CF₂=CF-CF=CF₂), octafluorocyclopentene (C₅F₈), etc, and study their etch characteristics. Although many efforts have been made to study alternative chemistries to PFCs in the fabrication of microelectronics devices, there are few reports on the use of UFCs for the Bosch process in the fabrication of MEMS devices.

Hexafluoro-1,3-butadiene (C₄F₆, CF₂=CF-CF=CF₂), which is one of the unsaturated fluorocarbons (UFCs), has been chosen as an environmentally benign alternative to PFCs in this study. Deep silicon etching using C₄F₆ and C₄F₆ plasmas in the deposition step of the Bosch process, respectively, was compared to show a feasibility of the use of UFC plasmas in the Bosch process. The characteristics of the fluorocarbon polymer films and radicals produced in each plasma were investigated to elucidate corresponding etch profiles.

The use of a C₄F₆ plasma in the deposition step was found to affect the etch profiles due to different characteristics of the fluorocarbon films and radicals from a C₄F₈ plasma. OES measurements showed that more CF₂ radicals were produced in a C₄F₆ plasma, resulting in the higher deposition rate of the fluorocarbon film in a C₄F₆ plasma than that in a C₄F₈ plasma. On the contrary, the fluorocarbon film deposited in a C₄F₆ plasma was etched slower, compared to a C₄F₈ plasma, because of the lower F/C ratio of the fluorocarbon film deposited in a C₄F₆ plasma, confirmed by XPS measurements.

Finally, by changing only the duration of the deposition step under the same process conditions, highly anisotropic silicon etching was successfully achieved in both SF₆/C₄F₆ and SF₆/C₄F₆ plasmas.
Experimental Studies on the Determination of Hydrogen distribution between Structure alloys and Alkali metal, 400 < T (°C) < 700.

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SUMMARY
Determination of the hydrogen solubility and transport behaviors for the BCC alloy and alkali metals has been conducted. This study has been focused for the forth coming hydrogen energy in the area of nuclear fusion, hydrogen fuel cell with the CHP (combined heat and power) along with the possible chemicals productions. Current studies has been done a low hydrogen partial pressure at 400-700°C as for the demonstration.

I. INTRODUCTION
In the hydrogen economy era, it is essential that concerns on the hydrogen storage, and feeding as fuel. Since we have experienced the currently developed hydrogen fuel cells, i.e., operation temperatures between ambient temperature and near 100°C; thus when it designed high power, it needs to be cooled down the system not to exceeding the operating electrolyte temperatures (T < 100°C). It is one of the handicaps for the PEM FC. However, for the SOFC case the operation temperatures are varies depend on the adapting electrolytes; for the stabilized zirconia, such as CSZ, YSZ (700-1050°C) or other Ceria based doped electrolytes (650-850°C). Therefore current studies has been focused for fitting to the effective fuel cell design those have been considered USD-DOE’s Energy Efficiency in the category of CHP (Combined Heat and Power-in this case fraction of thermodynamic reaction enthalpy, ΔH and devising effective devising to mining the reaction free energy, ΔG in the form of electricity, ΔG = nFΔE from the hydrogen and/or from the various hydrogen sourcing fuel from the gasification or reforming process, such as NG major CH4), CG (Coal gas CO, CO2, H2O, and H2). In the hydrogen economy era, it is essential that concerns on the hydrogen

II. EXPERIMENT
Details can be found in the reference. BCC metal tube with plugs samples has been performed to employ the highly hydrogen permeable and alkali metal compatible BCC metals as for the alkali metals container. After making the equilibrium at a given T, the hydrogen desorption has been controlled by raising T by supplying high electric current, e.g., 125-AC amperes, ½ inch diameter. Ta tube letting the hydrogen desorption from the samples.

III. RESULTS

![Figure 1: Determination of hydrogen amounts by desorption from the equilibrium phase.](image)

REFERENCES
Elastic Conductors from Nanoparticle Composites with Self-Organized Conductive Pathways

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SUMMARY
Elastic conductors from nanoparticles were demonstrated with exceptional properties and relevant conduction mechanism was also enlightened.

I. INTRODUCTION
The development of nanotechnology has the potential to transform traditional flat and rigid electronics into novel concepts of flexible and elastic electronics with unprecedented levels of performance. Successful realization of elastic electronics would be able to do many things on integrating human-machine interfaces that rigid and brittle wafer-based electronics cannot. Stretchable electronic skin can be used as linkage points that connect an artificial hand to the nervous system. Portable devices can be resilient; they could be worn like clothing rather than carried. Neural probe circuit that conforms to the surface of brain can help neuroscientists to understand the electrical signals that occur in the brain. For the realization of applications, many aspects of elastic electronics still need to be improved. The most urgent need, however, is found on the rigid and brittle electrodes. Problems mostly derived from brittleness of indium tin oxide (ITO) limit advantages of stretchable electronics and raise demand for an alternative to ITO. 1,2

II. RESEARCH DESIGN AND HYPOTHESES
A logical approach to making elastic conductor is to combine high aspect ratio and conductive nanoscale elements such as carbon nanotubes (CNTs) with polymer matrix. This approach was productively realized but also has critical limitations: metallic conductivity is impossible without challenge, and properties are irreproducible and anisotropic. For these reasons we investigated the possible alternative to high aspect ratio strategy to make elastic conductors from specially synthesized metallic nanoparticles (NPs) and judiciously chosen polymer matrix with following hypotheses: 1) percolating (conducting) path can be restructured to mimic high aspect ratio materials during stretching, because NPs has high degree of freedom to move 2) metallic conductivity can be reliably reached and 3) conductivity and strain will be isotropic regardless of stretching directions.3

III. RESULTS AND DISCUSSION
We achieved listed hypothetical advantages through the organized material processing strategies layer-by-layer (LBL) assembly. Also, to highlight the significance of specific structural aspects of the elastic conductors, we obtained composites from an aggregation layering method. Enlightening conduction mechanism and dynamics of NPs in the composites make this research unique, because elastic conductors from NPs are rarely demonstrated and understood. Significance of this research project can be found on two realms: exceptional properties and unique research design strategies. The field of biomedical can be the one that needs highly elastic, conductive, and curvilinear shape of materials which will enable innovations in surgical operations and human-machine interfaces.

REFERENCES
Crystallography of Functional Nanomaterials
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Functional properties of nanomaterials are well known, and yet the synthesis-structure-property relationship needs to be further studied to tailor the properties. The functional properties in energy and environment of these materials will be presented to illustrate the crystallographic relationship.

The best source of clean energy is believed to be the sun. Titania, as an excellent photosemicoductor and photocatalyst, has a great potential to contribute to the green energy technology. For an efficient photcatalytic reaction, high surface area is one of the prime goals in synthesis of nanomaterials. In the synthesis of titania nanoparticles in an aqueous medium, entrapment of extraneous protons in the crystal lattice can affect the catalytic properties. In this presentation, the way to extract the protons without sacrificing the surface area will be presented.

Energy storage is another critical area for the green energy. High permittivity materials have been used for capacitors and for storage electrical charges. In this talk, synthesis and fabrication of barium titanate nano-material and its composite structure with enhanced energy storage will be presented as an example.
Laser deinsulation of Parylene-C coated Utah electrode array

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SUMMARY
Parylene-C coated electrode tips of UEA are deinsulated for the collection of electrical signal from neuron. The UEA has adapted anisotropic oxygen plasma etching (OPE) by inductive discharge system as deinsulation method. But there is a disadvantage; nonuniformity of opened area of deinsulated tips. It leads to a high variation of impedance value between exposed tips consequently. This report presents results from laser deinsulation performed in Utah electrode tips. The value of impedance and XPS peaks showed that the Parylene-C was removed clearly. The resistance for the fracture tendency by laser power was studied according to different film thicknesses. The thicker one showed better tolerance of fracture and laser deinsulation was found to be an effective method to etch Parylene-C film.

I. INTRODUCTION
Utah electrode arrays (UEAs) are designed to measure or stimulate neural action potentials from central or peripheral nervous system. The measured signals can be used for applications including control of prosthetics (recording), and stimulation of proprioceptive percepts. The UEAs are coated with biocompatible Parylene-C, and the electrode tips are deinsulated to expose the iridium oxide tip coating used to transduce neural signals. In conventional UEA technology, the electrode tips are deinsulated by poking the electrodes through aluminum foil followed by an oxygen plasma etch of the exposed areas. However, this method has challenges with the poking through aluminum foil, uniformity, repeatability, and is time consuming. In this regard, we focus on laser tip-deinsulation technology for producing repeatable, uniform, less time consuming tip exposure method for UEAs.

II. EXPERIMENTS
The surface morphology and roughness of deinsulated area was examined by scanning electron microscope (SEM) and atomic force microscope (AFM). The condition of deinsulated surface was characterized by electrode impedance, X-ray photoelectron spectroscopy (XPS).

III. RESULTS
The optimized laser fluence, number of pulse and a higher thickness of iridium film resulted in clean iridium oxide surface on the electrode tips without any damage. The value of the impedance measured on ~64 um exposed tip was 43 kΩ which is very acceptable for a recording/stimulating electrode.

![Figure 1. SEM images of laser deinsulated Utah electrode tip.](image)

IV. CONCLUSION
The thicker film of iridium in electrode tip was used to make up for the weakness of film for the laser. It contributed the high tolerance of film fracture against high laser energy density. The electrode impedance was in the range of tens kΩ. The value is suitable for recording and stimulation the neural signal with sufficient exposure of the Parylene.

REFERENCES
Noncovalent functionalization of hydrophobic graphitized carbons using 1-Pyrene carboxylic acid and their use for catalyst supports in PEM fuel cells

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SUMMARY
The functionalization agent of 1-pyrene carboxylic acid (PCA) was used to functionalize CNFs and the effect of functional groups on the electrochemical properties was examined. The functionalization of CNF with PCA improves the distribution and loading of Pt as well as reduces the sintering of Pt particles. From the carbon corrosion test, unlike the oxidative acid treatment, a PCA treatment sustains the corrosion resistance of CNFs.

I. INTRODUCTION
In recent years, electrochemical oxidation of carbon supports in the corrosive conditions of polymer electrolyte membrane (PEM) fuel cells, especially during repeated start up/shut down procedures, has been considered to be a major contributor to the degradation of performance [1].

To alleviate this problem, substantial efforts have been devoted to discover corrosion-resistant catalyst supports. Among the various alternatives, graphitized carbon types, such as carbon nanofibers (CNFs) and carbon nanotubes (CNTs), have been studied extensively. However, there are two critical issues when applying this type of graphitized carbon as a catalyst support: (1) the homogeneous distribution of Pt particles on the carbon supports and (2) the sintering effect. Consequently, uniform and high dispersion of Pt catalysts on these carbon supports are eventually prohibited. Thus, the hydrophobic to hydrophilic conversion can be made via chemical oxidation by refluxing concentrated acidic solutions. This effect contributes to an even dispersion of small Pt particles and enhanced Pt content. However, it has been reported that this acid treatment method, unfortunately, damages the desirable properties of the CNFs, and as a result, it accelerates the electrochemical carbon corrosion [2]. To avoid these problems, a recent strategy to functionalize graphitized carbons using small organic bifunctional molecules by forming noncovalent π-π interactions has attracted particular interest.

In this work, we report a facile and novel method to synthesize Pt catalyst supported on noncovalently functionalized CNFs with 1-pyrene carboxylic acid. PCA enhanced the distribution of the particles without interacting with the Pt; PCA does not need to be removed prior to fuel cell applications. The remaining PCA on the surface of CNFs behaves as a barrier for Pt nanoparticle migration and decreases the sintering effect. Additionally, this non-destructive PCA treatment preserves the corrosion resistance of the CNFs.

