W O R C E S T E R P O L Y T E C H N I C I N S T I T U T E
M E C H A N I C A L E N G I N E E R I N G D E P A R T M E N T

P H . D . D I S S E R T A T I O N

ENTITLED

"VERSATILE HIGH PERFORMANCE PHOTOMECHANICAL ACTUATORS BASED ON TWO-DIMENSIONAL NANOMATERIALS"

B Y

VAHID RAHNESHIN

Abstract: The ability to convert photons into mechanical motion is of significant importance for many energy conversion and reconfigurable technologies. Establishing an optical-mechanical interface has been attempted since 1881; nevertheless, only few materials exist that can convert photons of different wavelengths into mechanical motion that is large enough for practical import. Recently, various nanomaterials including nanoparticles, nanowires, carbon nanotubes, and graphene have been used as photo-thermal agents in different polymer systems and triggered using near infra-red (NIR) light for photo-thermal actuation. Layered transition metal dichalcogenides (TMDs) provide intriguing opportunities to develop low cost, light and wavelength tunable stimuli responsive systems that are not possible with their conventional macroscopic counterparts. Compared to graphene, which is just a layer of carbon atoms and has no bandgap, TMDs are stacks of triple layers with transition metal layer between two chalcogen layers and they also possess an intrinsic bandgap. While the atoms within the layers are chemically bonded using covalent bonds, the triple layers can be mechanically/chemically exfoliated due to weak van der Waals bonding between the layers. Due to the large optical absorption in these materials, they are already being exploited for photocatalytic, photoluminescence, photo-transistors, and solar cell applications. The large breaking strength together with large band gap and strong light-matter interaction in these materials have resulted in plethora of investigation on electronic, optical and magnetic properties of such layered ultra-thin semiconductors. This dissertation will go in depth in the characterization, development, and application of two-dimensional (2D) nanomaterials, with an emphasis on TMDs and molybdenum disulfide (MoS_2), when used as photo-thermal agents in photoactuation technologies. It will present a new class of photo-thermal actuators based on TMDs and hyperelastic elastomers with large opto-mechanical energy conversion, and investigate the layer-dependent optoelectronics and light-matter interaction in these nanomaterials and nanocomposites. Different attributes of semiconductive nanoparticles will be studied through different applications, and the possibility of globally/locally engineering the bandgap of such nanomaterials, along with its consequent effect on optomechanical properties of photo thermal actuators will be investigated. Using liquid phase exfoliation in deionized water, inks based on 2D-materials will be developed, and inkjet printing of 2D materials will be utilized as an efficient method for fast fabrication of functional devices based on nanomaterials, such as paper-graphene-based photo actuators. The scalability, simplicity, and biocompatibility of the inkjet printing of 2D materials along with its applicability to a variety of substrates such as plastics and papers can be implemented to fabricate high-performance devices with countless applications in soft robotics, wearable technologies, flexible electronics and optoelectronics, bio-sensing, photovoltaics, artificial skins/muscles, transparent displays and photo-detectors.

Tuesday, April 17th, 2018 at 9:00 am

Higgins Lab, Price Conference Room 102

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