Epitaxial growth of γ-InSe and α, β, and γ-In_2Se_3 on ε-GaSe

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Here we demonstrate the epitaxial growth by physical vapor transport (PVT) of large-area (> 10^3 μm^2) uniform layers of In_xSe_y on ε-GaSe vdW crystals with stoichiometry and phase that can be controlled by the temperature within the PVT furnace, see Fig. 1a. The uniform cleaved surface of ε-GaSe enables the epitaxial growth of the In_xSe_y layers, which are aligned over large areas (Fig. 1b-c). The weak vdW interaction between ε-GaSe and In_xSe_y results in a negligible lattice-mismatch distortion in the grown layers even though they have significantly different lattice constants and an in-plane lattice mismatch ranging between 6% and 47%.

Each In_xSe_y phase and stoichiometry exhibits distinct optical and vibrational properties. The optical spectra and the temperature dependence indicate distinct electronic properties for the different phases of In_xSe_y and demonstrate a wide spectral range of photoluminescence from the visible (γ-In_2Se_3) to the near-infrared (γ-InSe, β-In_2Se_3 and α-In_2Se_3), see Fig. 1d. The successful growth of γ-InSe, α-In_2Se_3, β-In_2Se_3 and γ-In_2Se_3 on exfoliated ε-GaSe nanolayers offers the prospect for large-area device fabrication and junction devices that exploit the distinctive optical absorption and luminescent emission of the component layers.

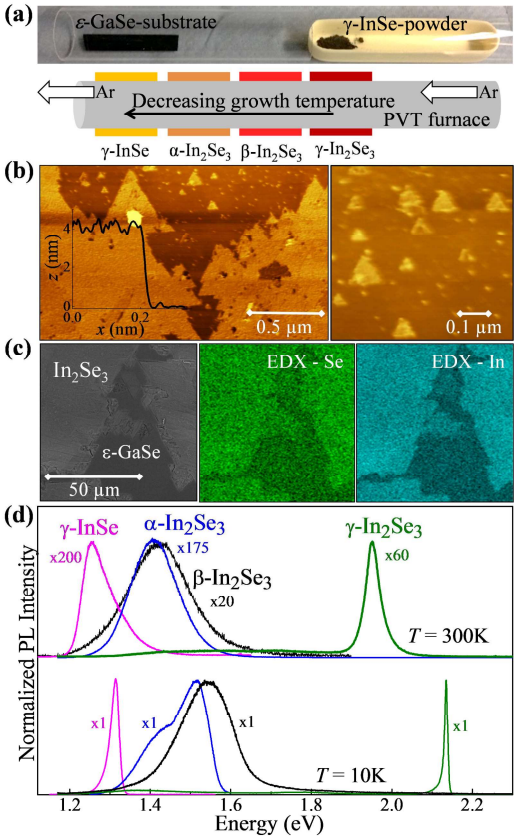

Fig.1: **(a)** Image and schematic diagram of the quartz tube for the PVT growth of In_xSe_y on ε-GaSe. The temperature gradient in the quartz tube enables the growth of different stoichiometries and phases of In_xSe_y. **(b)** AFM images and z-profile, **(c)** SEM image and EDX elemental maps of In_2Se_3 layers grown on a ε-GaSe substrate. **(d)** Room temperature (T = 300 K) and low temperature (T = 10 K) μPL spectra of γ-InSe, α-In_2Se_3, β-In_2Se_3 and γ-In_2Se_3 layers grown on exfoliated ε-GaSe flakes.