Materials Science & Engineering Seminar Series

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presents

Molecular Scale Engineering of Hybrid Thin Film Materials for Energy Storage

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ABSTRACT: Ceramic and polymeric thin film materials and the organic-inorganic (hybrid) interfaces they form are critical components in energy storage devices like batteries. This talk will introduce two novel approaches to engineer such materials.

I will demonstrate how initiated chemical vapor deposition (iCVD) polymerization can be used to synthesize nanoscale (~ 20 nm), conformal polysiloxane thin films which serve as hybrid electrolytes for the emerging field of three-dimensional (3D) batteries. An important consideration for miniaturizing on-board electrochemical energy storage for many applications including sensing, actuation, communications, and medical implants is the footprint area of the power source. 3D battery designs use electrodes with non-planar geometries, effectively enabling power sources to possess high energy density and high power density within a small footprint area (1 mm^2 – 1 cm^2). Electrolyte films in 3D batteries must cover these complex electrode geometries while retaining the underlying morphology of the electrodes, i.e. conformal coverage. Such uniform and thin polymer films are difficult to achieve by solution processing due to de-wetting and surface tension effects. In contrast, the conformal nature of the iCVD polymerization process realizes complete coverage of nanostructured electrodes like nanowires by a uniform, continuous, and pinhole free thin film. This is the first time nanoscale hybrid films with siloxane ring moieties, which are excellent electrical insulators, have been demonstrated as room temperature ionic conductors. These nanoscale films also exhibit good mechanical and chemical stability, and are easily scalable over large areas.

Next, I will introduce a solution-based process that crystallizes ceramic (TiO_2) thin films at low temperatures (~ 150 ^{o}C) using microwave radiation assisted selective heating. These materials require temperatures over 400 ^{o}C to crystallize using conventional synthesis techniques. High temperature processing creates incompatibility with microfabrication processes and limits the choice of substrate materials on which these films can be grown, as flexible plastic or polymeric substrates typically decompose at temperatures > 200 ^{o}C. The low temperature microwave process thus enables the integration of ceramic thin films directly onto temperature-sensitive substrates like plastic for use as electrodes and electrolyte layers in flexible thin film batteries.

BIOGRAPHY: B. Reeja Jayan is an Assistant Professor in Mechanical Engineering at Carnegie Mellon University (CMU). She also holds a courtesy appointment in the Materials Science and Engineering department at CMU. Prof. Jayan received her M.S. in Electrical Engineering and Ph.D. in Materials Science and Engineering from The University of Texas at Austin (UT-Austin), working with Professor Arumugam Manthiram. She was subsequently a Postdoctoral Associate in Chemical Engineering at the Massachusetts Institute of Technology (MIT), working under the supervision of Professor Karen Gleason. Her multidisciplinary research group at CMU explores novel design strategies for organic (polymers, small molecules), inorganic (metals, semiconductors, insulators), and organic-inorganic hybrid materials for applications in energy and sustainability. Her work has resulted in 18 peer-reviewed journal publications and filing of 4 patent applications. She is a recipient of the Cockrell School of Engineering Student Leadership Award from UT-Austin, a doctoral fellowship from the American Association of University Women (AAUW), and the H.H. The Maharaja of Cochin Endowment Prize from the University of Kerala, India.

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