Wafer-scale Single-phase 2D and Multi-dimensional Indium Selenide

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Different polymorphs and stoichiometries of indium selenide (In_xSe_y) display a wide range of electronic [1], optical [2], and thermal properties [3], making them promising next generation 2D semiconductors. However, achieving wafer-scale, phase-controlled, atomically thin layers remains challenging due to their closely competing thermodynamic stabilities and sensitivity to growth conditions. In this work, molecular beam epitaxy (MBE) is employed for wafer-scale synthesis of two-dimensional In-Se layers on c-plane sapphire substrates under ultra-high vacuum conditions. Precise control of growth parameters (atomic fluxes and growth temperature/time) enables the formation of thin and uniform In-Se films through desorption-controlled growth. Different stoichiometries and morphologies are measured by Raman spectroscopy and atomic force microscopy (AFM). The results demonstrate successful growth of single-phase InSe and In_2Se_3 layers by adjusting key growth parameters. Furthermore, at high In-flux, growth rate saturation occurs, accompanied by the nucleation of quasi-one-dimensional In_4Se_3 nanorods directly on an underlying InSe layer. The anisotropic, rod-like morphology of these In_4Se_3 structures suggests inherent directionality in thermal and electrical transport, as well as polarization-dependent optical responses. These results represent a significant advance in scalable synthesis of phase-controlled indium selenide 2D materials, providing a platform for exploring their high mobility and anisotropic properties while enabling integration into future optoelectronic and thermoelectric applications.

References

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[2] Tamalampudi, S. *et al*., Nano Letters, 5 (2014) 2800-2806
[3] Rhyee, J. *et al*., Nature, 7249 (2009) 965-968

Figures

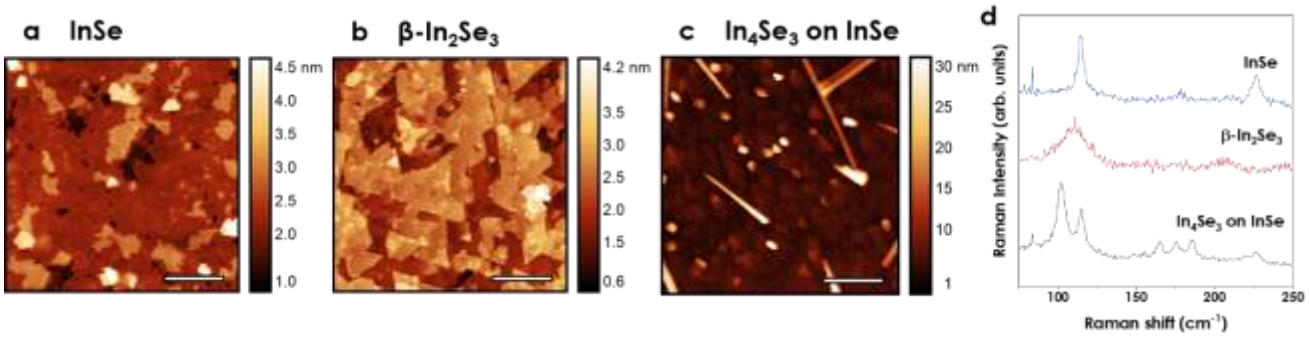

Figure 1: AFM Images (scale bar: 500 nm) of **a** InSe, **b** β-In_2Se_3 and **c** In_4Se_3 on InSe **d** with their respective Raman spectra.