Electrochemical Sculpting of Phosphorene Nanoribbons

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Abstract

In recent years, phosphorene, a two-dimensional (2D) form of black phosphorous (BP), has attracted significant attention due to its exceptional properties, including high carrier mobility, thickness-dependent bandgap, and strong in-plane anisotropy. Moreover, phosphorene nanoribbons (PNRs) exhibit even more impressive characteristics owing to their one-dimensional (1D) nanostructure, which gives rise to additional quantum confinement effects, density of states redesign, and a high density of active edge sites. In this study, we present an innovative and straightforward approach termed "electrochemical sculpting" to synthesize PNRs through an electrochemical process utilizing the highly anisotropic Na-ion diffusion in BP along the [001] (zigzag) direction. Inspired by our previous research on the anisotropic diffusion of Li-ions causing the segmentation of BP flakes into nanoribbon-like strips along the zigzag direction, we hypothesized that the highly anisotropic Na-ion diffusion in BP could lead to PNR formation. Our hypothesis was validated through a low-cost and scalable two-step electrochemical method, resulting in PNRs with confined widths (< 10 nm) that are significantly narrower than those produced by previous methods. In the first step, BP flakes are nanostructured via an electrochemical discharge process into bundles of parallel PNRs separated by regions of highly disordered phosphorous, as confirmed by transmission electron microscopy (TEM) and in-situ Raman spectroscopy. Subsequently, the PNR bundles undergo ultrasonic treatment in a solvent to isolate individual, well-defined PNRs. This study provides valuable insights into a novel synthesis approach for PNRs with confined widths, opening up new possibilities for the development of nanoribbons using BP and other highly anisotropic layered materials. The demonstrated electrochemical sculpting method offers improved scalability and holds promise for advancing the applications of PNRs.

Biography of Presenter

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.