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Fabrication of MSM-Type Photodetector Using Sn-Doped α-Ga_2O_3 Films Grown by Mist Chemical Vapor Deposition

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Abstract

Sn-doped α-Ga_2O_3 films were grown on c-plane sapphire substrates by mist chemical vapor deposition (mist CVD). The film grown at 450°C was single crystalline and conductive. Using this conductive single crystalline α-Ga_2O_3 film, a metal-semiconductor-metal (MSM)-type photodetector was fabricated. Current-voltage characteristics of this photodetector showed a rectifying property. Responsivity intensity was observed above the bandgap energy of 5.2 eV.

1. Introduction

Ultraviolet (UV) photodetectors with detection wavelength range below 280 nm have potential applications such as flame detection, sterilization, and medical cure. Most of researches have been carried out for high-Al-content AlGaN-based UV photodetectors [1] against their difficulties in epitaxial growth. We have been focusing on corundum-structured gallium oxide (α-Ga_2O_3) as an alternative material. The α-Ga_2O_3 has a wide bandgap energy of 5.3 eV. There are also a lot of corundum-structured oxide semiconductors such as α-In_2O_3, α-Al_2O_3 and α-Fe_2O_3. Moreover, bandgap engineering of α-Ga_2O_3 is possible by alloying with In or Al. Preferential control of their compositions allows us to fabricate corundum-structured heterostructures [2]. However, undoped-Ga_2O_3 is an insulator.

Mist chemical vapor deposition (mist CVD) is a solution-based growth technique using a simple system configuration with low cost, low environmental road, and it can be performed even under atmospheric pressure [3]. Recently, the growth of conductive Sn-doped α-Ga_2O_3 films by mist CVD has been reported [4, 5]. In this study, a metal-semiconductor-metal (MSM)-type photodetector structure was fabricated using a conductive single crystalline α-Ga_2O_3 film.

2. Experiments

Gallium acetylacetonate and tin (II) chloride dihydrate were used as source materials for these growths which were solved in deionized water with a small amount of hydrochloric acid. The concentration of Sn solution was 2.0×10^{-4} mol/L, which is followed in ref. 4. The solution was atomized using an ultrasonic transducer at 2.4 MHz and the formed aerosols were transferred to a quartz furnace using a carrier gas of nitrogen. Sn-doped Ga_2O_3 films were then grown on c-plane sapphire substrates set in the furnace. The substrate temperatures were changed at 400, 450 and 500°C. The crystal and electrical characteristics of these films were investigated using X-ray diffraction (XRD) and Hall effect measurement, respectively.

α-Ga_2O_3-based photodetector with a metal-semiconductor-metal (MSM) structure was also fabricated by employing Ti (10 nm)/Al (100 nm) and Ni (10 nm)/Au (100 nm) pads as an Ohmic and Schottky electrodes, respectively. Current-voltage characteristics and photo-responsivity of this photodetector were investigated. Monochromatic light source generated from a 450 W Xenon lamp was used for the photo-responsivity measurements.

3. Results and discussion

Figure 1 shows XRD 2θ-ω scan profiles of the films grown at 400, 450 and 500°C. In the sample grown at 500°C, both (0006)α-Ga_2O_3 and (-402)β-Ga_2O_3 diffraction peaks were observed. In the films grown at 400 and 450 °C, (-402)β-Ga_2O_3 diffraction peak was mostly suppressed, indicating to be single crystalline. The full-width at half maximum of the X-ray rocking curve in (0006)α-Ga_2O_3 diffraction peak is 45 arcsec.

Table 1 shows electrical characteristics measured by Hall effect measurement. The lowest resistivity of 1.5×10^{-2} Ω·cm was obtained in the film grown at 500 °C. The single crystalline Sn-doped Ga_2O_3 film grown at 450°C also showed conductivity of 1.1×10^{-1} Ω·cm. The film grown at 400°C was a high resistivity.

Figure 2 shows schematic diagram of the MSM-type photodetector. Current-voltage characteristics of the photodetector fabricated using the sample grown at 450°C is shown in Fig. 3. It shows a rectifying property.