Figure 1: HR-TEM images of Pt nanoparticles supported on a PCA-CN

REFERENCES
SUMMARY
Pt-embedded segmented Sb$_x$Te$_y$ and Bi$_x$Te$_y$ nanowires with controlled composition and dimensions were synthesized by a templatedirected electrodeposition method at room temperature. Prior to the synthesis of segmented nanowires, single Sb$_x$Te$_y$ and Bi$_x$Te$_y$ nanowire were electrodeposited in order to investigate the composition, morphology and crystal structure of each nanowires. Dimensions of synthesized nanowires from AAO template and polycarbonate membrane indicated a good uniformity with the diameter of 300nm and 80nm, respectively. Composition of Bi and Sb in nanowires was controlled by applying different current density or potential in electrodeposition and changing the concentration of electrolyte. The electrical properties of the synthesized nanowires such as temperature-dependent resistivity, FET mobility, temperature coefficient of resistivity and activation energy were investigated.

I. INTRODUCTION
Hydrogen (H$_2$) is being widely used in various applications including chemical production industry and fuel cells. Because of its explosive and flammable nature, however, an efficient and reliable H$_2$ gas sensor is needed for safety in use.

With the increase of interest of a H$_2$ gas sensor, it is required to be small, cost effective, and operated at near room temperature. However, conventional H$_2$ gas sensors require to operate at high temperatures (e.g., 400°C) with low selectivity. Recently, there are a few different types of H$_2$ gas sensors that have been reported with great selectivity. However, there are still limitations, such as large sized devices and requirement of high operating temperature.

REFERENCES
Fabrication of nanostructures by electrochemical processes

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SUMMARY

We made use of two electrochemical processes, electroplating and galvanic displacement reaction (GDR), to fabricate various nanostructures of metals and metal composites. Electroplating was used to fill in thin porous membranes and to acquire nanowires. We then applied GDR on the electroplated nanowires with various chemicals and obtained new nanostructures with different compositions and structures.

EXPERIMENTAL RESULTS

Electroplating has been a simple and easy electrochemical process to coat various materials on metallic surfaces. Due to the rapid advances in the technology in 1990’s it has been implemented in the fabrication of nanostructures including sensor elements[1] and metallic interconnects of semiconductor devices[2]. Fig. 1 shows a typical Cu interconnect structure and multilayered Cu/Co nanowires prepared by the method.

Figure 1: Cu interconnect structures (70-120 nm) and Cu/Co multilayered nanowires (200 nm).

GDR is another electrochemical process which can be used to manipulate material properties. It makes use of the difference in redox potentials between ions in an electrolyte and a sacrificial material[3]. We have attempted to convert the electroplated nanowires to different species of materials by using GDR. The sacrificial material was composition-modulated nanowires. Fig. 2(a) shows a electroplated NiFe wire with alternating Ni-rich and Fe-rich segments. GDR of the wire with ions of Sb and Te changed the composition to SbTe with alternating wire diameters. The diameter variation arised from the difference in redox potentials, and thereby exchange rates, between Ni and Fe.

We also tuned NiFe segments as to vary the relative contents of Ni and Fe in a continuous manner, as shown in Fig 3(a). Applying similar GDR process with Bi and Te ions, we obtained BiTe wires whose diameter changed gradually in proportion to the compositional variations, as shown in Fig. 3(b).

We think the fabrication procedure combining electroplating and GDR could be a useful tool to engineer new structures in nano-science and nanotechnology.

REFERENCES

Synthesis of One Dimensional Tellurium Branched Hollow Nanofibers and Their Room Temperature Gas Sensing

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SUMMARY

In this study, we describe the synthesis of 1-D branched Te hollow nanofibers combining electrospinning and galvanic displacement reaction (GDR). The morphology and wall thickness of as-synthesized 1-D Te hollow nanofibers could be controlled by varying electrolytes concentration. Furthermore, the as-synthesized 1-D branched hollow Te nanofibers showed the excellent sensitivity to different target analytes at room temperature and a fast response time compared to Te films.

I. INTRODUCTION

In recent years, 1-D hierarchical nanostructures have been considered as a very promising material for gas sensor applications because a very high surface area provides abundant chemical reaction sites for gas sensing and the rapid gas diffusion over the entire sensing surface.

Despite the excellent gas sensing properties of 1-D hierarchical nanostructures, most metal oxide gas sensors using hierarchical nanostructures require elevated temperatures. Recently, Te thin film- and dispersed 1-D Te structure-based gas sensors have been reported as high performance gas sensor devices operable at room temperature.

Tellurium is a narrow band gap (0.35 eV) p-type semiconductor with an anisotropic crystal structure consisting of helical chains. Various chemical methods have been developed to synthesize 1-D Te nanostructures. However, most of methods require complex procedures, relatively high temperatures and long reaction times.

One of the promising methods to overcome the problems of previous reported method to synthesize the 1-D nanostructure is the galvanic displacement reaction (GDR). GDR is a simple and versatile route to control the size, morphology, and composition of synthesized nanomaterials at near ambient conditions. This reaction is a spontaneous electrochemical reaction due to the electrical potential difference between the sacrificial materials and the other metal ion in the electrolyte.

In this study, we describe a simple and rapid route to synthesize the 1-D hollow Te nanostructures by GDR. Moreover, the gas sensing properties are investigated and compared using the as obtained 1-D branched Te hollow nanofibers with consideration of different morphologies.

REFERENCES


Nanopatterned Thermo-Responsive Polymer Brushes and Self-Assembled Monolayers for Biofouling Studies

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SUMMARY

Biofouling, the unwanted accumulation of biomolecules, cells (including microbes) and attaching organisms upon submerged surfaces, is a devastating problem in many industrial, marine and medical applications. For example, fouling of ship hulls increases the drag, power usage and thereby decreases fuel efficiency of ships. It is estimated that fouling costs the US navy in excess of one billion dollars per year.[1] In addition, biomedical devices and implants are often accumulated by infectious bacteria.

Most of the recent research in the biofouling arena is focused on developing fouling release and fouling resistant coating. Our studies are focused on developing new and efficient model approaches to reduce biofouling using two specific systems; (1) use of self-assembled monolayers (SAMs) with nanoscale chemical heterogeneity, and (2) use of nanopatterned surfacess that can exhibit both biocidal activity and fouling release ability to investigate the influence on marine microbial adhesion and release.

In our studies, interferometric lithography (IL) was used as a convenient direct means of patterning of silane and thiol SAMs over large areas. In general, IL utilizes two coherent beams that are made to interfere to produce a periodic patterned distribution of their intensity. Using IL, width of patterns can be easily changed by the angle of interference of the two coherent beams. First part of the research uses nano-patterned thiol SAMs to examine the effect of chemical nanoheterogeneity onattachment of marine microbes. Thiol SAMs (e.g., CH3 group terminated) which can be easily formed on Au were photo-oxidized using IL, and back-filled with contrasting thiol (e.g., OH or NMe2 terminated). Using IL and proper combination of thiols, we were able to produce patterns with feature sizes in the range of 150nm-1000nm. Bacterial attachment and release studies will be conducted on these surfaces to test if periodic change in surface chemical properties with the size of bacteria would reduce biofouling.

Second part of the research uses surface grafted stimuli-responsive (poly(N-isopropylacrylamide) (PNIPAAm)) brushes which exhibits a reversible surface hydration change in response to change in temperature above and below ~32°C. PNIPAAm brushes were synthesized using ARGET (Activators ReGenerated by Electron Transfer) ATRP (Atom Transfer Radical Polymerization) from patterned ATRP initiator immobilized surfaces. The nanoscale space intervals between the polymer brushes were backfilled with biocidal agent, (e.g., quaternary ammonium salt silane (QAS)). In this system, QAS exhibits the surface antibacterial activity, while PNIPAAM brushes facilitate the release of dead bacteria.

Formation of thiol SAM and polymer brush nanopatterns were verified using X-ray photoelectron spectroscopy (XPS), atomic force microscopy (AFM), scanning electron microscope (SEM), and contact angle measurements studies. Our preliminary results showed that different AFM friction images and contact angle measurement results were obtained for photooxidized SAMs on Au with exposure to second thiolate species than unpatterned dodecane thiol. We are presently investigating the effect of marine bacterial adhesion on thiol SAM nanopatterns using C.marina model bacteria. Also using Nanopatterned surface grafted PNIPAAm brushes coupled with biocidal compounds, it was possible to resist and also release the surface attachment of infectious bacteria.

Acknowledgements

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REFERENCES

Development of Diffusion Barriers for U-Mo Metallic Nuclear Fuels

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SUMMARY

Uranium-Molybdenum (U-Mo) dispersion and monolithic fuels are being developed as low enrichment metallic fuel system under the Reduced Enrichment for Research and Test Reactor (RERTR) Program [1]. This paper highlights the development of diffusion barrier layer (Zr or Mo) between U-Mo fuel and Al matrix alloy based on fundamental investigation of solid-state diffusion.

I. INTRODUCTION

The U-Mo dispersion and monolithic fuels are being developed as low enrichment metallic fuel system under the RERTR Program [1]. Metallurgical interactions occur between the U-Mo fuels and Al alloy matrix/cladding during processing and irradiation due to interdiffusion [2]. Extensive studies [3-5] have been carried out to investigate these complex interactions. Zirconium (Zr) and Molybdenum (Mo) have been proposed as a potential barrier layer between U-Mo fuel and Al alloy cladding.

II. RESULTS AND DISCUSSION

In order to investigate the compatibility and barrier effects between U-Mo alloy and Zr, solid-to-solid U-10wt.%Mo vs. Zr diffusion couples were assembled and annealed at 600, 700, 800, 900 and 1000 °C for various times. Intermetallic phase Mo2Zr was found at the interface and its population increased when annealing temperature decreased. Diffusion paths were also plotted on the U-Mo-Zr ternary phase diagram with good consistency. The growth rate of interdiffusion zone between U-10wt.%Mo and Zr was also calculated under the assumption of parabolic growth, and was determined to be about 10^5 times lower than diffusional interaction layer found in diffusion couples U-10wt.%Mo vs. Al or Al-Si alloy.

Solid-to-solid diffusion couples, U vs. Mo and U-10wt.%Mo vs. Mo, were assembled and annealed in the temperature range from 600 to 1000°C for various times. Interdiffusion coefficient and its activation energy in U-Mo alloy were determined in the composition range from 2 to 32 at.% Mo. A Kirkendall marker plane was clearly identified in each U vs. Mo diffusion couple, and intrinsic diffusion coefficients, tracer diffusion coefficients, atomic mobilities and vacancy wind parameters of U and Mo at the marker composition were estimated. The growth rate of the interdiffusion zone between U-10wt.%Mo vs. Mo was also calculated, which is 10^5 times lower than that in U-10wt.%Mo vs. Al and U-10wt.%Mo vs. Al-Si systems, which suggests that Mo could be an effective barrier.

Other desirable physical properties of Zr and Mo as barrier material, such as neutron adsorption rate, melting point and thermal conductivity are presented as supplementary information to demonstrate the great potential of Zr and Mo as the diffusion barrier in RERTR U-Mo fuel systems as listed in Table 1.

Table 1: Desirable properties of Zr and Mo for RERTR diffusion barrier applications.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Mo</th>
<th>Zr</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interdiffusion Rate*</td>
<td>x 10^{-5}</td>
<td>x 10^{-3}</td>
<td>-</td>
</tr>
<tr>
<td>Intermetallic Formation</td>
<td>UMo2 below 600°C</td>
<td>Mo2Zr</td>
<td>UAI2, UAI3, UAI4, U2MMAI43, UMo2Al20</td>
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<tr>
<td>Melting Point (°C)</td>
<td>2623</td>
<td>1855</td>
<td>660</td>
</tr>
<tr>
<td>Neutron Absorption (Barn)</td>
<td>2.48</td>
<td>0.18</td>
<td>0.22</td>
</tr>
<tr>
<td>Thermal Conductivity (W/m•K)</td>
<td>138</td>
<td>22.6</td>
<td>237</td>
</tr>
</tbody>
</table>

* Relative to U-Mo vs. Al interdiffusion

REFERENCES

SUMMARY
Using density functional theory (DFT), we found that the ZnO nanoplate has magnetism even at room temperature, which was confirmed by experiment.

