06 Nanomaterials: Synthesis, Manufacturing and Applications

Plasmonic Zirconium Nitride Nanoparticles, STEPHEN EXARHOS1, CHRIS RUDNICKI1, ALEJANDRO ALVAREZ-BARRAGÁN1, and LORENZO MANGOLINI1,2 (1Mechanical Engineering Department and 2Materials Science and Engineering Program, Bourns College of Engineering, University of California, Riverside, 900 University Avenue, Riverside, CA 92521; stephen.exarhos@gmail.com, crudn001@ucr.edu, aalva050@ucr.edu, lmangolini@engr.ucr.edu).

Localized surface plasmon resonance (LSPR) has garnered interest in a variety of fields recently, such as photocatalysis, photovoltaics, biophotonics, spectroscopy, sensing, and wave-guiding. LSPR is correlated with the density of free charge carriers in nanoparticle materials, so conductive metals like gold, silver, aluminum, and copper have the highest LSPR frequencies, absorbing within or near the visible spectrum. Cost and production concerns motivate the search for plasmonic materials alternative to coinage metals, like Group IV transition metal-nitrides. We present a novel technique for the synthesis of plasmonic zirconium nitride nanoparticles using a scalable non-thermal plasma process. The synthesized materials exhibit a plasmonic extinction peak at ~620 nm. Due to the small size of the particles – on the order of 10 nm – native oxidation is significantly detrimental to the material’s optical performance. We have studied the effect of oxidation on the zirconium nitride nanoparticles and present a facile solution to the issue, yielding a product comparable in performance to plasmonic gold nanoparticles. This work has the potential to introduce a scalable and relatively inexpensive material system to high-energy plasmonics applications allowing large-scale commercial implementation in a variety of fields.

Enhanced stability and n-doping effect of Al2O3 passive layer on MoS2 field-effect transistor-based DNA biosensor, TUNG PHAM1, JHOANN LOPEZ1, MEI YANG2, YOUNGWOO RHEEM2, and ASHOK MULCHANDANI1,3 (1Department of Chemical and Environmental Engineering and 2Materials Science and Engineering Program, University of California–Riverside, 900 University Ave, Riverside, CA 92521, United States, tpham052@ucr.edu, jlope086@ucr.edu, youngwoohem@engr.ucr.edu, adani@engr.ucr.edu; 2Key Laboratory of Biohistorical Science and Technology, Ministry of Education, College of Bioengineering, Chongqing University, 174 Shazhengjie, Shapingba, Chongqing 400044, PR China, yangmei@cqu.edu.cn).

Molybdenum disulfide (MoS2), a member of 2D-semiconducting material family, features a direct band gap of 1.9 V in its monolayer structure. This tunable band gap suggests MoS2 is a suitable conducting channel for field-effect transistors (FETs). In this work, we report for the first time the degradation of CVD-MoS2 FET-based sensor in the presence of water, which possibly causes the false response in detection. We conclude the degradation is not due to the properties of MoS2 altered during the exposure to water but the physical delamination of the material from the substrate, which in turn reduces the gating effect in FET transfer mode. We are able to alleviate the problem by coating the device with a 35 nm thick aluminum oxide (Al2O3) layer using atomic layer deposition (ALD). This passive oxide layer not only acts as a protective layer against device degradation but also enhances the n-doping effect in the FET. This permits multiple methods of detection, including using FET characteristic curve and chemiresistive I-V measurement at zero gate voltage (Vg = 0 V). Additionally, the Al2O3 layer provides available sites for functionalization with deoxyribonucleic acid (DNA) probes via silanization using (3-aminopropyl) triethoxysilane (APTES) and glutaraldehyde for biosensing. The functionalized Al2O3 coated MoS2 FET-based DNA biosensor is applied to detect mutations in human TP53 gene, a biomarker for a variety of cancers. The fabricated devices demonstrate high selectivity between the complimentary and non-complimentary DNAs, high sensitivity and excellent limit of detection at concentration as low as femto molar.

3D Printing Graphene-Enhanced Li-ion Battery and Graphene Supercapacitors, MATTHEW TISBE*, NICHOLAS FERGUSON, AMANDA RAMOS, JEFFREY LEE, CALVIN NGUYEN, BEN CHENG, ALEXANDER LAU, and ZHEN YU (Department of Electrical and Computer Engineering, California State Polytechnic University, Pomona, CA; zhenyu@cpp.edu).

Batteries are power storage devices that provide their stored power to connected electronics. Li-ion batteries are a widely used battery type due to their high energy density and ability to recharge. These properties make them well suited for portable electronic devices at the expense of taking the majority weight and volume of the device. The use of a liquid electrolyte also limits the recharging speed and operating temperature. Switching to a solid electrolyte yields enhanced environmental safety and higher energy density, thus a smaller volume needed for portable applications. Our research focuses on the ease of production of such batteries through the development of a superior solid electrolyte, and the robustness of 3D printing and robotic assembly.
Development of Individual Nano Scale Components and Elements, and the Impact on Nano Communication Technology, RICHARD CHANG\**, ANASTASIYA ALAYEV, MOISES GRAHAM, FARIA KAUSAR, and ZHEN YU (California State Polytechnic University, Pomona, CA; zhenyu@cpp.edu).

