Electronic Supplementary Information for

Distinct Ultrafast Carrier Dynamics of α-In_2Se_3 and β-In_2Se_3: Contributions from Band Filling and Band Gap Renormalization

Shengjie Meng[a], Jian Wang,[a] Hongyan Shi[a,b], Xiudong Sun[a,b], Bo Gao[a,b*]

[a]Institute of Modern Optics, School of Physics, Key Laboratory of Micro-Nano Optoelectronic Information System, Ministry of Industry and Information Technology, Key Laboratory of Micro-Optics and Photonic Technology of Heilongjiang Province, Harbin Institute of Technology, Harbin 150001, China

[b]Collaborative Innovation Center of Extreme Optics, Shanxi University, Taiyuan 03006, China

We used a home-built micro-absorption spectroscope to measure the optical absorption of the In_2Se_3 crystal. According to Tauc et al.,[1] the absorption coefficient that near the absorption edge of a direct-gap semiconductor is $\alpha = A\frac{(\hbar\omega - E_g^{opt})^{1/2}}{\hbar\omega}$, where α is the absorption coefficient of In_2Se_3 that can be calculated from its optical transmittance (*T*) and its thickness (*d*) as $\alpha(\lambda) =- \frac{log_{10}(T(\lambda))}{d}$, *A* is a material-dependent constant and E_g^{opt} is the optical energy gap of the material. The thickness of the In_2Se_3 crystal used in our experiment was 42 nm. Therefore, the wavelength-dependent optical transmission for α-In_2Se_3 a was shown in Fig. S1(a). The corresponding Tauc plots of optical absorption of α-In_2Se_3 was shown in Fig. S1(b). We found that the direct optical bandgap of α-In_2Se_3 is 1.43 eV, which was consistent with previous.[2-3]

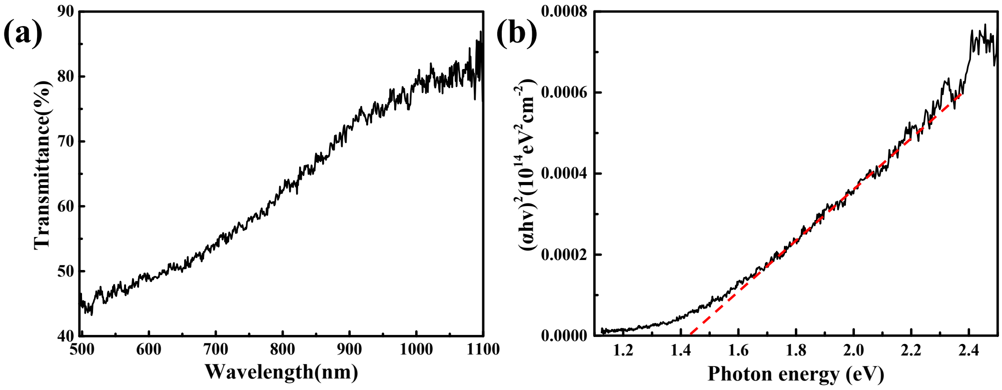

Fig. S1 (a) Wavelength-dependent optical transmission for α-In_2Se_3. (b) Tauc plots of optical absorption in α-In_2Se_3, the red dotted lines show the Tauc extrapolation of the absorption edge.

After annealing the In_2Se_3 flake shown in Fig. 1(a) at 200 °C for 2 hours in argon atmosphere, the α-In_2Se_3 was supposed to be converted to β phase.[4] Then we measured the optical absorption of β-In_2Se_3. The wavelength-dependent optical transmission for β-In_2Se_3 was shown in Fig. S2(a). The corresponding Tauc plots of optical absorption of β-In_2Se_3 was shown in Fig. S2(b). We found that the direct optical bandgap of β-In_2Se_3 is 1.55 eV, which was consistent with previous.[2-3]

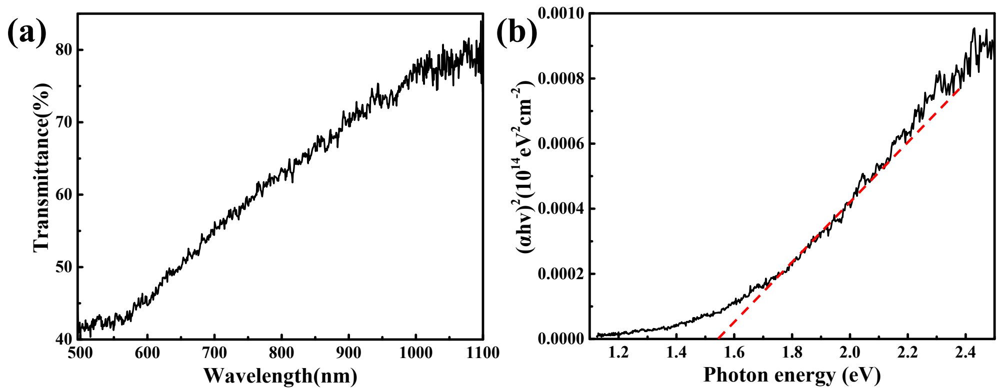

Fig. S2 (a) Wavelength-dependent optical transmission for β-In_2Se_3. (b) Tauc plots of optical absorption in β-In_2Se_3, the red dotted lines show the Tauc extrapolation of the absorption edge.

References

1 J. Tauc, R. Grigorovici and A. Vancu, *Phys. Status Solidi B,* 1966, **15**, 627-637.

2 C. Julien, M. Eddrief, K. Kambas and M. Balkanski, *Thin Solid Films,* 1986, **137**, 27-37.

3 C. H. Ho, C. H. Lin, Y. P. Wang, Y. C. Chen, S. H. Chen and Y. S. Huang, *ACS Appl. Mater. Inter.,* 2013, **5**, 2269-2277.

4 X. Tao and Y. Gu, *Nano Lett.,* 2013, **13**, 3501-3505.