Preparation and Transfer of Large-Area Graphene and 2D materials for Device Fabrication

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The distinctive characteristics of atomically thin two-dimensional (2D) materials provide significant pathways to explore physical phenomena at the 2D limit and show promise for next-generation electronic, optoelectronic, and quantum nanoelectronic devices. The development of such materials has been limited and one of the factors is a lack of effective large-area transfer processes.[1] Large yields of uniform monolayer materials transferable to oxide surfaces provide versatility for large-scale fabrication of nanoelectronic devices. The established methods to obtain large-area 2D materials include chemical vapor deposition (CVD) growth, metal exfoliation, liquid-phase exfoliation, and chemical exfoliation.[1] Although practical and cost-efficient, the traditional mechanical method of exfoliation using tape to acquire such materials provides relatively small flakes that are limited in their use for device fabrication, scaling feasibility studies, and freedom in device design. In addition, it has been reported that this transfer process could degrade the 2D material properties and in turn their device performance, and therefore a method to transfer larger area 2D materials without degrading the quality of the material would be ideal.[2] Here, we compare two methods of enhanced mechanical exfoliation using tape, for large-area monolayer flakes from bulk layered graphene and TMD materials. The first method consists of cleaning the substrate surface and increasing its adhesion by oxygen plasma treatment, followed by a heating treatment, whilst the tape is on the substrate.[3] The second method consists of utilizing tape whose adhesion can be controlled with ultraviolet light to exfoliate bulk layered graphene.[4] These methods can be used to exfoliate a range of 2D materials, including bilayer graphene and transition metal dichalcogenides.

1. Ullah, Sami, et al. "Graphene transfer methods: A review." *Nano Research* (2021): 1-17.
2. Kim, Jun-young, et al. "Van der Waals layer transfer of 2D materials for monolithic 3D electronic system integration: review and outlook." *ACS nano* 17.3 (2023): 1831-1844.
3. Huang, Yuan, et al. "Reliable exfoliation of large-area high-quality flakes of graphene and other two-dimensional materials." *ACS nano* 9.11 (2015): 10612-10620.
4. Nakatani, Maki, et al. "Ready-to-transfer two-dimensional materials using tunable adhesive force tapes." *Nature Electronics* (2024): 1-12.