Atomic Scale Investigation of Interfaces in MoS$_2$-ReS$_2$ In-plane Heterostructures Using High Resolution S/TEM

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Two-dimensional (2D) heterostructures are formed when two or more individual 2D materials are stacked or stitched next to each other. These heterostructures enable the ability to make multicomponent optoelectronic devices where each 2D material acts as a component. This makes them more conducive towards realizing practical applications such as transistors and photodetectors [1]. With the advent of semiconducting transition metal dichalcogenides (TMD), the interest in forming heterostructures with different members of the TMD family has gained momentum. This is because TMD materials present an opportunity to engineer the band alignment at the heterostructure interface [2]. Band alignment depends on the chemistry of constituent TMD and the interfacial features such as defects, strain and epitaxy. As an example, VS$_2$-MoS$_2$ heterostructures were shown to form metal-semiconductor contacts with very low contact resistance because of the metallic nature of VS$_2$ and semiconducting nature of MoS$_2$ [3]. In another example highlighting the importance of the interface structure, C. Zhang et al. have reported the band alignment changes from type-II to type-I in WSe$_2$-MoS$_2$ lateral heterostructures grown on monolayer WSe$_2$ because of the 3.8% lattice mismatch strain between WSe$_2$ and MoS$_2$ [4].

In this work, we study MoS$_2$-ReS$_2$ heterostructures that are synthesized through a two-step chemical vapor deposition (CVD) technique using powder precursors. MoS$_2$-ReS$_2$ vertical heterostructures were shown to demonstrate great photoresponse properties and strong interlayer interaction stemming from type-I band alignment [5]. Furthermore, ReS$_2$ is structurally very different from MoS$_2$ because it exhibits distinct crystal symmetry resulting in anisotropic properties [6]. This provides an opportunity to create heterostructures with different interface structure and novel properties. Thus, it is important to synthesize and study the atomic structure of interfaces in MoS$_2$-ReS$_2$ heterostructures. We have used scanning/transmission electron microscopy (S/TEM) imaging to investigate the atomic and chemical structure of MoS$_2$-ReS$_2$ heterostructures after growth. Figure 1a is a low magnification TEM image which shows a large field-of-view image of MoS$_2$-ReS$_2$ in-plane heterostructures at the end of two-step CVD process. It is evident that ReS$_2$ growing during the second step fills the gaps between MoS$_2$ triangles grown in the first step thus forming the in-plane heterostructures. Figure 1b shows a high angle annular dark field (HAADF)-STEM image of a MoS$_2$ triangle (red dashed outline) with ReS$_2$ nanoflakes grown around it. The presentation will further present the atomic structure, defects, epitaxy and strain between the MoS$_2$ and ReS$_2$ at the interface [7].
Figure 1. MoS$_2$-ReS$_2$ in-plane heterostructures: (a) Low-magnification TEM image showing MoS$_2$ triangles with ReS$_2$ grown between the triangles thus forming the in-plane heterostructures and (b) HAADF-STEM image of a MoS$_2$ triangle (red dashed triangle) and ReS$_2$ nanoflakes grown around the triangle.

References
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