Large-scale green production of 2D crystals for advanced technologies

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Two-dimensional crystals (2DCs) hold potential to revolutionize technologies spanning energy storage, flexible electronics, and water purification. Yet, their large-scale industrial implementation remains limited by the absence of scalable and environmentally benign fabrication routes. In this presentation, I will discuss our integrated, sustainable approach for producing 2DCs and translating them into functional devices. Our strategy replaces hazardous solvents traditionally used in liquid-phase exfoliation (LPE) with greener alternatives such as Cyrene, ensuring both dispersion stability and high exfoliation efficiency [1, 2]. Leveraging these optimized dispersions, we fabricated graphene- and MXene-based nanofiltration membranes that exhibit selective ion sieving, long-term water stability without swelling, and intrinsic antibacterial properties [3, 4]. To further enhance throughput, we developed a continuous, hybrid LPE process combining high-pressure atomization and high-shear mixing, enabling water-based graphene production at rates of 1 L h^{-1} with concentrations up to 1.2 mg mL^{-1} [5]. These dispersions served as the basis for sustainable, printable graphene pastes applicable in flexible microsupercapacitors, sensors, and electromagnetic interference shielding coatings [6]. Building on this foundation, we engineered textile-integrated supercapacitors using nanocarbon–elastomer composite electrodes processed in sustainable solvents such as 2-methyltetrahydrofuran, achieving sheet resistances below 50 Ω sq^{-1} and excellent cycling stability exceeding 10,000 charge–discharge cycles across a range of natural and synthetic fabrics [7]. Extending the same design principles to sensing, we created all-carbon hybrid nanocarbon/elastomer inks combining carbon nano-onions and carbon nanotubes, which deliver high gauge sensitivity, outstanding stability (>10,000 compression and 7,000 tensile cycles), and durable mechanical adaptability for wearable strain and motion sensing applications [8]. Collectively, these advances outline a comprehensive roadmap for the sustainable, high-volume production of 2DCs and their seamless integration into next-generation nanotechnologies, bridging laboratory innovation with scalable and green industrial manufacturing.

References

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