I. INTRODUCTION
Although it is known that bulk ZnO is a non-magnetic material, the electronic band structure of ZnO is severely distorted when the ZnO is in the shape of a very thin plate with its dimension along the c-axis reduced to a few nanometers while keeping the bulk scale sizes in the other two dimensions. In this letter, we report a surprising observation of magnetism in ZnO nanoplates with very high aspect ratios of a few hundreds to a thousand.

II. DETAILS IN DFT COMPUTATION
The electronic band structure of the ZnO nanoplates was calculated for various thicknesses using the density functional (DFT) [1] theory with general gradient approximation and the Hubbard potential (GGA+U) method [2]. In order to investigate the magnetic property, the plane-wave based DFT was performed with the spin polarized GGA+U method, which ensures appropriate electron correlations hybridization.

The surface reconstruction was achieved through geometry optimization in which atomic positions are relaxed via an energy minimization. Since the atomic structure in a nanoplate would be different from that in the bulk phase crystal structure due to the nearness of the surfaces on both sides, the atomic positions in a nanoplate adjusted through geometry optimization can be different from those in the bulk phase. For comparison, the band structure of the ZnO bulk phase and a ZnO nanowire were also calculated using the same method and parameters.

III. RESULTS AND DISCUSSION
As shown from the band structure and spin density of state in Figure 1, we found 1) no band-gap; 2) a growing asymmetry in the spin distribution within the distorted bands formed from Zn (3d) and O (2p) orbitals with the reduction of thickness of the ZnO nanoplates. This theoretical prediction was confirmed by the experimental observations such as magnetic hysteresis loops and photoluminescence.

Figure 1: Chemically synthesized ZnO nanoplate: its band structure and magnetic property.

REFERENCES
DNA Functionalized Single-Walled Carbon Nanotube Inks for Ultra-High Density Sensor Arrays

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SUMMARY
In this work, DNA functionalized single-walled carbon nanotube gas sensor arrays were fabricated by electroless deposition and with the assistance of an ink jet printing process. The selectivity of various analytes was shown by decoration with gold, platinum and palladium metal nanoparticles on the SWNT-DNA hybrid structure.

INTRODUCTION
Semiconducting single-walled carbon nanotubes (SWNT) are a promising 1-D nanomaterial for use as the transduction element and sensitive layer for a gas sensor due to their excellent electronic properties, and thermal and chemical stability under room temperature. However, their low selectivity and sensitivity makes surface modification a needed step to enhance their sensing performance for gas sensing applications under an ambient environment.

In order to enhance the selectivity and sensing performance of SWNT, the combination of a SWNT and DNA hybrid structure was chosen. Here, DNA plays the role as dispersing agent to effectively disperse pristine SWNT in water owing to the π-sacking that overcomes the van der Waal force interactions, which make the SWNT tend to form bundles. Secondly, negatively charged phosphate backbones and nucleobases work as metal ion chelating centers for the formation of nanoparticles.

SWNT/DNA-metal hybrid structure gas sensors were fabricated in two steps due to the precipitant present when mixing in the reducing agent to create the SWNT/DNA-metal ion ink. In this work, dimethylaminoborane (DMAB) was chosen as the reducing agent owing to the redox potential of DMAB of -1.18 volt (vs. NHE) which is a suitable reducing agent for Au, Pd, and Pt. Secondly, compared to NaBH₄ which has to be used at a pH of around 12, DMAB can be used under milder conditions such as pH = 7.4. The DMAB solution was made through the formula proposed by Richter et al.

Ultra-high density gas sensor arrays were fabricated through the assistance of ink jet printing technology. Despite the limitations of the nozzle size and the larger errors (± 25 µm) of pattern alignment compared to a photolithography process, it is still a powerful microfabrication tool due to the advantages of low cost, easy operation, flexibility in choice of pattern design, direct patterning on large substrate surface and capability of printing on large surface area for mass production.

REFERENCES
A New Nano-Platform for Drug Release via Nanotubular Alumina

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SUMMARY
The nanoporous and the nanotubular anodic aluminum oxide (AAO) had similar release kinetics.

I. INTRODUCTION
Nanoporous materials have many favorable properties for drug delivery. Controlled release of amoxicillin from the internal pore structure of nanopores and nanotubes was investigated.

II. METHODS
A. Al Pretreatment
A clean 0.5 mm thick Al foil was etched in 1 M NaOH (aq), and electropolished in a mixed solution of HClO₄ and ethanol (1:4(v/v)) at 5 °C under 20 V with Pt counter electrode.

B. Anodization
The Al foil was anodized at 25 V in 0.3 M H₂SO₄ solution for 24 hours, followed by etching in a mixed H₃PO₄ (1.8 wt%) and H₂CrO₄ (6 wt%) at 55 °C. It was anodized again to form nanoporous layer. Nanotubular layer was obtained by anodizing porous AAO at 25V in 0.3 M H₂SO₄ with an increment of voltage to 35 V for 30 min.

C. AAO Post-treatment
Top of AAO layer was attached to Si substrate. Al substrate was removed in mixed HCl and CuCl₂. AAO barrier layer was removed by 5 wt% H₃PO₄.

D. Porosity Calculation
Porosity was calculated based on pore size, and inter pore distance.

E. Antibiotic Loading, Release, and Collection
1 ml of 1% amoxicillin in PBS was loaded onto each sample. Loaded drugs were released into 1 ml of PBS, and the solution was collected to quantify drug concentration at each time point.

Figure 1: Absolute Release Rates of Amoxicillin

III. RESULTS & DISCUSSION
Controlled, sustained release was achieved for approximately 5 weeks. The nanoporous and the nanotubular AAO films had similar release kinetics with the amount of drug released proportional to the square root of time. This type of controlled release and longevity from AAO films has potential for therapeutic surface coatings on medical implants.

REFERENCES
Thermoplastic Particle Reinforced Polycarbonate Composites with Enhanced Energy Absorbing Capability

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SUMMARY
This study involves the investigation of energy absorbing properties of the micron-size thermoplastic particles reinforced polycarbonate composites. The particulate composites were fabricated via a solution mixing method and characterized in tensile and low-velocity penetration testing. It was experimentally observed that the thermoplastic particles reinforced composites at only 3 wt% particle loading fraction can exhibit enhanced tensile toughness and low-velocity impact properties.

I. INTRODUCTION
The particles as filler materials in a polymer matrix can play an essential role in effectively tailoring the material properties. In this study, we employed micron-size polyamide-nylon 6 particles as a filler material in PC matrix materials to explore a way to improve the energy absorbing properties, and experimentally investigated the energy absorbing properties of the polymer composites by characterizing their mechanical properties and also the low-velocity impact properties.

II. COMPOSITE FABRICATION
A solution mixing method was utilized to fabricate the polymer composites. It involves dissolving polycarbonate granules in Tetrahydrofuran, adding micron-size polyamide-nylon 6 particles, and then mixing the solution. That solution was mixed with methanol to facilitate the composite precipitation, which was then put into a compressive mold to create the specimens [1]. Tensile and the impact test specimens were prepared following ASTM D638 and ASTM D3763, respectively. SEM images confirmed the uniform dispersion quality of the particles in the matrix at 3 wt% loading fraction.

III. CHARACTERIZATION OF ENERGY ABSORBING PROPERTIES
It was clearly seen that the baseline PC exhibits a strong strain rate dependent behavior in the tensile properties. Also the test results indicate that the typical ductile behavior of PC proportionally becomes the brittle as the strain rate increases. In contrast, the polymer composites still showed the ductile response over the baseline PC even at the highest strain rate investigated in this study. The low-velocity impact tests were also conducted and each specimen was completely penetrated through the thickness. Noticeable improvements in the impact properties of the composites over the baseline PC were observed. In addition, the effect of the thickness of the composite specimens on the impact properties was also investigated.

In this study, the test results indicate that the thermoplastic particles reinforced PC composites can exhibit an improvement in energy absorbing capability over the PC in both tensile and low-velocity tests. The enhanced energy absorbing capability seems to result from the debonding at the particle/matrix interface and the corresponding inelastic deformation around the particles.

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REFERENCES
Three-Dimensional Graphene-Carbon Nanotubes Architecture for Supercapacitor Applications

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SUMMARY

This work describes the first steps towards fabrication and characterization of a novel hybrid nanostructure comprised of carbon nanotubes (CNTs) grown out-of-plane and in between graphene layers for supercapacitor applications.

The growth of novel graphene-CNT and graphene-CNT-graphene architectures is a milestone towards fabricating multistacking structures of alternating graphene and CNT layers for 3D hybrid electrode architecture.

I. INTRODUCTION

Electric double layer capacitors (EDLCs) are promising energy storage devices having high power density (e.g. ~14 kW/kg), fast charge storage (rate capability), and stable cycle life (e.g. over 10^5) by means of charge accumulation at the interface of the electrode and electrolyte [1]. Graphene has been identified as a promising material for supercapacitor applications, due to its outstanding theoretical specific surface area (SSA) (~2630 m^2/g), and an intrinsic capacitance of up to 21 μF/cm^2, the theoretical limit of carbon materials [2]. However, supercapacitors composed of graphene alone suffer from loss of active surface area due to aggregation of the material.

II. Experiments and Results

Graphene was grown under atmospheric pressure chemical vapor deposition (APCVD) and characterized by Raman spectroscopy.

Building on the results of the graphene-CNT structure using CH₄ [3], gas flow rates of C₂H₄, H₂, and Ar were varied at 700 °C to grow CNT layers between graphene layers (Figure 1). A metal catalyst film deposited between two graphene layers was thermally treated to breakdown into a CNT catalyst array. Use of ethylene reduced the incidence of graphene etching, likely due to the greater concentration of dissociated carbon for similar flow rates. This hydrocarbon produced long, densely-packed, vertically aligned CNTs grown on graphene, which implies large surface areas for charge storage, reduced self-aggregation of graphene, and efficient charge transfer between the CNTs and graphene, important characteristics for energy storage devices.

Future work includes test of the electrochemical behavior of the graphene-CNT-graphene structure. Electrochemical tests performed on the CNT-graphene structure resulted in outstanding measured capacitance, thus cementing the suitability of 3-D architecture use in high performance energy storage applications.

III. ILLUSTRATIONS

Figure 1: SEM images of direct growth of CNTs using (a) CH₄ and (b-d) C₂H₄ gas; Ni catalyst array on (inset of a) and in between (inset of d) graphene layers.

REFERENCES

Highly non-wetting superhydrophobic surfaces have recently shown multifunctional applicability, and many different fabrication techniques have been explored for the development of efficient superhydrophobic surfaces with a wide range of materials [1]. For the practical applications, it is important to design and manufacture robust and durable superhydrophobic surfaces that can sustain the partial wetting state with air entrapped on the structured surfaces in various thermodynamic and hydrodynamic conditions. The manufacturing technology should also be scalable and economical for large-scale applications such as civil and mechanical systems, where light metal such as aluminum is commonly used as substrate material. One of the most promising manufacturing technologies for the scalable nanopatterning of metallic substrates is electrochemical anodization. However, conventional anodizing techniques mostly produce planar nanopore structures, which typically result in relatively low superhydrophobic efficiency (i.e., low contact angle and large contact angle hysteresis), compared to three-dimensional (3D) pillar structures. Here, we demonstrate a new anodizing process that can create 3D pillared nanostructures on top of a porous layer to form novel “pillar-on-pore (POP)” hybrid nanostructures.

