Developing the XEOL and TR-XEOL at the X-ray Nanoprobe at Taiwan Photon Source

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The hard X-ray excited optical luminescence (XEOL) and time-resolved X-ray excited optical luminescence (TR-XEOL) have been developed successfully at the X-ray Nanoprobe (XNP) facility at Taiwan Photon Source (TPS). Not only the XNP at TPS provides 40 nm spatial resolution, but also the X-ray energy of synchrotron source is continuous and tunable, which make the XEOL and TR-XEOL are powerful tool to study the optical properties and dynamic luminescence of novel optoelectronic materials.

TR-XEOL spectra were collected by a fiber, which is coupled to a spectrometer (iHR320, HORIBA) with Hamamatsu C10910 streak camera and M10913 slow single sweep unit. The repetition rate and the temporal resolution of the single bunch mode at TPS are about 578 KHz and 30 ps ~1.72 μs, respectively. Comparing other time resolved methods, the advantage of using streak camera based TR-XEOL is the ability to simultaneously obtain both emission wavelength data and lifetime decay [1]. Figure 1 shows the abilities to study the optical and dynamic properties of the trihalide perovskite CH$_3$NH$_3$PbBr$_3$ by using XEOL and TR-XEOL. From the XEOL measurements, the emission wavelength was located at about 535 nm, which is shown in Fig. 1(a). Then, the streak image with 500 ns sweep time, and the lifetime decay can be obtained by using TR-XEOL, which are shown in Fig. 1(b) and 1(c), respectively. The fitting results of the lifetime decay were $\tau_1=6.4$ ns and $\tau_2=64.9$ ns.

In our previous reports using unfocused X-ray beam at Taiwan Light Source (TLS), we have demonstrated not only the temperature-dependent XEOL to study the optical properties of O and Zn polarity of a c-plane ZnO wafer [2], but also the polarization-dependent XEOL to study the crystallographic orientations of a non-polar a-plane ZnO wafer [3]. In this study [4], we used XEOL with nano-focused X-ray beam to study the optical properties of ZnO microrod. Figure 2(a) shows the SEM image of the ZnO microrod on Ga-polar c-plane GaN substrate. The diameter of ZnO microrod is about 5 μm with a hexagonal shape. Base on the benefit of nano-focused beam, the optical properties can be analyzed from specific nano-position of the ZnO microrod as shown in Fig. 2(b)-(e). The near-band-edges (NBE) of ZnO and GaN were measured at 3.299 eV and 3.369 eV, respectively. Besides the XEOL spectra, the XEOL mapping as well as the X-ray fluorescence (XRF) mapping was also developed at XNP. SEM, XRF mapping, XEOL mapping of GaN NBE, and XEOL mapping of ZnO NBE are shown in Fig. 3(a)-(d), respectively. From the XEOL mapping, we can obtain the information of the emission distribution of GaN and ZnO NBE. Then, the Zn element distribution can be measured.
by XRF mapping. After accomplished these test experiments, we believe that the XNP has the abilities and opportunities to investigate and explore the novel optoelectronic materials and nanotechnology.

References:


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