photonics

Supplementary Material

Terahertz Emission Spectroscopy and Microscopy on Ultrawide Bandgap Semiconductor β-Ga_2O_3

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1) Photoluminescence of β-Ga_2O_3 crystals and material parameters.

The photoluminescence (PL) was measured with a fiber optic spectrometer (HORIBA iHR320). Figure S1 shows the examples of photoluminescence (PL) spectra measured for the five β-Ga_2O_3 samples at room temperature (RT). The excitation wavelength is centered 245 nm. Note that the measurable minimum wavelength is limited around 350nm due to the optics, and since we use the fs laser as the excitation source, there exist some uncertainties in the wavelengths. All of the samples exhibited no near-band-edge (NBE) emission by PL spectra, as Laurent Binet et al. reported [1]. The PL spectra of UID-(010) and UID-($\bar{2}01$) show two sharp peaks at 3.22 eV and 2.60 eV. The peak at 3.22 eV corresponds to the recombination of free electrons and self-trapped holes (STH) or self-trapped exactions (STEs) [2]. The peak at 2.60 eV is considered to be a donor–acceptor pair (DAP) due to recombination with deep donors and acceptors [3,4]. Intrinsic point defects, such as oxygen vacancies (V_O) and intrinsic Ga (Ga_i) are donors. Ga vacancies (V_{Ga}) and V_O–V_{Ga} complexes are possible acceptors. In the Fe-doped sample, we observe no UV or blue-band emission because of the thermal activation of the nonradiative recombination centers [5]. Tadjer et al. reported that the activation energies of a shallow donor distribute 7.4–60 meV below E_C for the carrier concentration between 2.0 × 10^{16} cm^{-3} to 1.0 ×10^{20} cm^{-3} in the Sn-doped β-Ga_2O_3 [6]. Muad Saleh et al. have determined 7–30 meV as the activation energy for ionization of donors in unintentionally doped β-Ga_2O_3 for free electron densities between 1 × 10^{17} cm^{-3} to 1.0 × 10^{19} cm^{-3} [7].

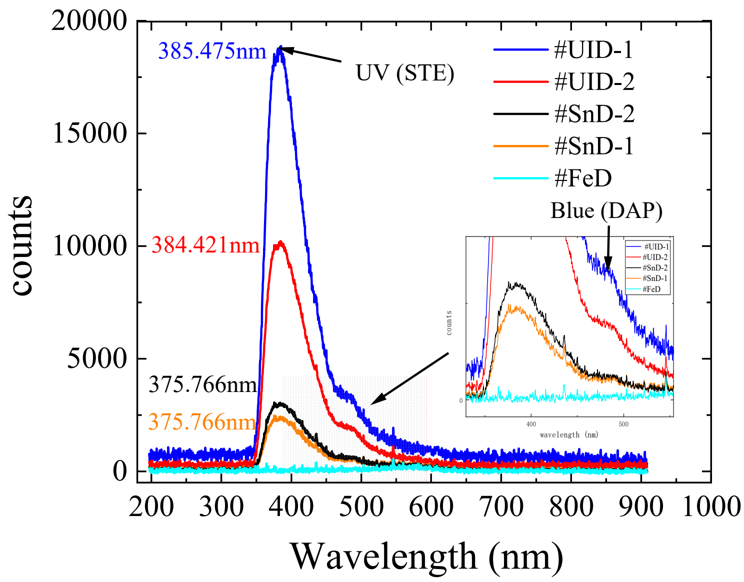

Figure S1 Photoluminescence of each sample.

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