Figure 1 shows the fabrication results of the POP hybrid nanostructures. Based on the characteristic of forming a self-ordered porous morphology in a hexagonal array, the modulation of anodizing voltage and duration enabled the formulation of the hybrid-type nanostructures having controlled pillar morphology on top of a porous layer in both mild and hard anodization modes [2]. Such hybrid nanostructures resulted in superior superhydrophobicity that cannot be attained with the conventional planar nanopore structures (Figure 2). The simple and efficient anodization technique demonstrated in this study has great potential for the design and fabrication of robust superhydrophobic surfaces on various metallic substrates. Its low cost and scalability makes the anodization technique readily transferrable to manufacturing industries and material processing with immediate impact.

REFERENCES
SUMMARY
We use direct laser writing to write 3D silver nanostructures that are embedded in a polymer matrix. Using a femtosecond ultra fast laser and various optimized chemistries, we allow nonlinear interactions to occur which results in metal nanostructures. These structures can be used for a wide variety of nanophotonics applications.

I. INTRODUCTION
Metal micro- and nano-structures play important role in various areas such as catalysts or in plasmonics field. A recent application with growing interest that also incorporates metal nanostructures is metamaterials. To generate these structures, most fabrication techniques can allow mass production but are either non-controllable, suffer from high cost and low throughput or are limited in two dimensions. Direct laser writing technique resolves these problems but has been mainly used to fabricate polymeric structures.

II. EXPERIMENT & RESULT
We direct laser write three dimensional metal structures of tunable dimensions ranging from hundreds of nanometers to micrometers. With computer-controlled 3D translation stage and by utilizing nonlinear optical interactions between chemical precursors and femtosecond pulses, we can limit the metal-ion photo-reduction process to a focused spot smaller than that of the diffraction-limit to create 3D metal nanostructures in a focal volume. This creates metal nanostructures in a focal volume that can be rapidly fabricated in any three dimensions by means of a computer-controlled translation.

We characterize the structures using SEM, EDS and TEM. We study the chemistry that effects the photo induced metal growth to generate desirable metal structures. By varying the types of solvent, polymer and the concentration ratio between metal ion precursors and a polymer capping agent, we demonstrate our control over the morphology of the resulting metal structures. From studying the various chemistries we create diverse metal nanostructures for a wider range of applications.

III. ILLUSTRATION
Figure 1(ref 1) below shows SEM images of an array of silver dots fabricated on a glass substrate. For characterization purposes we only observe one layer that was written on the glass substrate.

Fig. 1: High-resolution SEM images of a patterned sample. (a) An image of a 2D array of dots and (b) its corresponding EDS silver elemental map confirm that silver structures are grown in areas irradiated by the laser. Close-up views of individual dots shown (c) head on and (d) at a 61° tilt angle. SEM imaging requires a washing step to avoid sample contamination from additional silver growth driven by the electron beam.

REFERENCE
First principles study of BiVO$_4$ photocatalyst for hydrogen production

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Solar hydrogen production by direct water splitting using photocatalysts has attracted significant attention since its discovery by Fujishima and Honda in the early 1970s [1]. In their pioneering work, water was split into hydrogen and oxygen under UV irradiation using a photoelectrochemical (PEC) cell with titanium dioxide (TiO$_2$) and platinum. The underlying mechanism for this reaction involves light absorption, photogenerated charge (e-h) separation, and excess charge migration toward the catalyst surface to oxidize water (H$_2$O + 2h$^+$ → 2H$^+$ + $\frac{1}{2}$O$_2$) or reduce proton (2H$^+$ + 2e$^-$$\rightarrow$ H$_2$). Since the first successful water splitting using TiO$_2$, enormous efforts have been devoted to finding high-efficiency photoelectrode materials for water splitting. Metal oxide semiconductors have been recognized as promising photocatalysts for water splitting due to their low production cost and high stability in aqueous environments. Earlier studies mostly focused on binary metal oxides such as TiO$_2$, $\alpha$-Fe$_2$O$_3$, and WO$_3$; they show reasonable photocatalytic performance, but often have inherent limitations. For example, TiO$_2$ is the most widely used due to its strong redox power, high photocorrosion resistance, and nontoxicity, however its photocatalytic activity is limited to UV radiation due to its large band gap (~3eV). Thus, many PEC researchers have recently turned their attention to ternary metal oxides to expand the search for better photocatalytic materials for solar-powered water splitting.

Over recent years, bismuth vanadate (BiVO$_4$) has received much interest as a promising visible-light-active photocatalyst for O$_2$ evolution in aqueous solutions [2,3]. BiVO$_4$ is known to exist in three main crystal structures: tetragonal zircon (tz-), tetragonal scheelite (ts-), and monoclinic scheelite (ms-). Among them, ms-BiVO$_4$ exhibits the highest photocatalytic activity under visible light irradiation. The lower activity of tz-BiVO$_4$ has been explained by its large band gap (2.9 eV). While ts-BiVO$_4$ and ms-BiVO$_4$ have similar band gaps (2.3eV and 2.4eV, respectively), their main difference is a structural distortion associated with the stereochemically active Bi 6s$^2$ lone pair on ms-BiVO$_4$. It has been suggested that the monoclinic distortion might enhance the mobility of photogenerated holes, resulting in the better performance of ms-BiVO$_4$ over ts-BiVO$_4$ [2]. However, the photocatalytic activity of ms-BiVO$_4$ is still hampered by its low electron mobility. Although experimental attempts to increase the electrical conductivity have achieved some success in improving photocatalytic activities [3], the mechanism underlying these improvements is not well understood. Systematic experimental investigations coupled with solid theoretical studies of the nature and transport of photogenerated charge carriers in BiVO$_4$ are now needed to further improve the photocatalytic efficiency.

In this talk, we will present the conduction mechanisms of excess charge carriers in both ms- and ts-BiVO$_4$ phases based on first principles density function theory (DFT) calculations. We will also discuss possible factors that might affect photocatalytic performance of BiVO$_4$. The improved understanding explains many experimental observations, and provides a guide to enhance the photocatalytic performance of BiVO$_4$.

REFERENCES
Enhancing the Assembly and Properties of Nanoparticle Thin Films

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SUMMARY
We demonstrate that layer-by-layer assembly and mechanical durability of nanoparticle thin films can be drastically improved without sacrificing their functionality using spray-assisted layer-by-layer assembly and atomic layer deposition.

I. INTRODUCTION
Nanoparticle thin films (NTFs) composed of multiple nanoparticles have synergistic functionality, making them useful in numerous advanced applications. However, widespread use and commercialization of NTFs are hampered by difficulty associated with their large scale production and their weak mechanical durability. We use spray layer-by-layer assembly to facilitate the NTF fabrications. In addition, we use atomic layer deposition at a relatively low temperature to impart mechanical robustness to NTFs.

II. Experiment
Nanoparticle thin films (NTFs) composed of oppositely charged SiO$_2$ nanoparticles are generated using home-built spray layer-by-layer apparatus. Film growth is studied using ellipsometry. To study the effect of ALD, SiO$_2$ and TiO$_2$ NTFs are modified using Al$_2$O$_3$, SiO$_2$ and TiO$_2$ ALD. The mechanical properties and other physical properties of ALD-treated nanoparticle thin films are determined using nanoindentation, abrasion testing, contact angle measurement and optical characterization.

III. Results and Conclusion
Our results clearly demonstrate that spray layer-by-layer assembly can drastically expedite the growth of nanoparticle thin films. By varying the assembly parameters over 80 different conditions, we show that the growth behavior can be described using a single universal curve.

Nanoindentation of ALD-treated NTFs clearly show that the modulus and hardness of the films increase as a function of ALD cycles. ALD-treated NTFs also retain their original functionality such as superhydrophilicity and anti-reflection properties demonstrating the versatility of atomic layer deposition as a NTF reinforcement method.

We further study the effect of ALD materials on the mechanical properties of NTFs and show that ALD material, not the compositional matching between the nanoparticles and ALD materials, is the dominant factor that determines the mechanical properties of ALD-modified NTFs.

REFERENCES
High Resolution Electron Microscopic Study on Intermetallic Compound Formation in Cu-Al Wire Bond Interconnection

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Abstract

Implementation of Cu wire bond (WB) as replacement of Au WB has significantly increased in recent years. Due to the importance of bonding mechanism and reliability of the WB interconnection, extensive studies have been made to understand the IMC formation at the interface between Cu wire ball and Al pad metallization. However, there is still much to be learned on IMC phases and their properties. Most of the previous investigations implemented scanning electron microscopy (SEM)-based analysis techniques such as energy dispersive x-ray spectroscopy (EDS) and electron probe micro-analyzer to identify IMC phases. To understand IMC growth and phase evolution in depth, present investigation systematically used transmission electron microscopy (TEM)/electron diffraction (ED), EDS and structure factor (SF) simulation for a comprehensive study. IMC phase analysis was performed for Pd coated Cu wire bonds using SEM and TEM/nano-beam ED (NBED) combined with SF simulation. For SEM examination, cross-section of Cu wire bond samples was prepared by a combination of mechanical and Ar+ ion polishing techniques. TEM samples were prepared using dual-beam focused ion beam technique. SEM result showed that discrete IMC patches were initially formed at the Cu/Al interface and they spread across the Cu/Al interface during high temperature storage (HTS) environment at 150 °C for 1000 hours. At the same time the IMC thickens growing towards the Al pad. TEM, NBED, and EDS results combined with SF calculation revealed the evidence of metastable $\theta'$-CuAl$_2$ IMC phase formation at Cu/Al interfaces before the HTS test. This $\theta'$-CuAl$_2$ IMC phase grew in size after HTS test. The $\theta'$-CuAl$_2$ phase has a tetragonal structure with space group $I-4m2$, and its lattice parameters were $a = 0.404$ nm, $b = 0.404$ nm, $c = 0.580$ nm. Stable phases such as CuAl$_2$ or Al$_4$Cu$_9$ reported in previous investigations were not observed in the present work. During the formation and growth IMC phase, Pd stayed within Cu as solid solution. Possible reasons for the presence of the metastable CuAl$_2$ phase are discussed.

Figure below shows (a) TEM cross-sectional BF image showing growth of IMC phase, (b) their corresponding NBED patterns, and (c) SF simulations. SF simulation shows the NBED pattern in (b) is a net pattern of [021] of $\theta'$-CuAl$_2$ phase.
Heterogeneity of the Electrolyte/Catalyst Interface in Solid Acid Fuel Cells Measured by in-situ Electrochemical Atomic Force Microscopy

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SUMMARY
The complete current–voltage characteristics of Pt, Pt-Ni alloy | CsHSO\textsubscript{4} interfaces are measured using a conducting atomic force microscopy (AFM) setup, revealing a counter-correlation between exchange currents and transfer coefficients indicative of nanoscale heterogeneity for the oxygen reduction process.

I. INTRODUCTION
Solid acid compounds have been demonstrated as viable proton conducting electrolytes for fuel cells [1], with peak power densities of \sim 400 mW/cm\textsuperscript{2} at \sim 240 °C [2]. Such solid acid fuel cells (SAFCs) provide several advantages over polymer membrane fuel cells, including improved electrode kinetics due to higher operating temperatures, impermeability of the membrane to fuels, and the elimination of the need for complex water management systems. However, activation overpotential losses, particularly at the cathode, limit the performance [3], and electrode kinetics are not yet well understood. In this work, we report on the counter-correlation between exchange current, \(i_0\), and transfer coefficient, \(\alpha_c\), for the desired oxygen reduction reaction

\[
\text{O}_2 + 4\text{H}^+ + 4e^- \rightarrow 2\text{H}_2\text{O}
\]  

for Pt, Pt-Ni alloy | CsHSO\textsubscript{4} systems measured using a conducting atomic force microscopy (AFM) setup.

