Characterization and Integration of Large-Scale MBE-Grown In_2Se_3

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Two-dimensional(2D) ferroelectric materials are considered key enablers for next-generation nanoelectronic applications[1,2]. They are particularly promising, as they can be integrated with other layered materials via van der Waals (vdW) epitaxy to build multifunctional materials. Indium selenide(In_2Se_3) in the α-phase stands out due to its intercorrelated in-plane and out-of-plane ferroelectric polarizations. The growth of ultrathin α-In_2Se_3 has previously been reported using several techniques, including chemical vapor deposition (CVD)[3] physical vapor deposition (PVD) [4], and molecular beam epitaxy (MBE)[5].

In this work, we report the growth of large-area In_2Se_3 films by MBE on different substrates, mica and graphene, with thicknesses ranging from 1 to 40 monolayers (ML). The centimeter-scale films were characterized in situ using reflection high-energy electron diffraction (RHEED), angle resolved photoemission spectroscopy (ARPES) and ex situ by Raman spectroscopy, X-ray diffraction (XRD) and Atomic Force Microscope (AFM). Furthermore, the layers grown on mica are shown to be easily transferred and integrated with CMOS-compatible substrates.

Epitaxial growth was achieved by optimizing the substrate temperature (550-750°C) and the In_2Se_3:Se flux ratio (1:30). The Raman spectra provide evidence of the β-phase or mixed β-β' phases of In_2Se_3, while the XRD patterns (Fig.1a) confirm epitaxial growth on the substrate with high crystalline quality (e.g., FWHM = 4°). Crystalline growth differs between graphene and mica: two directions on graphene (Fig.1a) versus one on mica. Figure 1b shows an atomic force microscopy (AFM) image, illustrating a typical monolayer thickness of ~1 nm and an average lateral domain size of 200 nm. Further insights into the microstructure and ferroelectric properties are provided by STEM analysis,PUND (positive up negative down) electrical measurements and piezoforce microscopy (PFM).

References

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Figures

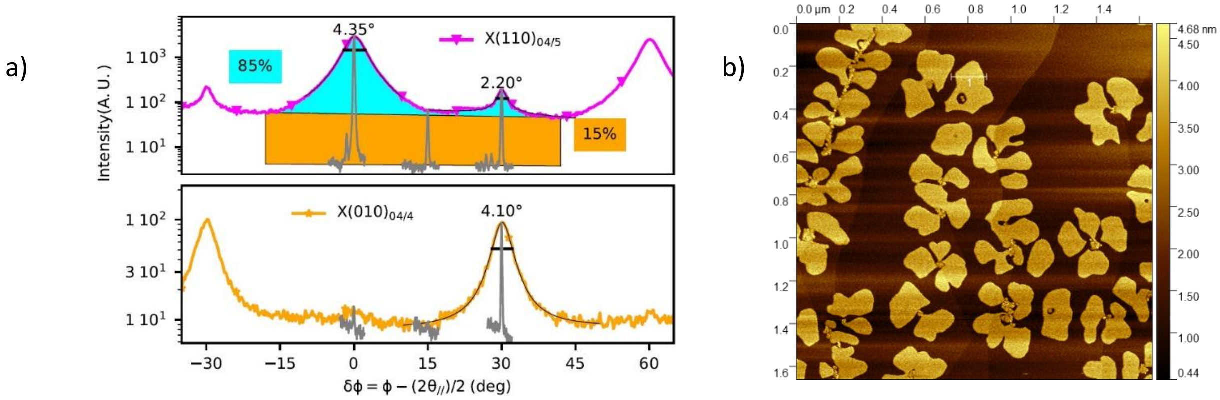

Figure 1: X-ray azimuthal scan of 6 ML of In_2Se_3 on Gr/SiC. Shows high quality growth and the two growth directions. AFM image at the beginning of In_2Se_3 growth on Gr/SiC.