Bipolar electrochemistry for the exfoliation and functionalization of 2D materials

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Abstract

Since the isolation of monolayer graphene, 2D materials have attracted significant attention due to their theoretically predicted exceptional properties. Covalent functionalization has emerged as an important strategy to further refine and enhance these properties, enabling their integration into diverse applications. However, these methods often require highly reactive conditions, making it difficult to control the degree and uniformity of surface functionalization. Additionally, existing techniques are largely limited to conductive surfaces, with minimal progress made on functionalizing non-conductive substrates or expanding beyond graphene to other 2D materials. Furthermore, achieving scalable production remains a crucial challenge for their industrial viability. In this work, we present a scalable, cost-effective, and straightforward one-pot approach for simultaneous exfoliation and functionalization of 2D materials in dispersion using bipolar electrochemistry. By applying a high voltage to the electrolyte cell, a gradient electric field induces polarization in the material placed between two electrodes, driving concurrent reduction and oxidation reactions at opposite poles. This method enables the functionalization of both inert and semiconductor materials. The resulting materials are thoroughly characterized using Raman spectroscopy, XPS, AFM, and TEM.

References

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Figures

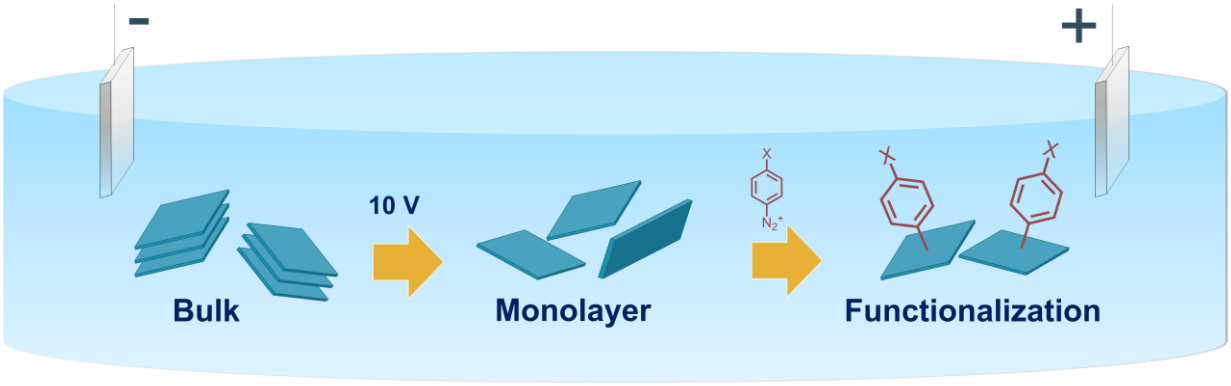

Figure 1. One-pot exfoliation-functionalization protocol proposed in this work.