Micropatterned PDMS Stamps for spatially selective dry transfer of exfoliated flakes[1]

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Introduction

2D materials, such as graphene, hexagonal boron nitride (hBN), and transition metal dichalcogenides (TMDs), can be stacked into van der Waals (vdW) heterostructures which possess properties that no individual sheet has alone. vdW heterostructures have a wide array of applications, such as in superconducting qubits[2, 3] and other superconducting circuit elements, such as Josephson Junctions[4]. However, the construction of such vdW heterostructures with traditional transfer slides have numerous issues which make transfer difficult and labor intensive.

We propose a new style of transfer slide which offers high visibility, alignment aids, and improved spatial selectivity. This technique is cheap (>$500) and easy to implement, and promises to be a facile, cost effective method to improve efficiency in the dry transfer process.

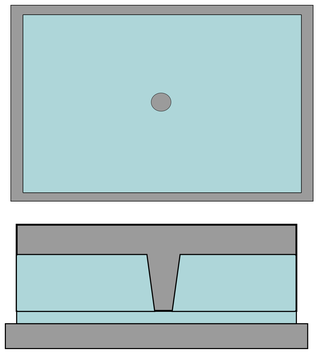

Fig. 1: Example of an application for a vdW heterostructure. Top: top-down cut-out view. Bottom: sideways cut-out view.

Exfoliation

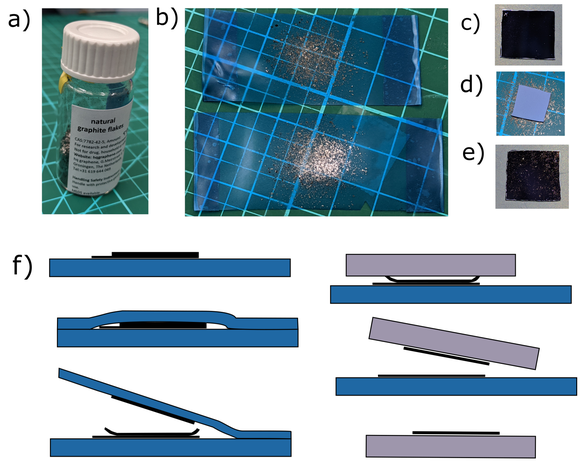

Fig. 2: a) Graphite flakes are b) repeatedly exfoliated using blue tape. c) A clean silicon chip is d) applied to the exfoliated graphite to e) collect loose graphene layers. f) An illustration of the exfoliation process.

Stacking and Transfer Slide

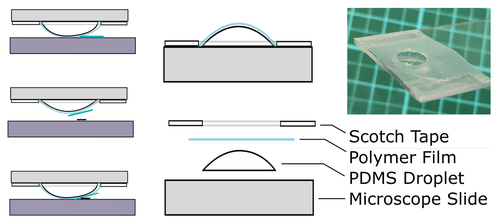

Fig. 3: Left: the process of stacking vdW heterostructures. Center and right: Typical construction of transfer slides used

Motivation

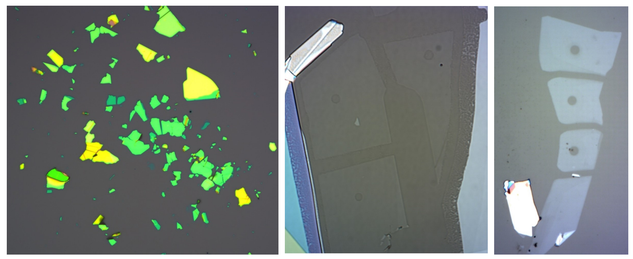

Fig. 4: Left: Manually exfoliated flakes tend to be in crowed environments, which makes picking up only the flake of interest very difficult. Center and right: large, pristine flakes can often be etched into smaller pieces[2]. In contrast to mechanically exfoliated flakes, all of the etched flakes need to remain pristine and undisturbed.

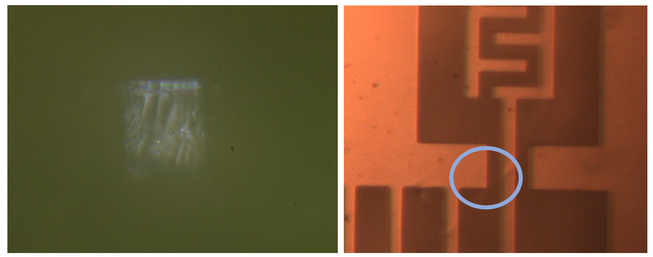

Fig. 5: Two traditional methods for constructing transfer slides. Left: rectangular PDMS stamps can be cut to a small point using a razor blade. However, the slanted slides cannot be viewed through, and making 20 µm features is inconsistent by hand. Right: Droplets have the advantage of visibility, but the roundness of the droplet makes predicting the point of first contact impractical. Also shown, circled: the contrast of monolayer flakes cannot be discerned by eye, making alignment in vdW heterostructures very difficult.

