Development of a fast zinc oxide scintillator for the short wavelength region using soft X-ray laser

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Abstracts: *Zinc oxide (ZnO) is a prominent scintillator material because of its improved growth technology and excellent optical properties. Large and high-quality ZnO single crystals have been prepared by the hydrothermal growth method. Moreover, hydrothermal-grown bulk ZnO crystals exhibit fast decay times related to ZnO's free excitonic emission. In this regard, ZnO is investigated as a scintillator using a Ni-like Ag-ion plasma soft X-ray laser. A ZnO crystal has a nanosecond temporal resolution and a sub-micron spatial resolution suitable for short wavelength applications. Improvement of ZnO as a scintillator using novel methods is then anticipated in the future.*

The application of light sources in the short wavelength region has been expected to aid in the development of various fields of science, medicine, and industry. Efficient and fast imaging scintillator devices with sufficient sizes are particularly needed because they are key elements for short wavelength applications. Zinc oxide (ZnO) is a prominent scintillator material because of its improved growth technology and excellent optical properties. A large, high-quality single crystal has been prepared with reasonable cost by the hydrothermal growth method. In the past, we have been investigating the various optical properties of ZnO materials. A hydrothermal-grown bulk crystal exhibit fast decay times regardless of the incident optical excitation. In this report, we summarize the development of a fast ZnO scintillator for the short wavelength region using the soft X-ray laser of the Japan Atomic Energy Agency (JAEA).

The Ni-like Ag-ion plasma soft X-ray laser was employed as the excitation source because its properties are appropriate for our desired experiment. The soft X-ray laser had an output wavelength of 13.9 nm with a picosecond duration and a microjoule energy. The sample used was a high-purity ZnO single crystal grown by hydrothermal method. The emission decay time of the sample at around 380 nm is determined to be 1 ns using a streak camera system. The response time is sufficiently short for lithography light sources since these sources have a few nanosecond duration. In addition, we are able to demonstrate that the emission wavelength and decay time is independent of the excitation wavelength by comparing it with the results using other short wavelength light sources. We have also demonstrated the evaluation of the beam profile of a soft X-ray laser focused by a spherical mirror or a Fresnel zone plate. The evolution of the beam radius around the focal point is monitored by observing the emission patterns of ZnO at each position. The measured spatial resolution with magnification optics and with a telescope for imaging is 5 μm. It is then estimated that ZnO has a sub-micron spatial resolution because the measurement from the optical configuration was estimated to be 4 μm. These high temporal and spatial resolutions indicate that ZnO is suitable to characterize lithography light sources. Since a short decay time leads to improved spatial resolution, we are currently exploring methods such as impurity doping or quantum beam irradiation. By using these doped and ion-implanted ZnO crystals, the performance of ZnO as scintillator might be improved.