II. RESULTS
The complete current–voltage characteristics of Pt | CsHSO\textsubscript{4}, Pt\textsubscript{3}Ni | CsHSO\textsubscript{4} and Pt-Ni | CsHSO\textsubscript{4} interfaces were measured at various points across the electrolyte surface at \sim 150 °C and reveal a variation of the oxygen reduction kinetics with position. Data analysis of the cyclic voltammetry (CV) experiments, within a multistep charge transfer framework, yielded cathodic transfer coefficients (\(\alpha_c\)) for ranging from 0.5 to 2.7 and exchange currents (\(i_0\)) spanning 33 orders of magnitude. The observed counter-correlation between the exchange current and exchange coefficient indicates that the extent to which the activation barrier decreases under bias (as reflected in the value of \(\alpha_c\)) depends on the initial magnitude of that barrier under open circuit conditions (as reflected in the value of \(i_0\)). Measurements of exchange coefficients (\(\alpha_c\)) and exchange currents (\(i_0\)) for the Ni-Pt | CsHSO\textsubscript{4} interface indicate its higher sensitivity to spatial heterogeneities relative to Pt | CsHSO\textsubscript{4}.

Figure 1: Exchange current versus transfer coefficient obtained from Tafel analysis of the Pt, Pt-Ni alloy | CsHSO\textsubscript{4} CV measurements.

REFERENCES
Evaluation of Stable Liposomal Nanoparticles for Controlled Delivery of Anticancer Drugs

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SUMMARY
This study demonstrated a stable and robust liposomal formulation, termed crosslinked multilamellar liposome, for controlled delivery of anticancer drugs. With its properties of sustainable drug release and enhanced vesicle stability, CML can achieve efficient delivery of cancer therapeutics, which result in the enhanced therapeutic effect of cancer treatment.

I. INTRODUCTION
Optimal treatment of many drugs often requires maintenance of the drug level for a prolonged time in order to achieve the therapeutic goals. While anticancer treatments require prolonged retention of highly concentrated cytotoxic drug levels to maximize antitumor effect, such requirement also poses the risk of systemic toxicity. Consequently, nanoparticle-based drug delivery systems, which can modulate the toxicity profile of anticancer drugs and improve drug circulation, have been widely viewed as a new treatment option for cancer therapeutics.

Liposomal nanoparticles are one of the most popular nanocarriers due to their ability to encapsulate both hydrophilic and hydrophobic drugs, liposomal formulations of anticancer drugs have been extensively evaluated for treating cancers. Particularly, the anticancer drug Doxil/Caelyx, which is a liposomal nanoparticle encapsulating anticancer agent doxorubicin (Dox), an anthracycline antibiotic, is used in the treatment of a wide range of cancers by intercalating the DNA of the tumor tissues. Thus, Liposomes have been shown to be promising drug carriers for cancer therapeutics. However, in the presence of serum components, conventional unilamellar liposomes are inherently unstable, thus limiting release kinetics and, hence, their utility for the delivery of anticancer agents. Studies have shown that the release rate of liposomal Dox correlates with toxicity level and therapeutic activity such that slower release rates usually result in lower toxicity and higher therapeutic efficiency. Therefore, it is desirable to develop a more robust liposomal formulation with sustainable release kinetics and improved vesicle stability.

In this study, we investigated a previously reported liposomal formulation as an anticancer drug nanocarrier and examined whether such nanoparticles could offer stable and sustainable delivery of cancer therapeutics. This nanoparticle formulation involves generating a robust multilamellar structure of the liposome by covalently crosslinking inter-lipid bilayers. As a novel nanocarrier platform for chemotherapy drug delivery applications, our study demonstrates that crosslinked multilamellar liposomes (CMLs) can lower systemic toxicity and enhance therapeutic efficacy. In addition, the intracellular trafficking of CMLs was monitored and visualized to provide a better understanding of their delivery mechanisms. This liposomal formulation can potentially provide a versatile platform for drug delivery applications and expand new possibilities of synergistic combinatorial therapies, thus vastly widening the options of therapeutic drug delivery.
Characteristics of PVDF-TrFE/PVA/Si Structures for FeRAM

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SUMMARY
We investigated the characteristics of Metal–ferroelectric–insulator–semiconductor (MFIS) structure using poly(vinylidene fluoride trifluorethylene) PVDF/TrFE (65/35) as a ferroelectric layer and polyvinyl alcohol (PVA)(0.4 wt%) as an insulating buffer layer. In MIS structure, we found that the 0.4 wt% PVA solution gave excellent insulator results at the bias sweep range ±5V and leakage current density of the PVA film with 0.1, 0.4 and 0.7 wt% were about 10^{-5} A/cm^{2}, 10^{-6} A/cm^{2} and 10^{-7} A/cm^{2}, respectively. With these results above, we selected the 0.4 wt% PVA solution in MFIS structure. In MFS and MFIS structures, the memory window widths of the measured for a voltage sweep ±5 V, were about 2 V and 3 V, respectively. Hysteresis loops due to the ferroelectricity of the PVDF-TrFE with β phase were observed in C-V characteristics. The current densities were about 10^{-5} A/cm^{2} and 10^{-6} A/cm^{2} at 5V for MFS and MFIS structures, respectively.

Figure shows the C-V curves of the 5 wt% PVDF-TrFE films above PVA films 0.4 wt% measured at a bias sweep range from ±1 V to ±5 V. Regardless of the capacitor structures, all C-V curves showed hysteresis loops with a clockwise trace as indicated by arrows. This loop indicated the ferroelectric behavior of the PVDF-TrFE films. Compared with MFS and MFIS capacitors, MFIS capacitor was more stable than MFS capacitor in the accumulation region, this is because of the insulator property of the PVA films. The accumulation capacitance of MFS capacitor was 130 nF/cm^{2} for a bias voltage sweep of ±5 V, but in MFIS capacitor, the accumulation capacitance decreased to the 85 nF/cm^{2} for same bias voltage sweep. As can be seen from figure, the memory window width gradually increased as the sweep voltage range increased from ±1 V to ±5 V. The memory window width of the MFS and MFIS capacitors, measured for a voltage sweep ±5 V, was about 2 V and 3 V, respectively. Contrary to the accumulation capacitance, the memory window width increased as using insulator buffer layer meaning that a large portion of the applied voltage could be distributed to the PVDF-TrFE film in a MFIS structure. This happens as the film thickness increased resulting in the decrease of the capacitance of the PVDF-TrFE thin film.

Figure 1: C-V characteristic for MFIS capacitors measured at 1MHz.

From these results, we suggest that PVA film in the Au/PVDF-TrFE/PVA/Si structure effectively accomplished the role of the insulating buffer layer. Consequently, the MFIS structure with PVA buffer layer would be suitable for OTFTs and NDRO-type ferroelectric memories with Fe-FETs.
Fabrication of Linearly-Ordered Pyrite (FeS$_2$) Nano-Arrays by Sulfurization of Vapor Deposited Iron Oxide Nanoparticles on Highly Oriented Pyrolytic Graphite (HOPG)

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SUMMARY

Pyrite nanoparticle arrays can be fabricated by sulfurization of physical vapor deposited iron oxide nanoparticles on a highly oriented pyrolytic graphite (HOPG) substrate. Pyrite nanoparticle arrays can be used as nucleation sites to study the growth mechanism of pyrite in future studies.

I. INTRODUCTION

Pyrite, one of the phases in the Fe-S system, is a promising material for solar cell applications because it is a photovoltaic absorber material with a high absorption coefficient, suitable bandgap ($E_g \approx 0.95$ eV), elemental abundance and nontoxicity. Despite the potential that pyrite has, the efficiency of a pyrite device is limited to about 3%. Low efficiency is due to a high dark current resulting from two main issues: large surface-state density due to sulfur deficiency on the surface and phase impurities such as marcasite ($E_g = 0.34$ eV). Although, the fabrication of high quality pyrite films has been studied by numerous methods, making a pure pyrite phase is still a challenge due to its naturally occurring mixed phases. It is not yet understood how to preferentially grow pyrite. Thus, it is essential to understand how the pyrite particle grows at very early stages. Growth of a pure crystal in solution is known to proceed more effectively with a help of a seed crystal which acts as a nucleation site. The role of nucleation sites can play a big role in pyrite growth mechanism. In this study, we primarily focus on fabricating pyrite nano-arrays by sulfurization of iron oxide nanoparticles on HOPG. These arrays can be used as nucleation sites to study pyrite growth mechanisms.

II. PRELIMINARY RESULTS

A. Fabrication of Iron-(III) oxide nanoparticles on HOPG

Iron-(III) oxide nanoparticles were fabricated on HOPG by physical vapor deposition. HOPG substrate temperature upon deposition affects the linearly-ordered structures of nanoparticles. At a low HOPG substrate temperature upon deposition, iron adatoms disperse over the HOPG substrate and decorate both terraces and step edges due to low mobility. At a high enough HOPG substrate temperature, the mobility of iron adatoms is high and step edge decoration is preferred. Transmission electron microscope (TEM) diffraction of a selected area and X-ray photoelectron spectroscopy (XPS) of these linearly-ordered arrays revealed the presence of iron and iron-(III) oxide.

B. Conversion of iron-(III) oxide nanoparticles to pyrite nanoparticles

Iron-(III) oxide nanoparticles are converted to pyrite by sulfurization methods using H$_2$S, or elemental sulfur. H$_2$S sulfurized iron-(III) oxide coalesces to form FeS$_2$ nanowires which are a desirable morphology for pyrite nucleation studies. The FFT of TEM lattice fringes of these nanowires corresponds to the (200) plane of pyrite. Raman spectroscopy indicates the presence of the vibrational modes from marcasite as well as pyrite. Although sulfurization of iron-(III) oxide with H$_2$S produced the favorable morphology of nanowires, the mixed phases of FeS$_2$ prevent the study of pyrite growth mechanism.

In order to prevent the mixed phase of FeS$_2$, a sulfurization method utilizing elemental sulfur was investigated. Sulfurization of iron-(III) oxide nanoparticles by annealing in elemental sulfur converts iron-(III) oxide to pyrite; however, the favorable nanowire morphology is lost due to the formation of clusters with mixed grain sizes. Further work is required for fabricating morphologically desirable and pure pyrite nano-arrays.

IV. REFERENCES

Electron Transport Properties of Reduced Graphene Oxide Sheets

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SUMMARY

We present temperature dependent electron transport properties of reduced graphene oxide (RGO) to provide insight on its disordered structures. We observe Coulomb blockade (CB) at low temperature (~ 4.2 K), and that temperature dependent resistance follows Efros-Shklovskii variable range hopping (ES VRH) conduction. These findings imply that RGO sheets can be considered as a graphene quantum dots (GQD) array.

I. INTRODUCTION

RGO, a chemically functionalized atomically thin carbon sheet, provides a convenient pathway for producing large quantities of graphene via solution processing. The easy processibility of RGO offers interesting electronic, chemical and mechanical properties that are currently being explored for advanced electronics and energy based applications. Although the electrical properties of RGO sheets can be tuned by varying degrees of reduction, the properties are much inferior to that of pristine graphene due to large amount of residual disorders which localizes charge carriers. Understanding the role of these disorders in electron transport mechanism is of great significance for evaluating and improving the potential applications of RGO sheets. Here, we present temperature dependent electronic transport investigations of RGO sheets using CB and ES VRH conduction.

II. EXPERIMENTAL

RGO sheets were synthesized through a reduction of GO prepared by modified Hummers method. The pH of GO dispersion in water was adjusted to 11 using a 5% ammonia aqueous solution. 15 μl of hydrazine solution was then added to the mixture. The mixture was heated at 95°C for 1 hour. Source and drain electrode patterns were defined by means of electron beam lithography and deposition of 5 nm thick Cr and 20 nm thick Au on top of SiO2/Si substrate. RGO sheets were then assembled between the source and drain electrodes via AC dielectrophoresis technique.

