Controlling Electrochemical Exfoliation of 2D Nanoflakes for Optimized Performance

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Transition metal dichalcogenides (TMDCs) are an emerging class of nanomaterials exhibiting diverse electronic phases, including semiconducting, metallic, superconducting, and magnetic states. Their properties are highly sensitive to stimuli such as light, electric and magnetic fields, mechanical strain, and the local chemical environment.[1-3] This responsiveness enables fine-tuning through control of material phase, flake dimensions, and surface chemistry, making TMDCs prime candidates for next-generation optical and electronic devices that demand both tunability and scalable production.
TMDCs can be synthesized via top-down growth or bottom-up exfoliation from bulk crystals. The latter approach produces dispersions that can be formulated into inks for printed optoelectronic devices, including field-effect transistors, photodetectors, inverters, and sensors.[4] However, realizing widespread application of liquid-printable TMDCs still requires overcoming challenges related to scalability and material quality. Achieving the large-aspect-ratio nanoflakes optimal for many applications typically involves electrochemical intercalation of large ions between crystal layers to weaken van der Waals interactions, followed by sonication to form colloidal dispersions.[5] While effective, this process requires balancing production rate with structural integrity: higher potentials accelerate exfoliation but also induce undesirable side reactions and impurities, complicating post-processing.
To address these limitations, we developed a three-electrode compression cell that enables scalable exfoliation directly from bulk powder, avoiding the need for costly single-crystal precursors.[6] By optimizing electrochemical parameters, we achieved controlled intercalation with minimal defect formation, reducing both intrinsic structural damage and extrinsic chemical contamination.[7] Continued optimization of post-processing and washing protocols allows further purification of colloidal inks, while systematic identification of by-products informs targeted removal strategies.
Together, these studies advance the scalable synthesis of high-quality TMDC nanoflakes. Our approach reduces production cost and complexity while preserving the desirable electronic and optical properties that make TMDCs central to next-generation flexible and printed device technologies.

References

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