Communication technology plays a major role in our daily lives. However, such communication systems are innately integrated into engineering technology as well as technological advances. One key element is the development of nano-scale technology, namely carbon nanostructures and their integral role in the development and fabrication of carbon nanotube transistors. With the constant research in how to shrink transistors, thus adding more transistors to a single technological element (supported by Moore’s Law), there is a very strong possibility that communication technology today will eventually be reduced to the nano-scale, and thus generating the emergence of nano-communication technology. The research our group performed occurred on the component scale, with elements we believed to be instrumental in successful nano-communication technology, as opposed to researching nano-communication as a whole.

Elucidating Mechanism of Linker Folding in Computer Designed Kinematically Active Metal-Organic Frameworks for Gas Storage and Separation, WEIYI ZHANG1, CHARLES MANION1, LAURA DE SOUSA OLIVEIRA1, MATTHEW I. CAMPBELL2, and P. ALEX GREANEY1 (*Materials Science and Engineering, University of California – Riverside, Riverside, CA 92501, USA, wzhan097@ucr.edu, cam626@gmail.com, laura.ruta.oliveira@gmail.com, greaney@ucr.edu; 2School of Mechanical, Industrial, and Manufacturing Engineering, Oregon State University, Corvallis, OR 97331, Matt.Campbell@OregonState.edu).

Metal-Organic-Frameworks (MOFs) are molecular latticework structures composed of organic linking molecules (linkers) bonded with inorganic nodal unite (nodes). We recently developed a computer algorithm that uses grammatical evolution to design, without human supervision, MOFs with kinematically active linkers. In this work we dissect the folding mechanisms employed by the most successful MOFs that the computer designed. Large scale molecular dynamics simulations were performed of MOFs collapsing under pressure and cooperative patterns of linker folding and node rotation identified. By analyzing the patterns of folding we assess the diversity of kinematic strategies that the computer algorithm discovered. In the next step, we introduced machine learning into the analysis to identify the potential flexible MOFs for the further research mapping out the structure factors influencing properties related to gas storage and separation and designing the possible and better performed structure for specific applications.

Photocatalysis of Propanil in Water using Nanotechnology, ZHEN YU1, VICTORIA WU2, and ZHUANGJIE LI2 (*Department of Electrical and Computer Engineering, California State Polytechnic University, Pomona, CA, zhenyu@cpp.edu; 2Department of Chemistry and Biochemistry, California State University, Fullerton, CA, zhi@exchange.fullerton.edu).

Propanil water samples with concentration at ppm (part per million) level are placed into a beaker containing trace amount of hydrogen peroxide and a glass plate coated with nanoparticles. The samples are then exposed to visible light radiations coming from either regular light bulb or the Sun, and the change of the Propanil concentration was monitored using ultraviolet-visible spectroscopy. Cataphotolysis of Propanil molecules takes place at the surface of nanoparticles, on which the reduction-oxidation reactions occur, leading to oxidative degradation of the Propanil molecules. The Propanil degradation is indicated by the absorbance decrease of the ultraviolet-visible spectrum of Propanil at 248 nm. The product of cataphotolysis is probed using liquid chromatography coupled with mass spectrometry (LC-MS), and the acidity of the water sample was measured using a pH meter. Kinetics information is acquired by monitoring the decay of Propanil as a function of time during its cataphotolysis. Propanil molecules were found to undergo decomposition during cataphotolysis when the water samples are radiated by visible light either from light bulb or from the Sun. The sunlight was found to increase the degradation rate in comparison to the visible light from the light bulb. The cataphotolytic degradation of Propanil in water follows the first order chemical kinetics, with a rate constant of $k = (4.29\pm 0.49) \times 10^{-3}$ s$^{-1}$.

Predicting the Surface Energy of Pyramidal Facets in ZnO and Their Role in Triggering Growth of Nanowires, PEGAH MIRABEDINI1*, TAEHOON LIM2, ALFREDO A. MARTINEZ-MORALES2, and P. ALEX GREANEY1,3 (*Material Science and Engineering Program and 3 Department of Mechanical Engineering, University of California, Riverside, 900 University Avenue, Riverside, CA 92521, pmira002@ucr.edu, agreaney@ucr.edu; 2Southern California Research Initiative for Solar Energy, University of California, Riverside, Riverside, CA 92507, taehoon.lim@ucr.edu, alfmart@ece.ucr.edu).

ZnO materials have been widely used in optics and electronics, photoelectrodes in energy-conversion devices, photoelectrochemical biosensors used in water splitting, and materials used for electronic and photonic device applications. ZnO nanowire materials are being developed commercially for photocatalytic applications due to their wide and direct band gap, large exciton energy, high electron mobility, and high thermal conductivity. Recent experiments growing ZnO through chemical vapor deposition observe the autocatalytic growth of nanoscale [0001] aligned ZnO wires from the apex points of much larger pyramidal shaped ZnO islands. Motivated to understand the mechanisms behind this abrupt transition in growth morphology, we here report on density functional theory calculations to predict the structure and surface energy of these facets at different stages of growth.