II. RESULTS AND DISCUSSION

As the temperature is lowered to less than 15 K as shown in Fig. 1 (a), a complete suppression of the current below a threshold voltage (Vt) was observed. Such current suppression was explained due to CB of charges, as at low temperatures there is not enough energy for the charges to overcome Coulomb charging energies of the GQDs in RGO sheets. In a QD array, the current (I)-voltage (V) curves should follow a relation I ~ [(V-Vt)/Vr]α for V > Vt, where α is the scaling exponent that depends on the dimensionality of the arrays. This is also shown to be the case in RGO (Fig. 1 (b)) where α was estimated to be ~3.4. The higher α compared to theoretical value of ~ 2 indicates that electron transport occurs in an inhomogeneous quasi 2D GQD array with topological defects in RGO sheets.

![Figure 1](image)

Figure 1: (a) I-V characteristics at temperatures (~ 4.2 K). Below 15 K, the current is zero for V<Vt. (b) I vs. (V-Vt)/Vr curves plotted in a log-log scale. (c) Resistance in log scale as a function of T1/2.

For inhomogeneous QD array system, temperature dependent resistance follows ES-VRH: R ~ exp (Tc/T)1/2, where Tc is related to localization length (ξ) through Tc= 2.8e2/4πcεε0kBTcξ. As shown in Fig. 1 (c), log scale of R strongly follows T1/2 and ξ was calculated to be 3.5 nm which is comparable to graphene domain size, suggesting strong localization of wave function inside each GQDs.

REFERENCE

Surface engineered nanomaterials for stem cell engineering

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ABSTRACT

Multiple cellular-level processes such as cell mobility and biosynthesis often work in concert with their immediate surroundings both in and outside the cell. Networked biological pathways (hierarchical reaction systems) that include the stem cell self-renewal and differentiation processes exhibit an even greater complexity. In this sense of cellular organisms operating under various dynamic environments, it will be useful and ideal to construct dimensionally diverse structures that incorporate modular organic components. In an attempt to develop such complex biomimetic systems, two different classes of synthetic materials that show different bioactivities towards human neural stem cells (hNSCs) will be presented during this talk. Engineered peptide amphiphiles (PAs) that self-assemble into high-aspect ratio structures (e.g. fibrous micelles) exhibit a spectrum of responses from hNSCs based on concentration and surface engineering modulations while inorganic structures do not. Physicochemical and biological properties of both platforms of synthetic materials will be presented interfaced to hNSCs. Further discussions involving surface engineered nanomaterials will be presented within the context of stem cell and biomedical applications.

REFERENCES


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Gate-modulated Thermoelectric Power Factor of Ge/Si Core/Shell Nanowires

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SUMMARY

Heterostructure core-shell semiconductor nanowires can be excellent thermoelectric materials due to their remarkable properties, such as high mobility and good electrical properties [1]. Our results show that nanowires with core diameter down to 11 nm still follow the bulk Ge Seebeck coefficient and the carrier mobility is the key for high power factor, which could be enhanced in Ge-Si core shell nanowires compared to bulk Ge due to the absence of ionized impurity scattering, and the surface passivation by the Si shell.

I. INTRODUCTION

Thermoelectrics is the solid state technology of energy conversion between thermal energy and electrical energy. Nanowire based thermoelectrics have the potential to increase the power factor through quantum confinement [2] and decrease the thermal conductivity by way of the small nanowire diameter[3]. In particular, core/shell semiconductor nanowires that are well known as good field effect transistors can enhance the thermoelectric power factor and thereby increase the performance.

II. Experiments

A. Nanowire Fabrication

Ge/Si core/shell NWs were synthesized by a chemical vapor deposition (CVD) method with the framework of VLS growth. Based on HRTEM analysis, both core and shell materials are high quality single crystalline and the interface between core and shell is epitaxial.

B. Gate-modulated power factor measurement

The power factor measurement device is composed of a metal heater and two four-point electrodes. To apply a back-gate voltage, the device is fabricated on a highly-doped silicon substrate with a SiO$_2$ insulation layer. The diameters of all nanowires were measured by AFM.

III. Results

The gated modulated thermoelectric power factor measurement on Ge/Si core/shell nanowires with core diameters ranging 11-25nm was performed. Surface Fermi level pinning causes high concentration interface hole gas in the dopant-free Ge core nanowire. The suppressed ionized impurity and surface charge scattering could lead to high mobility. The Seebeck coefficient of nanowires studied here follows the bulk Ge. Consequently, the power factor of nanowires could be enhanced by high mobility. In addition, the gate-modulated system could be a good platform to improve the thermoelectric performance of nanowires.

REFERENCES

Probing nano-confinement effects on metal borohydrides incorporated in nanoporous frameworks for hydrogen storage applications

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SUMMARY

Complex hydrides have been under intense investigation with an aim of improving the hydrogen storage properties. Nano effects on the kinetics and thermodynamics of hydrogenation/dehydrogenation reactions of complex hydrides, metal borohydrides in particular, are found to be substantial. Such advancement would eventually lead to successful development of the viable materials for hydrogen storage applications.

I. INTRODUCTION

Hydrogen rich complex hydrides are potentially viable hydrogen storage materials that could solve the key hydrogen storage problems in hydrogen fuel-cell based automobile applications. Despite their high gravimetric and volumetric densities, the poor kinetics and thermodynamics of hydrogen absorption/desorption reactions are the limiting factor. Improvements via nano-engineering have been demonstrated in the literature and there have been growing interests recently. Major focuses are to make thorough examination and to understand the effects of shortening of mass transport distances by nano-confining and catalytic effect via surface interaction of complex hydrides and the framework. Numerous carbon based meso- or nanoporous scaffolds have been preferably utilized for this purpose because of their inertness and light mass. We have explored nano-confined metal borohydride that was incorporated into mesoporous carbon (CMK-3). Solid state NMR methods, in particular, have been utilized to characterize [BH₄]⁻ surface interaction and the chemical reactions in the system during the hydrogen storage processes.

II. Experimental Approaches

A. Incorporation of metal borohydrides into mesoporous carbon

Melt infiltration of LiBH₄-Ca(BH₄)₂, binary borohydrides that forms eutectic mixture at 2:1 mole ratio at around 200 °C, into CMK-3 carbon channel (pore size of ~ 3.5 nm) was achieved at temperatures lower than melting points of individual borohydrides.

B. Probing BH₄ anions/C structures

Multinuclear high resolution NMR spectroscopy was found to be instrumental in accessing the structure modification of borohydride anions and cations. ¹¹B and ¹²Li MAS NMR measurement in situ during the infiltration process performed.

III. Results

As an example, ¹¹B variable temperature provides with valuable insights of interaction changes among [BH₄]⁻ anion and cations (Li⁺ and Ca²⁺) on the highly active carbon surfaces during the nano-confining process. The catalytic effects of the carbon surface could be addressed from the measurements.

Figure 1. ¹¹B MAS NMR spectra of LiBH₄-Ca(BH₄)₂ with mesoporous carbon.
REFERENCES


High Efficiency Cu$_2$ZnSnSe$_4$ Solar Cells by Sputtering

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SUMMARY

This work presents the recent research results on Cu$_2$ZnSnSe$_4$ thin film solar cells prepared by single-target sputtering. Influences of several critical parameters, including nonstoichiometry, sputtering power and selenization temperature, will be correlated to observed microstructures, electrical properties and high cell efficiencies of > 4.0%.

I. INTRODUCTION

Quaternary semiconductor compounds Cu$_2$ZnSnSe$_4$ (CZTSe) are attractive materials for thin film solar cells, which can potentially substitute CuInSe$_2$-based thin film cells with the limited source of indium. The CZTSe has known to have high absorption coefficient of > 10$^4$ cm$^{-1}$ and band gap energy of ~1 eV [1]. High quality of the absorbing thin film layer has been regarded as one of the key success factors for high efficiency solar cells. The highest solar cell efficiency of 10.1% has been reported for Cu$_2$ZnSn(S,Se)$_4$ (CZTSSe) when toxic hydrazine based solution was used [2].

There are very limited reports on successful sputtering examples of the CZTSe solar cells even though sputtering is one of the most viable techniques for the large scale panel production. In this work, we propose a promising example of high efficiency CZTSe-based solar cells using single-target sputtering. Several processing parameters will be investigated as critical factors in controlling the performance of the solar cells.

II. Results

A. RF Power Dependence

Effects of different RF powers of 30-100 W were investigated with regard to crystallization, surface microstructure and optical properties of the films. Different sputtering yield of each element might result in Sn-rich surface of the as-deposited films. As increasing RF power, the ratio of Zn/Sn decreased and deviated more seriously from the stoichiometric composition. The slight decrease of optical band gap energy from 1.09 to 0.94 eV was observed as a result of increased RF power.

B. Compositional Effects

Several nonstoichiometric compositions utilizing excess Zn and Cu are investigated. The results are substantial. For example, by adopting certain level of excess Cu, the resultant cell efficiency reached to >4.0%, which is the best value so far compared to any vacuum-processing for the absorber layer.

Figure 1: SEM cross-sections of CZTS absorber layers with sputter power.

REFERENCES


Graphene/V₂O₅ nanotube composite electrodes for Energy storage application

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SUMMARY
Graphene and V₂O₅ nanotubes composite electrodes were fabricated and tested as electrodes for supercapacitor application. The enhancement of the electrochemical performance of the composite over the individual materials was demonstrated using cyclic voltammetry (CV), constant current charge/discharge testing and electrochemical impedance spectroscopy in aqueous (2 M KCl) and organic (1 M LiTFSI in acetonitrile) electrolytes. The calculated specific capacitance was 36 F/g in aqueous electrolyte and 240 F/g in organic electrolyte for the composite material at a scan rate of 10 mV/s. Asymmetric coin cell devices were also fabricated using activated carbon cloth as the counter electrode and the obtained energy and power densities were 28 Wh/kg and 303 W/kg, respectively.

I. INTRODUCTION
Energy storage devices that possess both high energy and power densities with excellent cycling ability have been an attractive area of research (1). Supercapacitors, also known as ultracapacitors or electrochemical capacitors (ECs), store energy as charge on the electrode surface, rather than by chemical reaction of the bulk material as in batteries. As a result, the electrode does not undergo drastic structural change (2). ECs can be divided into two groups: electrical double layer capacitors (EDLCs) and pseudocapacitors. In EDLCs, the energy is stored electrostatically at the electrode-electrolyte interface in the double layer. Charge storage in pseudocapacitors, on the other hand, occur via fast redox reactions along the surface of the electrode. Pseudocapacitors make use of redox active materials such as conducting polymers (polyaniline, polypyrrole, polythiophene) or metal oxides such as (MnO₂, V₂O₅ and RuO₂) and are known to have relatively higher specific capacitance values than EDLCs(3).

II. RESULTS AND DISCUSSIONS
The synthesis of V₂O₅ was carried out using sol-gel method. V₂O₅ sols were prepared by mixing 0.8 g ammonium metavanadate (NH₄VO₃) and 8 g acidic ion exchange resin (DOWEX 50WX8-100) in 160 ml water. The mixture was heated at 60 °C for 20 minutes to produce an orange sol that darkened with time. The xGnP/V₂O₅ composite was synthesized by stirring a mixture of 100 ml of 0.3% graphene dispersion in ethanol and 100 ml of the synthesized V₂O₅ for 9 days. The final product was isolated by filtration and dried in an oven at 100 °C overnight.

The CV plot (Fig. 1) of the composite shows peaks at 0.25 V in anodic scan and at -0.38V and -0.75V at cathodic scan which can be attributed to the lithium intercalation/deintercalation process in which the electrochemical Li⁺ insertion process that occur at V₂O₅ electrodes. The specific capacitance obtained in 1M LiTFSI in acetonitrile was 240 F/g was for the composite

Figure 1: CV plots of xGnP, V₂O₅ and the composite in 1M LiTFSI at 10 mV/s

REFERENCES
Large-scale fabrication of highly sensitive SnO$_2$ nanowire network gas sensors by single step vapor phase growth

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SUMMARY

A facile route to fabricate single crystalline SnO$_2$ NW network gas sensors on a large scale has been suggested. The SnO$_2$ NW networks were grown on 16 different sensor elements via a single step vapor phase reaction. The sensor showed highly sensitive and selective detection of NO$_2$ and C$_2$H$_5$OH. The present method provides a high-throughput fabrication method of SnO$_2$ NW network gas sensors using a vapor phase reaction.

