2D Heterostructures from Microfluidically Exfoliated Quantum Materials

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Abstract:

The exfoliation of two-dimensional (2D) materials has emerged as a crucial technique for exploring their unique properties and potential applications in various fields [1]. In this study, we investigate the exfoliation process of $HfTe_2$, a topological 2D material, using a microfluidic system. The microfluidic system offers precise control over the exfoliation parameters, enabling efficient production of mono- and few-layer $HfTe_2$ flakes.
Transition metal dichalcogenides (TMDs) have emerged as a class of materials with remarkable electronic and optical properties, making them promising candidates for various applications ranging from electronics to optoelectronics [2]. Among these, $HfTe_2$ stands out due to its unique characteristics, including high carrier mobility, sizable bandgap, giant magnetoresistance, and strong spin-orbit coupling, making it particularly attractive for next-generation electronic devices and quantum technologies [3]. Here, we focus on the exfoliation of $HfTe_2$ utilizing a microfluidic system, which offers precise control over the process parameters and allows for the production of mono- to few-layer flakes with tailored thickness and quality.
The exfoliation process involves the dispersion of bulk $HfTe_2$ crystals in a suitable solvent within the microfluidic device, where shear forces generated by controlled fluid flow result in the delamination of layers from the bulk material. Through optimization of flow rates, solvent composition, and other parameters, we achieve efficient exfoliation while minimizing defects and preserving the structural integrity of the resulting flakes. The reduction in thickness leads to a quantum confinement effect, resulting in the emergence of direct bandgap behavior and tunable electronic band structure. Moreover, the large surface-to-volume ratio of the 2D flakes enhances light-matter interactions, enabling efficient absorption and emission of photons across a wide spectral range.
We analyzed the exfoliation yield and quality of the obtained $HfTe_2$ flakes, indicating the influence of various parameters such as solvent type, flow rate, and concentration on the exfoliation efficiency. Additionally, the structural and electronic properties of the exfoliated flakes are characterized using techniques such as atomic force microscopy (AFM) and scanning electron microscopy (SEM), providing insights into their morphology, thickness, and crystallinity.

References

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[2] Lv, R., Robinson, J.A., Schaak, R.E., Sun, D., Sun, Y., Mallouk, T.E. and Terrones, M., 2015. Accounts of chemical research, 48(1), pp.56-64.
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Figures

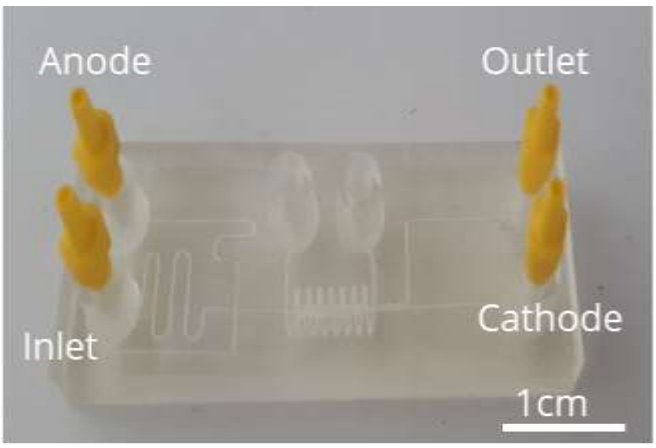

Figure 1: Microfluidic device.

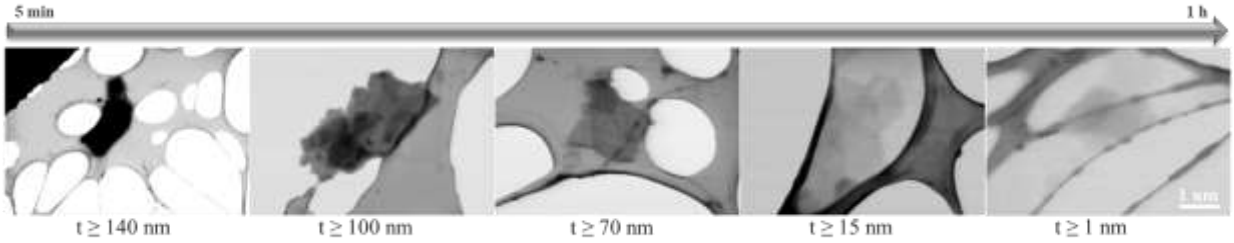

Figure 2: STEM images of exfoliated $HfTe_2$ by the microfluidic system with increasing time.