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## Atomic scale characterization and dynamics of two dimensional In Se materials

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III-VI semiconductors are currently being investigated as potential candidates for optoelectronic and phase change memory devices. Among several III-VI semiconductors, In-Se systems are an interesting type of materials due to their multiple phases and excellent optical properties. For example, In<sub>2</sub>Se<sub>3</sub> is a direct bandgap material with a layered structure. There are at least five different phases of In<sub>2</sub>Se<sub>3</sub> ( $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ , and  $\kappa$ ). The  $\alpha$  and  $\beta$  -phases can crystallize in both  $\alpha$ (3R) and  $\alpha$ (2H) crystal structures while  $\gamma$  -phase has a defective wurtzite structure. The  $\kappa$ -phase is reported to have a structure more similar to the  $\alpha$ -phase with larger unit cell. On the other hand, InSe also has several different phases, which hold substantial potential device applications. For the suitability of device applications, it is important to have single phase materials which is still a great challenge because different phases of In<sub>2</sub>Se<sub>3</sub> can co-exist with each other. We investigate how the growth

temperature, fluxes and type of substrates (GaAs (100), GaAs (111) A and Mica) influence the growth of In<sub>2</sub>Se<sub>3</sub> and find the optimum parameters for obtaining phase controlled In<sub>2</sub>Se<sub>3</sub> by using molecular beam epitaxy (MBE). We have found that Se-rich and high temperatures favour growth of  $\beta$  phase In<sub>2</sub>Se<sub>3</sub> while  $\gamma$  phase is obtained in In-rich conditions and low temperatures on GaAs (100) substrates. Within the same parameter range,  $\gamma$  phase was predominant on GaAs (111) A substrates. We are now combining the state-of-the-art scanning transmission electron microscopy (STEM) with density functional theory (DFT) calculations to systematically investigate atomic structure of the grown In<sub>2</sub>Se<sub>3</sub> and the possible defects in the material. Moreover, we also conduct in-situ TEM and STEM study of 2D InSe materials upon heating and will present some interesting direct in-situ observations.

### Biography

Zhongchang Wang received his PhD in materials science and engineering from the University of Tokyo in Japan (2007). He thereafter worked at Advanced Institute for Materials Research, Tohoku University (Japan) as a research associate, assistant professor and associate professor. In 2016, he was also a visiting scientist at University College London (UCL), UK. Since 2017, he started as a senior staff researcher and group leader at the International Iberian Nanotechnology Laboratory (INL). He has and (co-) authored over 200 peer-reviewed SCI-indexed papers in Nature, Nat. Nanotech., Nat. Commun. Adv. Mater., Nano Lett., Angew Chemie, JACS, etc., where more than 10 papers appear in Nature and its sister journals. He received a total of more than 20 research grants from Chinese, Japanese and European government and companies. Moreover, he has also delivered over 40 invited talks in international conferences and received several awards from Japan and USA. He is now working on structure-property interplay of two-dimensional (2D) materials and nanomaterials at the atomic scale so as to fulfill atomic manipulation of quantum nanostructures through combining scanning transmission electron microscopy, spectroscopy, first-principles calculations and property assessment for functional applications.

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