MECHANICAL ENGINEERING

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of:

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Monday, June 6, 2011, 11am

EBUII 202

Graphene and its Hybrid Nanostructures for Nanoelectronics and Energy Application

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University of California, Riverside, June 2011
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This dissertation focuses on investigating the synthesis of graphene and its hybrid nanostructures by CVD process, as well as studying their potential applications in nanoelectronics and energy conversion/storage. The substantial understanding of interaction of graphene layers between the bio-molecules and gas molecules will enable the improvement in the applications of graphene in bio-sensor and chemical sensor. To achieve these objectives, graphene field effect transistors are fabricated to study the interactions of graphene between single stranded Deoxyribonucleic Acids (ssDNA) and gas molecules. ssDNA is found to act as negative potential gating agent that increases the hole density in single layer graphene (SLG). The molecular photodesorption and absorption from pristine and functionalized graphene are studied. The photodesorption induced current decrease in functionalized graphene by concentrated HNO_3 becomes less significant than pristine graphene layers. We suggest this is due to the passivation of oxygen-bearing functionalities to CVD grown graphene structure defects via HNO_3 functionalization, which prevents the further absorption of gas molecules.

The advance of synthesis of graphene by chemical vapor deposition (CVD) promotes the industrial applications of graphene, especially in optoelectronics. We synthesize the graphene both on nickel thin film and copper foils by CVD, and investigate the grow kinetics, such as the effect of growth pressure on the uniformity and quality of Cu-grown graphene. By controlling the growth pressure we achieve uniform single layer graphene sheets. To decrease the sheet resistance, we stack the single layer graphene using layer-layer transfer technique. Highly concentrated HNO_3 is employed to improve the conductivity and surface wettability of graphene layers. Four-layer graphene films with optical transmittance of 90% after HNO_3 treatment are applied in organic solar cell as anode electrode. Further, we report the fabrication of highly conductive, large surface-area 3D pillar graphene nanostructures (PGN) films from assembly of vertically aligned CNT pillars on flexible copper foils and directly employed for the application in electrochemical double layer capacitor (EDLC). The PGN films with MWCNTs on graphene layers, which were one-step synthesized on flexible copper foil (25 um) by CVD process, exhibit high conductivity with sheet resistance as low as 1.6 Ohm per square and high mechanical flexibility. The fabricated EDLC supercapacitor based on high surface-area PGN electrodes ($563m^2/g$) showed high performance with high specific capacitance of 330F/g.

We demonstrate the synthesis and characterization of three dimensional heterostructures graphene nanostructures (HGN) comprising continuous large area graphene layers and ZnO nanostructures, fabricated via two-step chemical vapor deposition. The material characterization exhibits the highly crystalline ZnO nanostructures synthesized on few-layer graphene film. Fabricated electronic devices from graphene/ZnO nanostructures/graphene show excellent electrical and photoelectrical properties. A combination of electrical and optical properties of graphene and ZnO building blocks in ZnO based HGN provides unique characteristics for opportunities in future optoelectronic devices.