Epitaxial Growth and STM Characterization of 2D Magnet $MnSe_2$ and VSe_2

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Magnetism in 2D materials is a fascinating topic. Although extensively studied theoretically, the experimental realization of 2D magnets was not achieved until 2017 [1, 2]. Being only a few atoms thick, the high surface to volume ratio makes 2D magnets extremely sensitive to the surface environment, thus their magnetic properties can be strongly manipulated through proximity with other materials. Recently, the demonstration of epitaxial growth of 2D magnets [3,4] further brings more potential to the material. By directly synthesizing 2D magnet on different substrates, one could manipulate the electrical and magnetic properties of 2D magnet, explore new phenomena at their interface, as well as novel device structures for spintronic applications.

In this talk, we will present the epitaxial growth of 2D magnet $MnSe_2$ and VSe_2 on various substrate materials and characterize some of them with scanning tunneling microscopy (STM). First, we will present our recent discovery of $MnSe_2$ [3], one of the first 2D magnets with intrinsic ferromagnetic ordering at room temperature (Fig. 1). The magnetic properties of $MnSe_2$ grown on GaSe and $SnSe_2$ is compared. Furthermore, we will also show our exploration of the epitaxial growth of 2D magnet VSe_2 on different substrates, including HOPG, GaAs(111) and Bi_2Se_3. Despite of the large lattice mismatch between VSe_2 and the substrates, all the growths show epitaxial registry, as demonstrated by low energy electron diffraction (LEED) and STM (Fig. 2). The epitaxial alignment and clean interface between VSe_2 and the substrate material make it possible to host proximity interaction between them. Finally, some preliminary result of characterizing the 2D magnet materials with spin-polarized STM will be discussed.

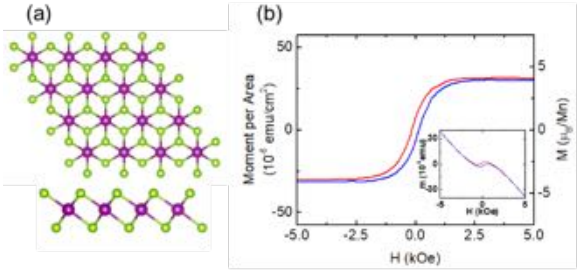

Figure 1 (a) Top and side view of 1T-$MnSe_2$ lattice. (b) Magnetic hysteresis loop of ~ 1 ML $MnSe_2$ at 300K.

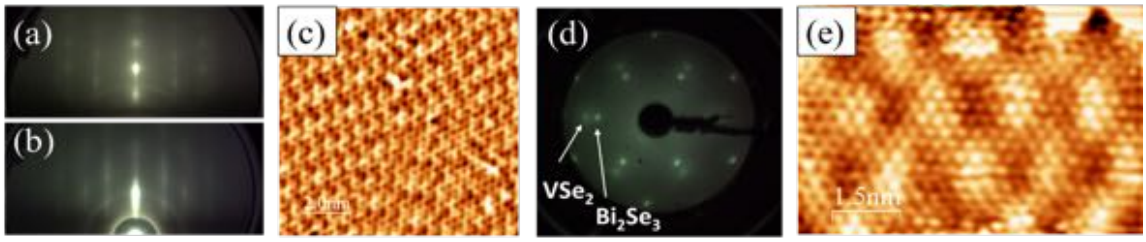

Figure 2 RHEED pattern of (a) HOPG and (b) ~1 ML of VSe_2 after deposition on HOPG. (c) Atomic resolution image of VSe_2 on HOPG measured with STM. (d) LEED pattern of ~0.4 ML VSe_2 grown on Bi_2Se_3 showing good epitaxial registry. (e) STM image of VSe_2 on Bi_2Se_3 showing Moiré pattern.

[1] Huang, Bevin, et al., *Nature* **546**, 265 (2017).

[2] Gong, Cheng, et al., *Nature* **546**, 270 (2017).

[3] O'Hara, Dante J., et al., *Nano letters* **18**, 3125 (2018).

[4] Bonilla, Manuel, et al., *Nature nanotechnology* **13**, 289 (2018).