Materials Science &
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Mechanical Exfoliation as a Route to Nanomanufacturing of 2D van der Waals Bonded Heterostructures

By now, the remarkable properties of 2D materials are well known. Graphene is expected to be very strong,and also to have "massless" electrons. Transition metal dichalcogenides (TMDCs) display high excitonic binding energies, and can be made to emit light with near unity quantum efficiency. Even more remarkable are the properties that emerge when one stacks these layers to form van der Waals heterostructures. For example, two layers of graphene rotated relative to one another by about 1° display nontraditional superconductivity. Heterostructures involving TMDCs offer the means to explore the so-called "valleytronics." Given these discoveries and their potential for expanding our understanding of 2D materials and the development of new devices, one would like an efficient means to assemble a broad range of van der Waals heterostructures.

The initial studies of 2D materials relied on samples obtained through repeated, tape-mediated, mechanical exfoliation from a bulk source. While samples prepared this way can be of high quality, the prospects for using this processing route to reliably produce devices is remote at best. The process yields very small samples at random positions. Moreover, the number of exfoliation steps needed to yield a monolayer is not known a priori, and varies from sample to sample. Nevertheless, the such a process would be extremely useful, enabling the fabrication and characterization of a broad spectrum of van der Waals heterostructures.

In this talk I present a mechanical exfoliation method able to reliably produce large patterned monolayer samples and place them with upon a substrate in desired locations. The method relies on the epitaxial strain imposed upon the layer to be exfoliated by the deposition of a thin metallic film. The theoretical origins of the process are presented (a phenomenon known as compliant substrate epitaxy), and the mechanics underlying the process are presented. Examples of samples prepared using the process are also presented.

Biosketch

Daryl C. Chrzan is a Professor and Chair of Materials Science and Engineering at the University of California, Berkeley, and holds a joint appointment at Lawrence Berkeley National Laboratory, where he is a member of the Electronic Materials Program. He received his Ph. D. in Condensed Matter Theory from Physics Department of the University of California, Berkeley in 1989. Immediately thereafter, he joined the Computational Materials Science Group at Sandia National Laboratories in Livermore, California. In 1995, he joined the Department of Materials Science and Engineering at the University of California. He has received an NSF CAREER award, and more recently, was awarded a Miller Research Professorship. Professor Chrzan specializes in Computational Materials Science. His research interests include the mechanical properties of metals and metallic compounds, the structure of extended defects in solids, and the growth of nanostructures. studies of low-dimensional nano and quantum materials, with a most recent focus on topological materials. He is also a co-founder of two high-tech start-up companies.

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