Strained MoO_3/MoS_2 Heterostructures: Facile Fabrication, Structure and Electronic properties

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Few atomic-layer-thick MoO_3/MoS_2 heterostructures are receiving increasing attention for application in optoelectronics as a result of their unique mechanical and electrical properties. For instance, this material combination can support a high strain field without undergoing plastic deformation, due to its nanoscale thickness. Strain significantly affects the band structure of MoS_2 and MoO_3, allowing a variety of different electronic heterostructures without altering the chemical composition of the bilayer on nm-scale transverse dimensions. Despite all this interest, the fabrication technology of MoO_3/MoS_2 heterostructures is still relatively primitive, and the fundamental electronic properties of this material combination have not been investigated in detail. We develop a facile process to fabricate few-layer MoO_3/MoS_2 heterostructures on textured substrates, and therefore achieve mechanically strained films. In our approach a ~1-3 μm-thick MoS_2 flake is extracted from a bulk crystal *via* mechanical exfoliation and transferred to bulk Si patterned into a matrix of ultra-sharp tips. After this process step the MoS_2 flake is only supported by the ultra-sharp tips and hence mostly suspended over the substrate. A thermal annealing step in air/Ar atmosphere results in: (i) formation of MoO_3 at the top and bottom surface of the MoS_2 flake, (ii) delamination of few-layer Mo-compounds at the bottom surface of the transferred flake (*i.e.*, the one in contact with the Si tips), (iii) conformal contact of the delaminated layers to the substrate pattern. We obtain ultra-sharp tips of Mo-compounds with height ranging from 350 to 500 nm, and base of ~350 nm, as measured by scanning electron microscopy (SEM). The remaining portion of the MoS_2 flake stays intact, and it is removed by mechanical exfoliation. We demonstrate that different annealing conditions result in guided self-assembly of a variety of Mo-compounds. Specifically, we vary annealing temperature, air partial pressure, and annealing time to gain some insight on the chemical and physical processes which result in delamination and guided self-assembly of the ultra-thin films. The geometry, structural quality and spatially varying strain are characterized by optical contrast, electron microscopy, Raman and photoluminescence spectroscopies. The effect of different annealing conditions on carrier type and carrier concentration is estimated by X-ray photoelectron spectroscopy.

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