I. EXPERIMENTAL

The fabrication procedures of in situ grown SnO$_2$ NW network gas sensors are shown in Figs. 1. The Au electrodes and Pt heater patterns were formed on the top and bottom sides of the Al$_2$O$_3$ substrate by screen printing and subsequent heat treatment (Fig. 1a). The square-shaped Au catalyst layers (thickness: 3 nm) were deposited on the regions near the Au electrodes using thermal evaporation (Fig. 1b). The SnO$_2$ NWs were grown on Au electrodes via the thermal evaporation of metal. The Au electrodes were placed downstream of the quartz tube. After evacuating to 10$^{-2}$ Torr by using a rotary pump, the furnace was heated up to 700 °C and then 0.5 sccm of O$_2$ was introduced as a reactive gas for 20 min (Fig. 1c).

II. RESULTS and DISCUSSION

The SnO$_2$ NW networks were uniformly grown on the rectangular region with an Au catalyst (Fig. 2a). The high magnification SEM image shows that SnO$_2$ NWs are several tens of micrometers long and 30–100 nm thick (Fig. 2b).

Figure 2: (a) and (b) SEM image of SnO$_2$ nanowire networks. (c) gas responses to NO$_2$, CO, H$_2$ and C$_2$H$_5$OH at various sensing temperatures.

The $R_g/R_a$ ($R_g$: resistance in gas, $R_a$: resistance in air) value to 5 ppm NO$_2$ was as high as 1909 at 141 °C and decreased to 9.1 as the sensor temperature increased to 240 °C (Fig. 2c). The decrease of NO$_2$ response above 141 °C can be attributed to the diminishment of NO$_2$ adsorption on the surface of SnO$_2$ NWs in the form of NO$_2$−(ads). The response to H$_2$ ($R_g/R_a$) at 190 °C was low (2.9), but it monotonically increased to 54.6 as the sensor temperature was increased to 296 °C. A similar increase in gas response with sensor temperature was also observed during CO detection. The response to C$_2$H$_5$OH showed the highest value at 240 °C, which then decreased slightly at 296 °C. Considering the decreasing tendency of responses to CO, H$_2$, C$_2$H$_5$OH as sensor temperature decreases, the above results suggest that the selective detection of NO$_2$ and C$_2$H$_5$OH can be accomplished at low (141 °C) and high (240–296 °C) sensor temperatures, respectively.

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Novel Process for the Preparation of Composite Carbon Nanotube/PVA Fibers/Yarns

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SUMMARY
We report the discovery of a new process to produce composite carbon nanotubes (CNT) fibers from single-walled carbon nanotubes (SWNTs), multi-walled nanotubes (MWNTs) or the combinations thereof utilizing already an adhesive (polymer) coated layer on polyethylene terephthalate (PET) film strip by simply applying CNT coating on the layer followed by an acid dipping. We also found that applying either an additional base treatment or an additional polyvinyl alcohol (PVA) polymer coating to the CNT-coated strip after the strip was dipped in acid enables us to achieve even higher mechanical properties compared to the former process.

I. INTRODUCTION
Carbon nanotubes have extremely high strength, high stiffness, low density, good chemical stability and high thermal and electrical properties (1). Potential applications of carbon nanotube fibers as hydrogen storage, actuator, microelectrodes and supercapacitors (2) have been reported. There are three main processes of making fiber: wet solution spinning, dry spinning and gas-state spinning. CNT fibers are more attractive for practical applications than individual carbon nanotubes as-synthesized due to short length. There are three main processes of making fiber: wet solution spinning, dry spinning and gas-state spinning. We would like to report that we discovered a novel and versatile process for the preparation of composite CNT fibers from SWNTs, MWNTs or combinations thereof utilizing already an adhesive (polymer) coated layer on polyethylene terephthalate (PET) film strip by applying CNT coating on the layer followed by an acid dipping. We would also like to report that we found that applying an additional base treatment or polyvinyl alcohol (PVA) polymer coating after the acid dipping enables us to achieve even higher mechanical properties compared to the former process.

II. RESULT AND DISCUSSIONS
Scheme 1 shows an illustration of one novel spinning process utilizing adhesive layer already coated on PET (polyethylene terephthalate) film strip produced by a PET supplier. CNT coating method on the PET strip is detailed by Rahy et al. (38). The PET strip coated with CNTs was then dipped in acid solution (6M sulfuric acid) for a few seconds, washed in DI water for 1min, then dipped in an alcohol (either methanol or ethanol) solvent, delaminated in air, stretched and dried at room temperature.

REFERENCES
SUMMARY
In the research of advanced secondary batteries, it is important to develop high-capacitive anode materials for high-energy-density lithium secondary batteries. Current commercial anode (negative) material is graphite having intercalation mechanism and cheap cost. Overcoming the capacity limit of graphite (372 mAh/g), metal phosphides are considered as one of the potential candidates together with Sn and Si-based materials.

In here, the electrochemical reaction of metal phosphides was studied using First Principle calculation. From the results, properties of reaction energies, potentials, and volume expansion were discussed.

I. INTRODUCTION

The formation of Li$_x$MP$_3$X phases as M of Ti, V, Cr, Mn, Fe, Co, Ni and X of B, Si, P, As, Sb from the corresponding starting materials of MP$_3$X were analyzed using Vienna Ab-initio Simulation (VASP) package. The total energies of Li$_x$MP$_3$X, MP$_3$X and Li materials were evaluated using Projector Augmented Wave (PAW) method. Structure of Li$_8$MnP$_3$ was obtained and ICSD database. Volume changes were evaluated based on energy minimized structures of Li$_7$MP$_3$X and MP$_3$X. Nazar et al. reports the equilibrium potential as 1.02–1.06 V vs. Li/Li$^+$ for the reaction (1)

The structures of reactant and product are illustrated in Fig. 1. The equilibrium potential of VASP calculation for the reaction of Li$_7$MnP$_3$ = MnP$_3$ + Li$^+$ + e$^-$ was 0.6253 V vs. Li/Li$^+$. 

Li$_7$MP$_3$X = MP$_3$X + Li$^+$ + e$^-$(1)

Calculation results of potential and volume expansion were presented in Figs. 2 and 3, respectively, by the reaction (2).

II. CONCLUSION

Volume expansion of Li$_7$MnP$_3$ was calculated as 160% from delithiated MnP$_3$. This value is some different compared to the value of 192% based on ICSD data. Reaction potential of 0.6253 V also some different compared to reported value. Relative properties of potential and volume expansion can be evaluated for phosphide substituted materials.

REFERENCES


Standardization of Materials Reliability Issues and New Movement for Forensic Engineering in Korea

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SUMMARY
This study presents current issues of materials reliability and introduces instrumented indentation test and its standardization, and the reliability center which was established to support industries, and application of the reliability evaluation technology to forensic engineering, which is new to Korea.

I. INTRODUCTION
Current issues of materials reliability can be shown as 3Ss; Simple, Selective and Smart. This concepts aim to shorten the testing time innovatively by simplifying the testing procedure, to pin point the root causes by selecting the weak area in the whole system, and to solve the reliability problems by using smart analysis techniques. Researches to deal with above mentioned area have continuously performed, and standardization and application of the technology are on progress as well.

II. INSTRUMENTED INDENTATION TEST
IIT (Instrumented Indentation Test) is one of the best examples of above mentioned 3Ss. The application of IIT has been increased because of its advantages; it is nondestructive, single test measures various mechanical properties, and testing on multiple scales uses the same testing principle. Using IIT, tensile properties, residual stresses, and fracture characteristics of materials can be measured and locally mapped at macro to micro/nano scale.

IIT has standardized internationally. The technique for evaluation of indentation tensile properties using IIT is published as ISO/TR 29381 in 2008. In addition to that, by a de facto international standard, ASME Boiler & Pressure Vessels Code, IIT is published as Code Case 2703 as criteria for qualification of temper bead welding in October 2011.

III. CENTER FOR MULTISCALE TESTING AND ASSESSMENT AT COMBINED ENVIRONMENT
It is also important to support the material reliability evaluation techniques including IIT to be applied to various industries. CMTAC (Center for Multiscale Testing and Assessment at Combined Environment) was established to serve above mentioned purpose sponsored by the joint research cultivation program of Ministry of Knowledge and Economy. CMTAC aims to set the system of material reliability assessment for multiscale (macro, micro, nano) at combined environment (temperature, pressure, humidity, etc.).

IV. FORENSIC ENGINEERING IN KOREA
Materials reliability assessment techniques are fundamental technology for forensic engineering for public safety. When a safety accident happened, it can be used for investigating the causes of the accident to figure the legal liability and to prevent the further accident. In 2010, Seoul National University and National Forensic Service signed MOU to establish the FERI (Forensic Engineering Research Institute) to launch forensic engineering first time in Korea. FERI will be the cornerstone of forensic engineering in Korea with researches and cooperation with related organizations.

Figure 1: Forensic engineering; the fundamental support for public safety and the medium for application of reliability technique
Complex-oxide thin-film heterostructures that work with strongly correlated electrons

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Strongly correlated electrons in complex-oxides are the ones that make the field of materials physics interesting and attractive. From high-Tc superconductivity to multiferroicity, their unexpected functions have always been in the center of attention of materials science. Moreover, recent advances of complex-oxide synthesis capabilities have opened a new pathway not only to exploring their physics but also to developing nano-scale device application.

In this presentation, I will introduce how beautifully atomic-scale complex-oxide heterostructures can be synthesized by precisely controlled pulsed-laser deposition with in-situ growth monitoring. Moreover, I will discuss recent experimental results of strongly correlated electrons’ intriguing phenomena in heterostructures: 1) the spin/orbital reconstruction due to the quantum confinement, and 2) the multichannel high-mobility transport due to the electronic reconstruction at an interface. Both examples show that the interesting properties of complex-oxide materials can be deliberately modified at atomically-sharp interfaces, yielding an even richer variety of properties.
Effect of Carbon Steel Microstructure on Aqueous CO2 Corrosion in Simulated Oil and Gas Production Environments

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SUMMARY

CO2 is ubiquitous in oil and gas fields, and aqueous CO2 corrosion of carbon steel equipment is a challenging issue in the oil and gas production operations. Prior corrosion studies had suggested that the microstructure of carbon steels is an important factor that affects CO2 corrosion behavior, but in-depth understanding is still lacking.

This study used three ferrous metals having different microstructures. These include pure iron, and two carbon steels that included AISI 1018, and N80. Corrosion experiments were performed in 10w% NaCl brine solution at 85°C, pH 6.5, sparged with CO2 at 1atm. Electrochemical polarization measurements were performed in small dc voltage range in a manner similar to that of linear polarization resistance (LPR) measurement. A new analysis methodology was applied to the electrochemical polarization data to separate out anodic and cathodic currents that underlie the CO2 corrosion reactions. The corrosion scale that formed during the experiment was analyzed using scanning electron microscopy and x-ray diffraction.

