Wireless Electrochemical Exfoliation and Functionalization of Hexagonal Boron Nitride

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Abstract

The production of high-quality two-dimensional materials at large-scale remains a fundamental challenge for advancing their practical applications. Current top-down exfoliation methods suffer from significant limitations, including reliance on harsh chemicals, persistent surfactant contamination that degrades material properties, and production of structurally compromised flakes. Beyond material production, achieving controlled covalent functionalization for property modulation presents an additional layer of complexity, particularly for chemically inert dielectric materials like hexagonal boron nitride (hBN), where conventional approaches prove entirely ineffective due to the material's insulating nature and exceptional chemical stability.
This work presents a wireless electrochemical approach that integrates material production and functionalization into a single scalable process. By applying a high voltage to the electrolyte cell, a gradient electric field induces polarization in the material placed between two electrodes, which drives effective exfoliation while additionally enabling covalent surface modification. The protocol operates entirely in aqueous media, eliminating the need for harsh chemicals or persistent surfactants that compromise material integrity.
We demonstrate the methodology's capability using hBN as a representative dielectric material, achieving both high-quality exfoliation and successful covalent grafting via diazonium chemistry. Comprehensive characterization through Raman spectroscopy, XPS, AFM, and TEM confirms both effective exfoliation and successful functionalization.

References

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Figures

Figure 1: One-pot exfoliation-functionalization protocol used in this work.