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Solution-Based Processing and Applications of Two-Dimensional Heterostructures

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Two-dimensional materials have emerged as promising candidates for next-generation electronics and optoelectronics, but advances in scalable nanomanufacturing are required to exploit this potential in real-world technology. This talk will explore methods for improving the uniformity of solution-processed two-dimensional materials with an eye toward realizing dispersions and inks that can be deposited into large-area thin-films. In particular, density gradient ultracentrifugation allows the solution-based isolation of graphene, boron nitride, montmorillonite, and transition metal dichalcogenides (e.g., MoS_2, WS_2, ReS_2, $MoSe_2$, WSe_2) with homogeneous thickness down to the atomically thin limit. Similarly, two-dimensional black phosphorus is isolated in organic solvents or deoxygenated aqueous surfactant solutions with the resulting phosphorene nanosheets showing field-effect transistor mobilities and on/off ratios that are comparable to micromechanically exfoliated flakes. By adding cellulosic polymer stabilizers to these dispersions, the rheological properties can be tuned by orders of magnitude, thereby enabling two-dimensional material inks that are compatible with a range of additive manufacturing methods including inkjet, gravure, screen, and 3D printing. The resulting solution-processed two-dimensional heterostructures show promise in several device applications including photodiodes, anti-ambipolar transistors, gate-tunable memristors, and heterojunction photovoltaics.