Methodology

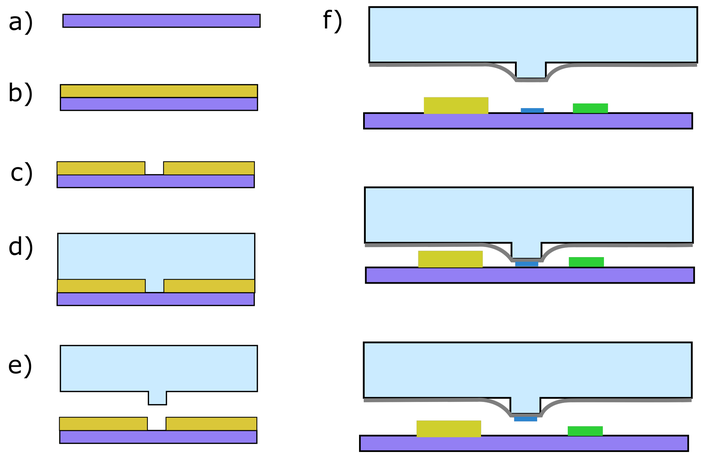

Fig. 6: a) A (100) polished silicon wafer is cleaned before b) SU-8 is spun on to the desired thickness. The SU-8 is c) exposed to UV and developed, then used to d) mold PDMS, mixed in a 10:1 ratio with catalyst. The molded PDMS is e) peeled off of the mold, cut out using a biopsy punch, and assembled as in Fig. 3, center. f) The prominense of the molded PDMS spikes allows spatial selectivity, as compared to Fig. 3, left.

Advantages: Visability, Alignment, and Improved Spatial Selectivity

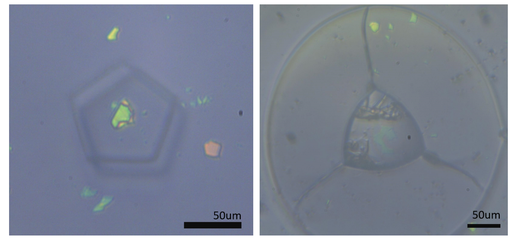

Fig. 7: The micropatterned PDMS transfer slides offer high visibility, and the shape of the spike itself offers a powerful alignment tool for monolayer flakes. Left: spike with no polymer layer, Right: spike with polymer layer from reused mold

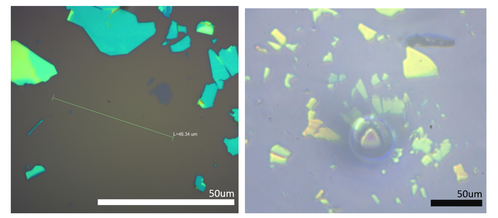

Fig. 8: Micropatterned PDMS can be designed to fit into small gaps. Left: a flake inside a ≈ 30 µm gap, right: a PDMS stamp fitting inside the gap

Validation

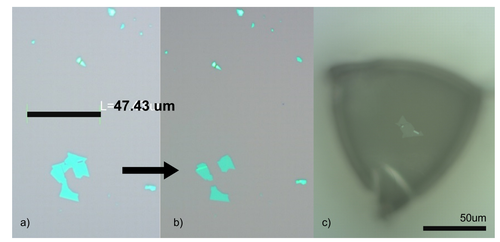

Fig. 9: Flake before (left) and after (center) stamping. Flake on stamp (right).

References

[1] C. Yang, J. W. Lyons, and B. M. Hunt, "Micropatterned pdms stamps for spatially selective dry transfer of exfoliated flakes", Bulletin of the Americal Physical Society (2022).

[2] J. W. Lyons, P. J. Patel, M. J. Hatridge, and B. M. Hunt, "Incorporation of hexagonal boron nitride into superconducting circuit elements", Bulletin of the Americal Physical Society (2022).

[3] M. Sinko, "Integration of van der waals superconductors into 2d-3d hybrid superconducting circuits", PhD thesis (Carnegie Mellon University, Dec. 2020).

[4] M. R. Sinko, S. C. de la Barrera, O. Lanes, K. Watanabe, T. Taniguchi, S. Tan, D. Pekker, M. Hatridge, and B. M. Hunt, "Superconducting contact and quantum interference between two-dimensional van der waals and three-dimensional conventional superconductors", Phys. Rev. Materials **5**, 014001 (2021).

Physics