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Luminescence Characteristics and Annealing Effect of Tb-doped AlBNO Films for Inorganic Electroluminescence Devices

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1. Introduction

Inorganic electroluminescence (EL) devices have attracted attention owing to their application in low-power-consumption displays. Moreover, inorganic EL devices are cheap and suitable to make large area devices because the luminescence layers are either amorphous or polycrystalline films. However, the operating voltage of inorganic EL devices is very high.

To lower the operating voltage, a luminescence layer with a low dielectric constant is required. In addition, it has been reported that the thermal quenching of the luminescence is suppressed by increasing the bandgap of the luminescence layers. We have investigated AlBNO films as the host material of the luminescence layer. Fig. 1 shows the dielectric constants and the bandgaps of the materials that have been investigated as the host materials such as ZnS and SrS. In fact, AlBNO films have a lower dielectric constant and wider bandgap than other host materials [1]. Therefore, AlBNO films are promising as the host material for high-performance inorganic EL devices with low-voltage operation. Moreover, we have used Tb as the luminescence center because Tb^{3+} ions show green luminescence that has high luminous coefficient.

In this paper, we study the luminescence characteristics and annealing effect of Tb-doped AlBNO (AlBNO:Tb) films in order to apply AlBNO:Tb films to the luminescence layer.

2. Experimental procedure

AlBNO:Tb films were deposited by RF magnetron sputtering. The target was an AlN wafer on which small pieces of BN wafer and Tb chips were placed, and nitrogen was used as the sputtering gas. The working pressure and RF power were 1 Pa and 100 W, respectively. AlBNO:Tb films were annealed at 500 degrees C in vacuum for 60 min after deposition. The composition ratio was measured by X-ray photoelectron spectroscopy (XPS). The luminescence was investigated with the cathodoluminescence (CL) and the photoluminescence (PL) measurements at room temperature. These excitation sources were an electron beam and a He-Cd laser, respectively. The PL excitation (PLE) measurement was performed at room temperature. Fourier transform infrared spectroscopy (FT-IR) and XPS measurements were performed to investigate the bonding state.

3. Results and discussion

The composition ratios of Al, B, N, O, C and Tb were estimated to be 30%, 11%, 24%, 28%, 6% and 1%, respectively. There was a small change, such as a decrease in N by a few percent after annealing.

Fig. 2 depicts the PL spectra of AlBNO:Tb films. The PL spectra show the strongest emission line at 550 nm due to the f-f transition of Tb^{3+} ions ($^5D_4 \rightarrow {}^7F_5$). Other three peaks are also attributed to the f-f transition of $^5D_4 \rightarrow {}^7F_{J=6,4,3}$. The PL intensity increases by 5 times after annealing. The CL spectra of AlBNO:Tb films also show the f-f transition of Tb^{3+} ions. The CL intensity increases by 1.5 times after annealing.

Fig. 3 shows the CL spectra of non-doped and Tb-doped AlBNO films at the short wavelength side. There are three peaks at 243 nm, 270 nm and 308 nm in the CL spectra of non-doped AlBNO films. It is possible that these peaks are associated with the band-edge luminescence because the bandgap of AlBNO films is about 5.0 eV. These peaks disappear in the CL spectra of AlBNO:Tb films. This indicates that the luminescence of Tb is attributed to the energy transfer from AlBNO films to Tb. In addition, this luminescence mechanism changes negligibly with annealing.

Fig. 4 depicts the PLE spectra of AlBNO:Tb films monitored at 550 nm. It has been reported that the f-d transition of Tb^{3+} ions shows a broadband peak between 250 and 300 nm. Therefore, the broadband peak in Fig. 4 is possibly due to the f-d transition of Tb^{3+} ions. Moreover, this peak possibly includes the energy transfer from AlBNO films to Tb. Moreover, the PLE spectra from 450 nm to 500 nm are depicted at a magnification of 100 times in Fig. 4 inset. This figure shows the PLE spectra peak at 488 nm that is associated with the $^7F_6 \rightarrow {}^5D_4$ transition. It suggests that the direct excitation process contributes to the luminescence of Tb. In addition, this process occurs regardless of the annealing procedure.

Fig. 5 depicts the FT-IR spectra of AlBNO:Tb films. B-O bonds increase after annealing. Fig. 6 depicts the XPS spectra from Tb 4d. Tb^{4+} ions decrease after annealing. This suggests decrease in Tb^{4+} ions due to dissociation of O from Tb and formation of B-O bonds. As the result, the increase in Tb^{3+} ions that are luminescence center leads to the increase in the luminescence by annealing.

4. Conclusion

We clarified the luminescence characteristics of Al-

BNO:Tb films. The luminescence is attributed to both the energy transfer from host material to Tb^{3+} ions and the direct excitation of Tb^{3+} ions. Moreover, we achieved drastic increase in the luminescence by annealing treatment due to increase in Tb^{3+} ions, luminescence center. Therefore, AlBNO films could be used for inorganic EL devices.

Aknowledgements

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Thanks to JASCO Corp. for PLE measurements.

Reference

[1] K. Masumoto et.al., MRS Proceedings, 1195-B13-02 (2009).

