Stacked heterostructures based on transition metal dichalcogenides

Ghidewon Arefe[1], Xu Cui[1], Gwan-hyoung Lee[1], James Hone[1]

[1] Department of Mechanical Engineering – Columbia University in the City of New York

ga2345@columbia.edu

Two-dimensional materials have opened up new possibilities for advanced electronics and optical applications. While graphene is a widely known 2D material with great properties, there has been a recent surge of interest in transition metal dichalcogenides (TMDCs) which are a group of materials with sizeable bandgaps that can be prepared as a 2D layer making them suitable for many applications[1]. With semiconducting properties, 2D TMDCs such as MoS_2 and WSe_2 can be stacked in combination with graphene to form nanoscale elctronics such as field-effect transistors and photovoltaics[2].

2D TMDCs are harvested using mechanical exfoliation. In this method, atomically thin layers of material are cleaved from a bulk crystal using Scotch Tape[a]. Following exfoliation and transfer to a substrate, flakes of layered material are characterized with optical microscopy, atomic force microscopy, and Raman spectroscopy to determine the size, topography, and thickness of the material before stacking. These cleaved layers can then be transferred to a substrate where layers can be stacked and fabricated into a device.

Heterostructures are assembled using a novel stacking method where specific 2D layers are selectively targeted and transferred[3]. A transfer system employing a micromanipulator stage with three degrees of movement allows for precise placement of layered materials. Following the transfer of stacked layers, conventional semiconductor processing techniques such as lithography and electron beam evaporation are used to pattern and deposit metal electrodes which can then be probed to conduct measurements.

1. Michael S. Strano, Q.H.W., Kourosh Kalantar-Zadeh, Andras Kis, Jonathan N. Coleman, *Electronics and optoelectronics of two-dimensional transition metal dichalcogenides*. Nature Nanotechnology, 2012. **7**(November 2012): p. 699-712.

2. L. Britnell, R.M.R., A. Ecmann, R. Jalil, B. D. Belle, A. Mishchenko, Y.-J. Kim, R. V. Gorbachev, T. Georgiou, S. V. Morozov, A. N. Grigorenko, A. K. Geim, C. Casiraghi, A. H. Castro Neto, K. S. Novoselov, *Strong Light-Matter Interactions in Heterostructures of Atomically Thin Films*. Sciencexpress, 2013.

3. C. Dean, A.F.Y., L. Wang, I. Meric, G.-H Lee, K. Watanabe, T. Taniguchi, K. Shepard, P. Kim, J. Hone, *Graphene based heterostructures*. Solid State Communications, 2012. **152**: p. 1275-1282.

---

[a] Trademark, 3M Co. (St. Paul, MN)