Sustainable strategies for large-scale 2D crystal production and applications

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Two-dimensional crystals (2DCs) could advance diverse technological areas such as energy storage, nanoelectronics, and water purification. However, industrial adoption is limited by the lack of scalable, eco-friendly, and reproducible fabrication methods. In this talk, I will outline our approach to sustainable 2DC production, tailored to distinct application needs – from printable technologies to electronic device integration.
Our efforts on top-down, solution-based processing overcome the reliance on toxic solvents in liquid-phase exfoliation by employing greener alternatives, such as Cyrene, which guarantees dispersion stability while retaining high exfoliation efficiency [1,2]. Building on these dispersions, we developed graphene-based nanofiltration membranes capable of selective ion filtering, showing no swelling and extended water stability [3]. To boost throughput, we introduced a hybrid technique combining high-pressure atomization and high-shear mixing, scaling water-based graphene production to 1 L/h at 1.2 mg/mL [4]. These inks underpin eco-friendly graphene pastes for flexible micro-supercapacitors, sensors, and electromagnetic interference shielding coatings [5]. All-carbon composites derived from these processes also serve as strain sensors for wearable systems [6].
In parallel, we focus on bottom-up chemical vapor deposition techniques that enable precise control over material structure and composition, supporting integration into electronic architectures such as memristive devices [7] and sensors [8].
Together, these complementary strategies offer a practical roadmap towards industrial-scale 2DC manufacturing and targeted integration into advanced technologies.

References

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