Vacuum Ultraviolet Photoconductive Detector Based on YF₃ Thin Film Deposited by Pulsed Laser Deposition

Masahiro Yanagihara¹), Hiromu Ishikawa¹), Takayuki Tsuji¹), Shingo Ono¹), Nobuhiko Sarukura²)

¹) Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya, Aichi 466-8555, Japan
²) Institute of Laser Engineering, Osaka University 2-6 Yamadaoka Suita, Osaka 565-0871 Japan

INTRODUCTION

Ultraviolet (UV) light sources such as a xenon excimer lamp (172 nm) and a low-pressure mercury lamp (185 nm) are used in various applications, such as UV-curable of ink, sterilization, surface modification, and cleaning semiconductor surfaces. Many researchers have been actively developing light sources that emit light at shorter wavelengths. The applications for UV light sources are expected to increase in the near future. As a result, the demand for UV detectors that are capable of monitoring these light sources will continue to grow. On the other hand, a vacuum ultraviolet (VUV) detector is required for radiation detectors. Scintillation materials combined with photo detectors are used to detect high-energy photons as radiation detectors. The applications for radiation detectors are in the medical field, such as X-ray computed tomography, and positron emission tomography, and in high-energy physics. In recent years, great effort has been focused on developing faster and more efficient scintillators to detect ionizing radiation [1–6]. However, there is still a continuous demand for scintillator materials with even higher capabilities. Scintillator materials with short decay times are needed for many applications that require high counting rates and high timing resolution. Therefore, the use of VUV detectors as key components in the radiation detectors is attracting considerable attention and the development of more sophisticated VUV detectors is also extremely important. In this paper, we report on the development of VUV photoconductive detector, which has no sensitivity in DUV region without any filters, by utilizing the YF₃ thin films.

EXPERIMENTAL RESULT

YF₃ thin film was grown by pulsed laser deposition (PLD) on the quartz glass substrate. YF₃ ceramic target was irradiated with the femtosecond laser pulses (wavelength: 790 nm, laser fluence: 13.5 J/cm²). Growth was carried out 3 h under high vacuum condition (2×10⁻⁴ Pa). The substrate heating temperature was controlled at 670 K. Figure 1 is scanning electron microscope (SEM) images of YbF₃ thin film. A sub-micron-sized particulates make up the majority of the deposition layer. The thickness of the thin film was about 170 nm.

Fig.1 SEM images of the surface and section of YbF₃ thin films

To evaluate these thin films as photoconductive detectors, a pair of interdigitated aluminum electrodes was fabricated onto the thin film by vacuum deposition. The patterned area of interdigitated electrodes was 5×4 mm². Both the gap between the electrodes and the width of the electrodes were 0.2 mm. In addition, we covered them with YF₃ thin film to prevent photoelectron emission from electrodes.

Fig.2 I-V characteristic of YF₃ thin film
Figure 2 shows I-V characteristic measured in the dark (unirradiation) and under illumination of VUV light from deuterium lamp (irradiation). The dark current was below 1 pA. The current value increased 3-digit before and after VUV illumination at an applied bias of 300 V. The YbF$_3$ thin film also functioned without breakdown at an applied bias of 1 kV (50 kV/cm electric field).

To evaluate the spectral responsivity of the detector using YbF$_3$ thin film, a bias voltage of 200 V was applied to a pair of interdigitated electrodes. Photocurrent was measured at each wavelength of irradiative light from 100 to 300 nm. Figure 3 shows the results of the spectral responsivity evaluation combined with the transmission of the sample. It turned out that this detector responded only to VUV wavelengths shorter than 170-nm wavelength. The 170-nm wavelength corresponds to band gap of YbF$_3$. Consequently, these results indicated that we developed a VUV photoconductive detector.

CONCLUSION

We fabricated filterless VUV photoconductive detectors using YbF$_3$ thin films on quartz glass substrates by PLD. Evaluation of spectral responsivity confirmed that the fabricated detector had a selective sensitivity to irradiative light with wavelengths of less than 170 nm (VUV region). The obtained results indicate that we have demonstrated a filterless VUV photoconductive detector using YbF$_3$ thin film. It is expected that development of such a filterless VUV photoconductive detector will expand further application.

REFERENCES