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PLASMA ASSISTED PVD APPROACHES FOR SYNTHESIS OF 2D ELECTRONIC MATERIALS

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Physical vapor deposition (PVD) of large area two-dimensional (2D) materials is an emerging technology, which can provide a reproducible, substrate agnostic, and cost effective direct growth for 2D semiconductor and dielectric heterostructures over wafer scale areas for electronic device applications. Plasma assisted PVD growth of semiconducting transition metal dichalcogenides (MoS2, WS2) and dielectric materials (BN) was recently demonstrated as an alternative to mechanical exfoliation and chemical vapor deposition. Pulsed DC magnetron sputtering from MoS2 targets in argon and pulsed laser deposition from BN targets in nitrogen were developed to produce 2D materials on a variety of substrate materials: amorphous silicon dioxide, highly oriented sapphire and graphite, as well as flexible polymers. The thermodynamic tendency toward island formation is overcome by maximizing ad-atom mobility through the control of incident flux, ionization state, energies, and densities, while avoiding defect formation, such as vacancy creation by sputtering of S atoms. Plasma assisted PVD processes are shown to yield highly (002) oriented 2D polycrystalline films exhibiting sub-monolayer thickness variability over 40 mm diameter areas when using 30 mm diameter sputtering plasma sources. In-situ XPS and Raman spectroscopy were used to analyze film stoichiometry, structure, and initial growth stages. Pin-hole and gap free 2D MoS2 and BN films were confirmed by TEM, conductive AFM, Raman, and electrical probe measurements. The challenges of plasma assisted PVD processes in maintaining 2D film stoichiometry, minimizing point defect formation, and improving crystallinity are discussed. A direct laser writing route is also presented, where a room temperature PVD growth of amorphous ultra-thin materials on polymer substrates is followed by laser annealing for selected areas to form crystalline 2D structures. Advantages and challenges of PVD processes for scalable synthesis of 2D materials and applications in electronic devices are discussed.

SHORT BIO

Professor Andrey A. Voevodin is a Chair of Department of Materials Science and Engineering in The College of Engineering, University of North Texas. Before joining UNT in the Fall of 2015, he was a Principal Research Scientist and Team Leader at the US Air Force Research Laboratory's (AFRL) Materials and Manufacturing Directorate, where he established and led tribological, thermal management, and nanoelectronic material research laboratories. Dr. Voevodin's expertise includes thin film deposition, plasma processes, surface engineering, surface analysis, electrical, thermal, and mechanical interfaces. His current research areas are nanolayered, nanostructured, and 2-dimensional materials for electron and phonon transport, hybrid and pulsed plasma deposition technologies, surface engineering and high temperature tribology. Dr. Voevodin has over 300 technical publications, from which 220 are in peer-reviewed archived journals, one book, eight book chapters, 12 patents and inventions. Dr. Voevodin is a Fellow of AVS Science and Technology Society and serves as 2017 Chair for the Advanced Surface Engineering Division of AVS.