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Formation of porous 4H-SiC by modified voltage controlled anodic oxidation for realization of high color rendering nitride-based white LEDs

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Nitride-based white LEDs have a wide range of applications. Most white LEDs are realized by coating GaInN-based blue LEDs with YAG-based yellow phosphors. SiC substrates are used as substrates for nitride semiconductors. Therefore, if the phosphor function can be added to it, a monolithic high-performance white LED will be realized. In previous studies, SiC has been doped with B and N to obtain highly efficient yellow-orange fluorescence at 580 nm, which we call f-SiC. Nevertheless, fluorescence in the short wavelength region of the blue visible is low, and as it is, only white color with a low color rendering index can be obtained. The porous SiC is expected to be a promising solution. Porous SiC has a shorter fluorescence wavelength of 460 nm due to the surface-state-related transitions. Therefore, if fluorescent SiC can be partially porous, a substrate for nitride semiconductors with a phosphor function having high color rendering property can be realized. However, a stable method for porous fluorescent SiC with high resistance has not been developed. In this presentation, we discuss the usefulness of pulsed voltage application and appropriate negative bias voltage for porous SiC.

In this experiment, f-SiC with a free electron concentration n at room temperature of 1×10^{18} cm^{-3} was used as the sample. Samples were dipped in 2.5 at% HF aqueous solution and irradiated with UV light of 365 nm wavelength and 4000 W cm^{-2} intensity using a HgXe while an electric current was applied to the samples to porous them for 10 min. In previous experiments, it has been demonstrated that low-resistance SiC is porous by pulsed driving. The conventional pulse conditions are 50 ms, 25 ms, 0 V, and 1 0V for period, pulse width, bias voltage, and applied voltage, respectively. In this experiment, a negative bias voltage of -5 V was applied to verify the effect. These samples were evaluated by SEM and photoluminescence (PL) of He-Cd laser excitation at room temperature.

First, the thickness of the porous layer formation was observed by cross-sectional SEM. Clear differences in the thickness of the porous layer were observed depending on the bias voltage. First, in the case of a general pulse waveform with a bias voltage of 0 V, the thickness of the porous layer was confirmed to be very thin. Meanwhile, when the bias voltage was set to -5 V, the thickness of the porous layer was successfully obtained to be 16.7 μm, which is 10 times thicker than that with a bias voltage of 0 V, despite the same processing time. Observation of the structure of the porous layer by SEM confirmed that the shape of the porous layer was almost uniformly formed. Considering this effect, it is thought that OH^- is formed in this chemical reaction. When the bias voltage is set to 0 V, this OH^- may remain once formed on the surface and inhibit the reaction. In contrast, if a negative bias voltage is applied, the OH^- is removed by electrolysis, resulting in the formation of a uniform porous layer, which would explain the present phenomenon. Furthermore, PL spectra showed a broad emission wavelength of 460 nm at a bias voltage of -5 V. These results suggest that a monolithic white LED with high color rendering property can be obtained by layering nitride-based LEDs on f-SiC and porous SiC.

[1] W. Lu, Y. Iwasa, Y. Ou, D. Jinno, S. Kamiyama, P. M. Petersena and H. Ou, RSC Adv., 7, 8090 (2017).

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