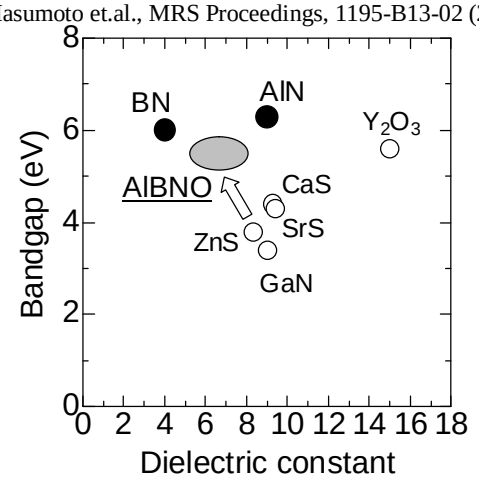


Fig.1 Dielectric constants and bandgaps of the host materials.

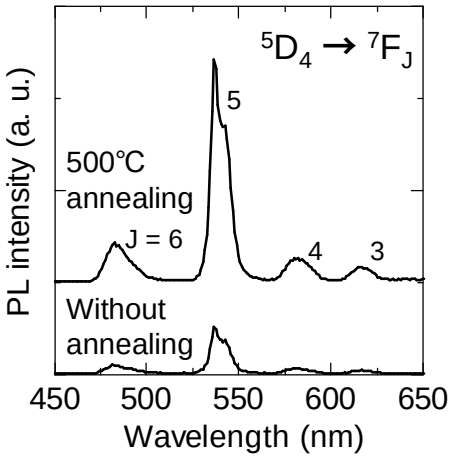


Fig.2 PL spectra of AlBNO:Tb films.

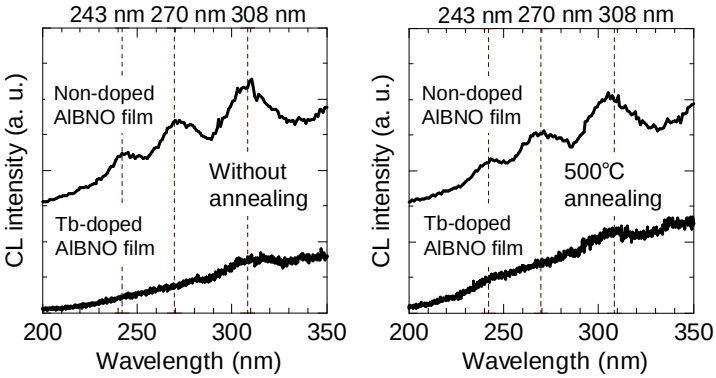


Fig.3 CL spectra of non-doped and Tb-doped AlBNO films.

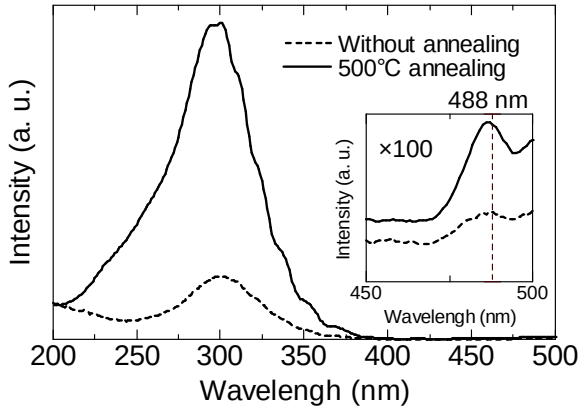


Fig.4 PLE spectra of AlBNO:Tb films.

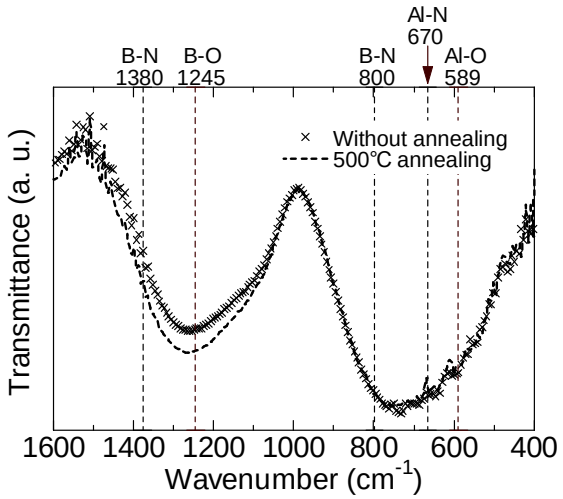
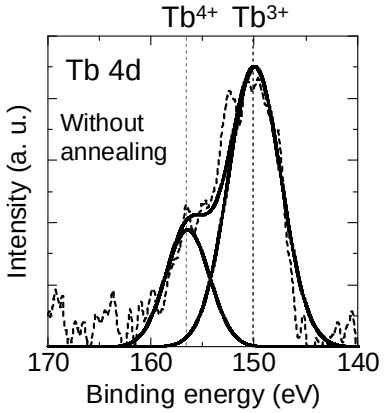


Fig.5 FT-IR spectra of AlBNO:Tb films.



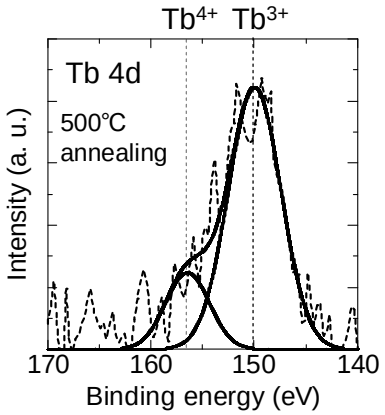


Fig.6 XPS spectra from Tb 4d of AlBNO:Tb films.