1602
doi:10.1017/S1431927618008498
Microsc. Microanal. 24 (Suppl 1), 2018

Surface Potential Imaging of Germanium / Monolayer MoS_2 Heterostructures

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The remarkable progress of material synthesis and assembly strategies enables the creation of new heterojunction structures that have electronic properties not seen in conventional homojunction materials and devices [1]. In particular, there has been a growing interest in heterojunction interfaces between atomically thin two-dimensional (2D) materials and conventional three-dimensional (3D) semiconductor materials (e.g., Si, Ge, compound semiconductors) that can be fabricated by the well-established microelectronic technologies. Transitional metal dichalcogenides (TMDs) are one of the emerging 2D materials that have tunable energy band-gaps and unique charge transport properties. However, unlike 3D semiconductors, the 2D materials do not have surface dangling bonds, presenting a challenge in synthesizing controllable 3D/2D heterojunction structures.

In this paper, we report the surface potential of germanium (Ge) islands on a molydisulfide (MoS_2) 2D material measured by Kelvin-probe force microscopy (KPFM). In KPFM, an electrically-conductive tip with a well-characterized work function is rastered on the sample to measure the surface potential. The contact potential different (CPD) of the sample is calculated by the potential offset between a probe tip and the sample surface (Figure 2a) [2]. We used a platinum iridium (PtIr) probe tip in this work. Prior to the KPFM measurement, the Ge/MoS_2 heterostructures were prepared by two consecutive chemical vapor deposition (CVD) processes. A monolayer MoS_2 was grown on a SiO_2/Si substrate first. Following the single-crystal MoS_2 triangle synthesis, the Ge layer was deposited using a low-pressure CVD system at 500 °C with the partial pressure of GeH_4 of 5 mTorr. Details of the synthesis processes were reported in elsewhere [3].

The representative scanning electron microscopy (SEM) images in Figure 1 show the Ge/MoS_2 heterojunction sample. As seen in this high-resolution SEM image, the large MoS_2 triangle was slightly torn to small pieces (a few μm in size). The Ge islands were grown on individual MoS_2 pieces with the size in the range of a few 10's of nm to a few μm. It is likely that the strain was induced on the MoS_2 during the Ge growth. The simultaneously collected atomic force microscopy (AFM) and KPFM images of the Ge/MoS_2 sample were presented in Figure 2. The Ge island height is on the order of 100 nm. Interestingly, the KPFM image shows distinct CPD domains in the MoS_2 underlayer. It is possible that the thickness variation of Ge islands can cause the CPD variation. However, the observed large CPD domains do not follow the height variation, as shown in Figure 3c. It was previously suggested that charge transfer between the Ge and MoS_2 layers can modify the electronic properties of Ge/MoS_2 heterojunctions [3]. The unexpected band-structures may also impact the surface potential of the sample. Further investigation of the CPD domains on an intrinsic MoS_2 as well as fully covered Ge thin-film on MoS_2 samples are in progress.

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[4] This work made use of University of Utah USTAR shared facilities support, in part, by the MRSEC Program of NSF under Award No. DMR-1121252. This work was also performed, in part, at the Center for Integrated Nanotechnologies, an Office of Science User Facility operated for the U.S. Department of Energy (DOE) Office of Science by Los Alamos National Laboratory (Contract DE-AC52-06NA25396) and Sandia National Laboratories (Contract DE-NA-0003525).

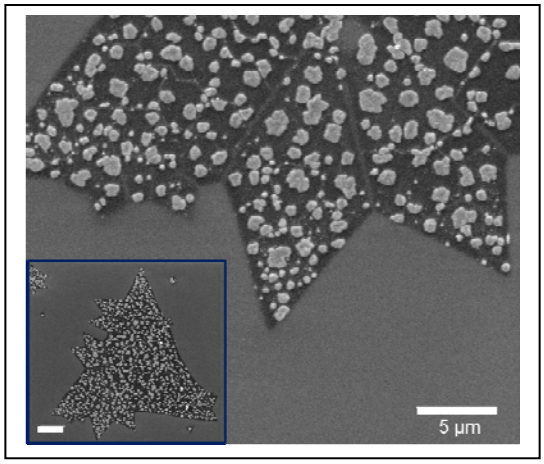

Figure 1. Representative SEM images of Ge/MoS2 on a SiO_2/Si substrate. Inset shows a lower magnification of the sample (scale bar: 10 µm).

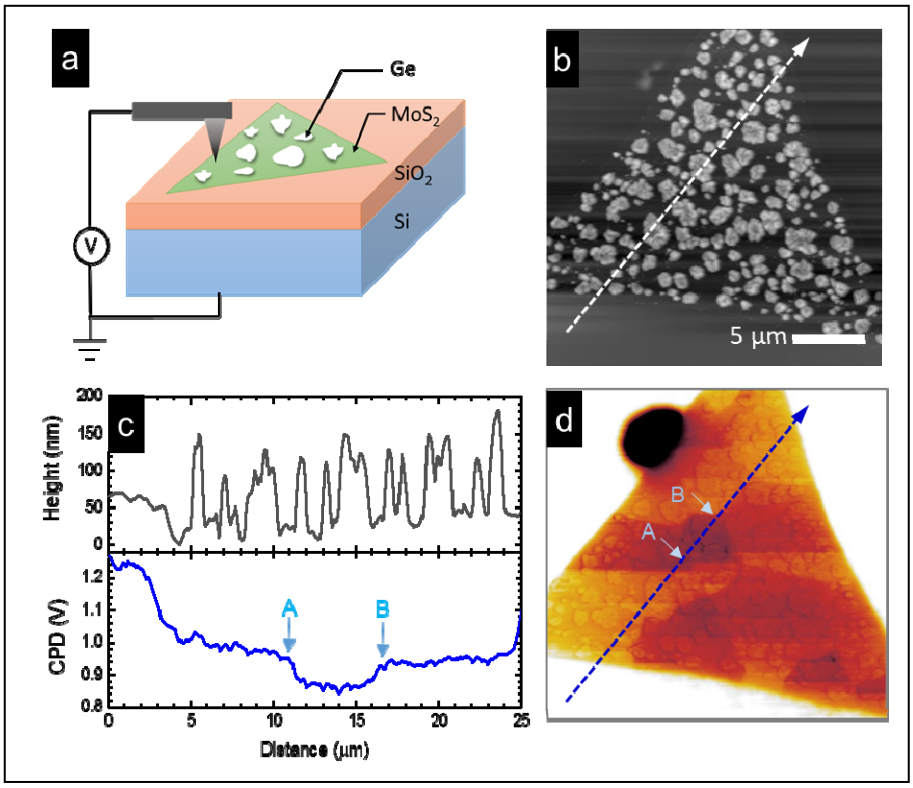

Figure 2. (a) Schematic of KPFM measurement setup. Simultaneously collected AFM (b) and KPFM (d) images. (c) Height and potential line scans. Dashed lines indicate the line scan position in the AFM / KPFM data. Ge island height is on the order of 100 nm

https://doi.org/10.1017/S1431927618008498 Published online by Cambridge University Press