The results showed that protective FeCO3 scale was formed only on carbon steel surface within a few days and reduced corrosion rate. However, different corrosion behavior was observed for pure iron. Cementite (Fe3C) in carbon steels was turned out as key microstructural factor affecting CO2 corrosion. The effects of steel microstructure and the roles of cementite phase were determined by correlating the observed corrosion behavior with the known metal/steel microstructures.
Modeling of Photo-enforced Stratification

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Abstract

Photopolymerization has temporal and spatial control. Thus copolymerization of an optically thick formulation may affect the properties of the final polymer by producing a film with a depth composition gradient. Each monomer in the copolymerization has different reactivity resulting in a monomer that preferentially reacts. The monomer that preferentially reacts polymerizes fastest in the high light intensity regions of the film. The light intensity is the highest at the surface near the light source, results in a concentration gradient. Thus, diffusion of one monomer toward the high light intensity region and a counter diffusion of the less reactive monomer to the bulk of the film will occur. The final polymer film will be enriched in the preferentially reacting monomer in the high light intensity regions of the film. A one dimensional kinetic model has been developed to predict the polymer composition of the final film. The model is based on expressing the chemical reactions occurring during the polymerization as differential equations. Solving the reaction equations coupled with the diffusion equations allows for the production of stratified films via photopolymerization to be mathematically modeled. In addition, through the mathematical model, rate of polymerization, diffusion, and light gradient through depth can be carefully examined. The expected result will be enrichment of higher reactivity monomers at the surface near the light source and stratified composition through the depth of the film. The model will further the understanding and allow for the prediction of the production of a stratified film.

References


Self-Adhering Graphene Transferring

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SUMMARY
Since graphene has been synthesized on copper foils by a chemical vapor deposition (CVD) growth process [1], various transferring methods have been developed, and each one has advantages and disadvantages [2]. Here we report a self-adhering graphene transferring method, which is simple, fast and cost-effective.

I. INTRODUCTION
Chemical vapor deposition of carbon on copper foils has enabled synthesis of large-scale and high-quality graphene films [1]. However, in order to measure graphene's optical and electronic properties, it must be transferred on insulating substrates [2]. We have focused on developing a transferring method, which is easy, reliable, and inexpensive, but guarantees good quality so facilitate wide application. This method utilizes the observation that the graphene coated with PMMA self-adheres without touching on SiO$_2$/Si wafer when heated.

II. METHODS

A. Preparation
Annealed Parafilm® M was prepared by floating on triethylene glycol in a glass petri dish, and was heated on a hot plate at 150°C until it stopped shrinking. Then it was cooled down to room temperature, rinsed with DI-water and cut into 5 x 5 mm pieces.

B. Graphene Growth
A similar growth method was used as in [1], but the synthesis was carried out at a higher temperature, 1070°C, in order to anneal out defects within the copper foils faster.

C. Graphene Transferring Steps
(1) Cautiously cut graphene/copper foils into 6 x 6mm squares (2) Coat with PMMA with one drop of 12.5% 50 PMMA (diluted by ethyl acetate) using a dropping pipette, baking 5 minutes at 50°C and another 20 minutes at 150°C, and taking out of the hot plate. (3) Place a piece of annealed Parafilm on top, put on the hot plate, pre-heated at 150°, wait a few seconds until the Parafilm attached, and take it out. (4) Etch the copper by floating about 2 minutes on the mixture of 10mL 20% HCl (6M) and a few drops of 30% H$_2$O$_2$ [3], rinse with DI-water, and dry in the air. (5) Self-adhering : Gently place on a 290nm SiO$_2$/Si chip, place it on the pre-heated hot plate at 150°C, wait until self-adhered on wafer, peel off the Parafilm while hot using tweezers and take out. (6) Dissolve PMMA with ethyl-acetate.

Figure 1: Graphene on the wafer. Scale bar, 2mm

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Enhancement of Electrical Properties of Printed TCO Films

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SUMMARY
In this work, electrical resistance of complex TCO layer consistent of ITO and second elements was enhanced. As well, optical transmittance was showed above 90%.

I. INTRODUCTION
Recently, printed TCO layer using ITO ink is paid attention for decreasing indium amount. However, the resistance of the printed ITO layer is higher than that of sputtered ITO layer. In order to apply to TCO successfully, the resistance of the printed ITO layer should be lowered. Therefore, in this work, second elements were adopted to lower the resistance. The complex TCO layer consistent of ITO and second element was fabricated and characteristics of the complex TCO layer were evaluated in order to determine whether it is useful for transparent electrodes.

II. EXPERIMENTALS
ITO nanoparticle ink was formulated as previous work [1]. ITO ink was printed onto film substrate followed by oven drying at 120°C for 10 min. Then, the second elements were printed onto the dried ITO layer followed by Curing at 150°C for 20 min. The printed complex TCO layer was evaluated by observing electrical and optical properties with 4 point probe and UV/Vis spectrometer.

III. RESULTS AND DISCUSSION
The composite TCO layer was well fabricated on the film substrate. That is, ITO ink and the second elements were well contacted together by printing. Dense contact between ITO and second layer enhances electrical properties. That is, in spite of low temperature curing at 150°C, the resistance of the TCO layer was ranged between 40 and 120 Ω/sq. The deviation of the resistance value is owing to distribution of the second layer. It is guessed that the deviation is reduced by improving the distribution uniformity. In case of optical properties, transmittance of the complex TCO layer was slightly decreased compared to printed ITO layer as shown in Fig. 1. The decrease of optical transmittance is attributed to destructive interference between second element and light. Despite of decrease, optical transmittance value of the complex TCO layer showed above 90%. Therefore, it is guessed that the complex TCO layer is possible to apply to transparent electrode.

![Figure 1: Change in optical transmittances](image)

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Pattern-Controlled Vertical and Lateral Growth of ZnO Nanorods Arrays for Optoelectronic Devices Application

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SUMMARY
We present a hybrid method for the pattern-controlled vertical and lateral growth of multiple nanorods of zinc oxide (ZnO) selectively on wanted areas of substrate in solution without the use of any metal catalysts. The as-grown ZnO nanorods arrays were utilized for optoelectronic devices. Especially, the FETs fabricated with the laterally-grown ZnO nanorods showed better performance than the previously reported solution-based ZnO nanowire FETs and thin film transistors.

I. INTRODUCTION
For practical device applications of zinc oxide (ZnO) nanostructures, it is crucial to grow them selectively on wanted areas of substrate either in vertical or horizontal direction. The growth of vertically-aligned ZnO nanowires on substrates has been performed by various methods such as vapor-liquid-solid growth with metal catalysis, nanosphere masking lithography, photolithography and electron-beam lithography. As for lateral growth of ZnO nanowires/nanorods, it is even difficult compared to the vertical growth, so limited papers reported. Another issue for the nanowire-based transistors is how to obtain relatively high on-current and how to adjust the drive current capability of the device. Because of the limited current drive per single nanowire, to meet the drive-current requirement for application a number of nanowires are generally integrated within the device channel by a physical arrangement method. However, such method is not easy to control the number of nanowires and to properly align them between electrodes, and thus not an ideal for economical integration.

In this talk, we present a reliable hybrid method for both lateral and vertical growth of ZnO nanorods arrays and their devices application.

II. Experimental
A hybrid method was used to selectively grow ZnO nanorods arrays either in vertical or horizontal direction on wanted areas of a substrate by combining electron-beam lithography and simple solution growth techniques. This hybrid approach resulted in excellent control of periodicity, location, and density of ZnO nanorod arrays on substrates.

III. RESULTS
Figure 1 shows the SEM images vertically grown ZnO nanorods arrays on Si and field emission current density vs. electric field plot for selectively grown spherical-shaped ZnO nanorod arrays. Figure 2 exhibits the FET fabricated using ZnO nanorods, laterally grown between electrodes and its I-V characteristics. All the results showed reliably better performances than those of the previously reported.

REFERENCES
Electron holography study on perpendicular magnetic recording media

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SUMMARY
Currently the data storage density of perpendicular magnetic recording (PMR) media in hard disc drive is at its limit for improvement. Fundamental understanding at the bit boundary is crucial to resolve this issue. This research focuses on the observation of magnetic field using electron holography technique in transmission electron microscopy (TEM).

I. INTRODUCTION
The demand for data storage has never been higher, and magnetic recording media played a great role in stable data storage. Magnetic recording started in the form of films and its density has been improving by changing its form to longitudinal magnetic recording media to perpendicular magnetic recording media. However, as each data bit gets smaller and smaller, superparamagnetism impeded further improvement.

TEM is a very powerful tool studying crystallographic properties of materials in atomic scale. However, it has been very difficult to relate the crystal structure to magnetic field profile because it is very difficult to observe the relationship of the crystal structure and magnetic field profile. The aim of this research is to use TEM and electron holography technique which will reveal the relationship between those two.

II. EXPERIMENTAL SET UP
A. Sample preparation
PMR media with CoCrPt-TiOx magnetic layer hard disc is used with magnetic grains in 7nm dimensions. Conventional plan view TEM sample preparation is done by mechanical grinding, polishing, dimpling, and ion milling.

B. Electron holography
Using the electron biprism, hologram image of the sample is taken. From the electron hologram, magnetic field profile of the sample can be extracted.

C. Conventional TEM
In order to compare the crystallographic orientation with the magnetic profile, conventional bright field TEM image is taken at the same region where the hologram was taken. Then two images are overlaid to correlate the grain structure and magnetic field.

III. EXPECTED RESULTS
Expected electron hologram image can be deduced from the conventional TEM image and micromagnetic simulation of PMR media.

REFERENCES
Lanthanide oxychlorides (LnOCl) possess unique optical, magnetic, electronic, and catalytic properties that are characteristic to each specific metal. Scaling LnOCl to nanoscale dimensions offers the potential to further tune the properties of these materials. Most reported approaches for preparing LnOCl nanostructures do not yield well-defined morphologies because of the lack of control in separating the nucleation and growth steps. We have established a novel synthetic methodology for preparing LnOCl nanocrystals with controllable dimensions and morphology based on a non-hydrolytic sol-gel synthetic route involving the ligand exchange and condensation of rare earth halides and alkoxides in the presence of coordinating solvents. The synthetic approach represents a unique low-temperature route for the preparation of well-defined and faceted nanocrystals of ternary rare-earth oxychlorides in the PbFCl matlockite phase. Electrophoretic deposition of anisotropic GdOCl nanodisks in the proper organic media results in the highly oriented GdOCl thin films with high packing densities. We have also been able to create free-standing films without the necessity of sacrificial polymer layers, which has yet to have been reported for any other system.
Conductive Polymer Nanotubes Patch for Enhanced Transdermal Controlled Delivery

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Poly(3,4-ethylenedioxythiophene) (PEDOT) nanotubes of well controlled length, wall thickness and diameter are electrochemically synthesized in porous membranes. The intrinsic electrical properties of PEDOT allow for the controlled release of model drugs by varying the potential. The design criterion of the transdermal drug delivery patch system is based on the electrostatic interaction between the PEDOT nanotubes with anionic model drugs. The oxidation and reduction of PEDOT results in the uptake and release of drugs accordingly. The PEDOT patch has been shown to control the release rate of drugs based on varying the potential strength. Both hydrophobic and hydrophilic drugs have been uploaded into the nanotubes and release through porcine skin. This research highlights potential biomedical applications for PEDOT nanotubes within a broad range of fields such as biomedical engineering, tumor targeting, and pharmacology.
Light-Mediated Pattern Formation in Chalcogenide Nanostructures

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The chemical synthesis of inorganic materials whose nanoscale morphologies respond to changing illumination conditions can enable the development of complex structures with tailored optical responses. We have developed a method for light-mediated pattern formation during the electrodeposition of photoresponsive selenium-tellurium (Se-Te) alloys. While no long-range order is observed for Se-Te films prepared in the dark, those deposited under illumination display a nanoscale lamellar pattern that is continuous over the entire growth substrate. The resulting pattern is dependent on the illumination conditions including the intensity, wavelength, polarization, and angle of the incident light during the growth process. We attribute the light-induced pattern formation to interference between scattered light at the surface of the growing film, which produces a periodic modulation in the light intensity. The deposition rate of the Se-Te alloy is increased in regions of greater local intensity such that the growth of the film follows the light intensity pattern created at its surface. Because the patterns are dynamically responsive, further structural complexity can be built into the Se-Te nanostructures by changing the illumination conditions during the electrodeposition process. This light-mediated growth technique provides the possibility for optimizing the absorption and transmission characteristics of a material by using light in a feedback loop to direct the film’s structure and morphology.