Electrochemical Intercalation for Modification and Processing of Phosphorene and Other 2D Materials

Jacek B. Jasinski

Conn Center for Renewable Energy Research, University of Louisville, Louisville, KY, 40292, USA

Abstract: Two-dimensional (2D) materials have recently attracted significant attention due to their unique properties, which are often drastically different from those of their bulk van der Waals (vdW) layered counterparts. In this seminar, I will explore the role of anisotropy in 2D and layered materials, focusing on phosphorene and its bulk counterpart—black phosphorus (BP)—as well as black arsenic phosphorus (b-As_xP_{1-x}) alloys. The discussion will cover our recent synthesis, characterization, and intercalation studies of these materials. Intercalation, which generally refers to the insertion of foreign atoms, ions, or molecules into the vdW gaps between weakly bonded layers, is becoming widely recognized as a versatile approach for modifying the electronic, structural, and chemical properties of vdW-layered and 2D materials. In particular, I will focus on our recent research on alkali metal intercalation in BP and b-As_xP_{1-x} alloyed materials. A key highlight of the talk will be electrochemical sculpting, a novel technique we have developed for the fabrication of BP and b-As_xP_{1-x} nanoribbons (NRs) via controlled intercalation. This method utilizes the highly anisotropic ion diffusion in these materials, yielding NRs with well-defined widths that, in the case of phosphorene, are narrower than those produced by traditional methods. The mechanism of electrochemical sculpting, as well as our investigations into the process, will be discussed. Additionally, I will introduce Angular Resolved Polarized Raman Spectroscopy (ARPRS) as an advanced tool for structural and symmetry analysis. Recently, we have used this technique successfully to investigate the complex structure of b-As_xP_{1-x} alloys, as well as BP NRs, shedding light on their unique anisotropic structures.

Biography: Dr. Jasinski earned his M.Sc. in Solid State Physics (1992) and Ph.D. in Physics of Semiconductors (1997) from the University of Warsaw, Poland. His early career research was recognized with awards from the Polish Physical Society (1992) and the Foundation for Polish Science (1997). He began his professional journey as a junior faculty member at the Institute of Experimental Physics, Warsaw University, Poland (1997-2000). Subsequently, he served as a Post-Doctoral Researcher at the Materials Science Division, Lawrence Berkeley National Lab (2000-2004), followed by positions as a Post-Doctoral Researcher (2004-2005) and a Research Scientist (2005-2008) at the School of Engineering, University of California, Merced. In 2008, he joined the University of Louisville, where he currently holds the position of Materials Characterization Theme Leader at the Conn Center for Renewable Energy Research.