Figure 4 shows photo-responsivity of the MSM-type photodetector fabricated using the sample grown at 450°C. Gradual increase in responsivity intensity was successfully observed above the bandgap energy of 5.2 eV. Additional peak at around 4.2 eV may be ascribed to transitions induced by intrinsic defects or impurities in Sn-doped Ga_2O_3 film.

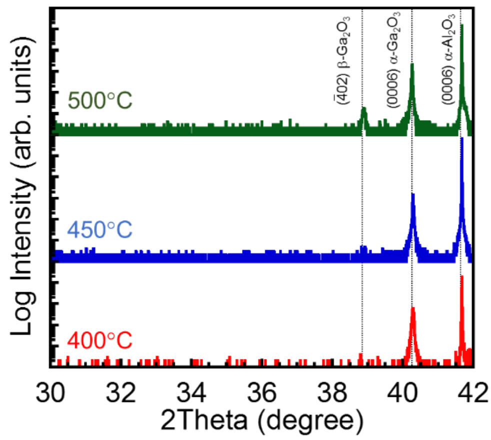

Fig. 1. XRD 2θ-ω scan profiles of Sn-doped Ga_2O_3 films grown at 400, 450 and 500 °C.

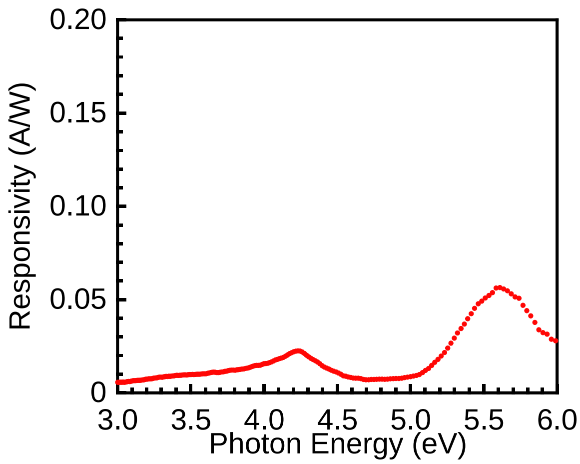

Fig. 4. Responsivity spectrum at room temperature in MSM-type photodetector fabricated using sample grown at 450°C.

Table 1. Electrical characteristics of Sn-doped Ga_2O_3 films grown at 400, 450 and 500 °C.

Temperature (°C)	Resistivity (Ω·cm)	Mobility (cm^2/V·s)	Carrier concentration (/cm^3)
400			
450	1.1×10^{-1}	2.8	2.1×10^{19}
500	1.5×10^{-2}	8.9	4.4×10^{19}

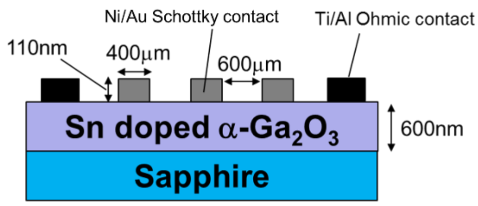

Fig. 2. Schematic diagram of MSM-type photodetector.

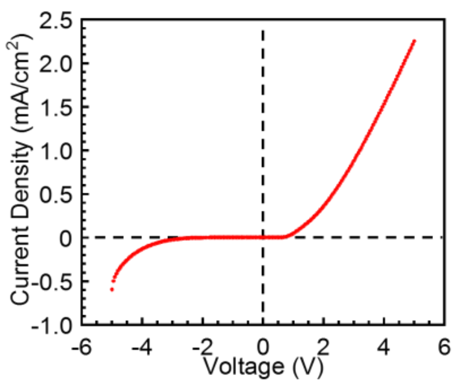

Fig. 3. Current-voltage characteristics of photodetector fabricated using sample grown at 450°C

4. Conclusions

Sn-doped Ga_2O_3 films were grown on c-plane sapphire substrates by mist CVD. Conductive single crystal α-Ga_2O_3 film was realized by adjusting growth temperature. The photodetector with a metal-semiconductor-metal (MSM) structure was fabricated using the conductive single crystal α-Ga_2O_3 film. Current-voltage characteristics showed a rectifying property. Gradual increase in responsivity intensity was successfully observed above the bandgap energy of 5.2 eV.

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