Formation of porous SiC and PL enhancement by Al2O3 passivation

Iwasa, Yoshimi; Lu, Weifang; Kamiyama, S.; Ou, Haiyan; Takeuchi, Tetsuya; Iwaya, Motoaki; Akasaki, Isamu

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Formation of porous SiC and PL enhancement by Al_2O_3 passivation

Y. Iwasa[1,a*], W. Lu[2], S. Kamiyama[1], H. Ou[2], T. Takeuchi[1], M. Iwaya[1]
I. Akasaki[1]

[1]Department of Materials Science and Engineering, Meijo University, 1-501 Shiogamaguchi, Tenpaku-ku, Nagoya 468-8502, Japan

[2]Department of Photonics Engineering, Technical University of Denmark, DK-2800, Lyngby, Denmark

[a]email: 163434006@ccalumni.meijo-u.ac.jp

White LEDs consisting of blue LED chip and yellow phosphor have expanded in LCD backlight and general lighting applications due to their superior performance. However, they still have insufficient color rendering index, because of the lack of green and red color components. In this study, we propose a new solid state phosphor material, porous SiC. Since this material can create continuous visible spectrum similar to sun light, it is possible to create high quality white LEDs with high color rendering index.

Fluorescence (f-) SiC doped with N (donor) and B (acceptor) can create donor-acceptor-pair (DAP) emission with a yellow-orange broad bandwidth spectrum [1], despite of an indirect bandgap material. However, to realize high color rendering index white light, shorter component light emission has to be added. To create such short wavelength light, porous SiC from a commercial 6H-SiC substrate, which contains N (intentional; 5×10^{18} cm^{-3}) and B (unintentional; 1×10^{18} cm^{-3}) was produced by anodic oxidation technique [2,3]. The porous SiC is known to produce UV to green light, which may be due to the quantum size effect on DAP recombination [3]. A problem of the porous SiC is strong surface recombination. Therefore, surface passivation technique is indispensable.

In this study, the porous SiC samples were prepared by anodic oxidation technique with a solution of 5% hydrofluoric acid. In the anodic oxidation, a pulsed current was varied with a fixed period of 25ms and duty ratio of 50 %. The thickness of the porous SiC is approximately 40 μm in all samples. As a reference, a bulk SiC sample is also characterized simultaneously. The photoluminescence (PL) spectra of porous SiC samples with different pulsed current are shown in Fig.1. It is found that PL intensities of porous SiCs are higher than that of reference sample. And blue shift of PL peak wavelength is clearly observed. Among the porous SiC samples, PL intensity and peak wavelength are dependent on the pulsed current. It may be due to the variation of porous crystal structure. The best sample with the pulsed current of 1.25 mA has 6.6 times higher PL intensity than the reference sample. However, PL intensity is significantly reduced by elapsing time, because of the progress of surface oxidation. Therefore, to passivate the surface, 20 nm-thick Al_2O_3 film was deposited by atomic layer deposition (ALD) technique at 160 °C. Figure 2 shows cross-sectional SEM images of porous SiC samples before and after the passivation. Before the passivation, a lot of ordered open pores can be seen. However, they are disappeared after the passivation. Figure 3 shows PL spectra of samples before and after the passivation. As

in the figure, passivation greatly improves the PL intensity. After the passivation, PL intensity has no change even after several days.

Finally, efficient porous SiC was successfully produced with a optimum anodic condition and passivation technique. This is promising phosphor material to create high color rendering index.

References

[1] S. Kamiyama, et al. J. Appl. Phys., Vol. 99, 093108 (2006).

[2] L. T. Canham, Appl. Phys. Lett., Vol. 57, 1046 (1990).

[3] T. Nishimura, et al. physica status solidi (c), Vol. 7, 2459 (2010).

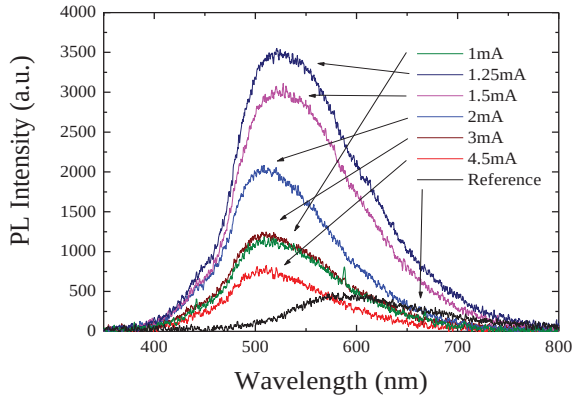

Fig. 1.PL spectra of porous SiC samples with different pulsed current

(a) (b)

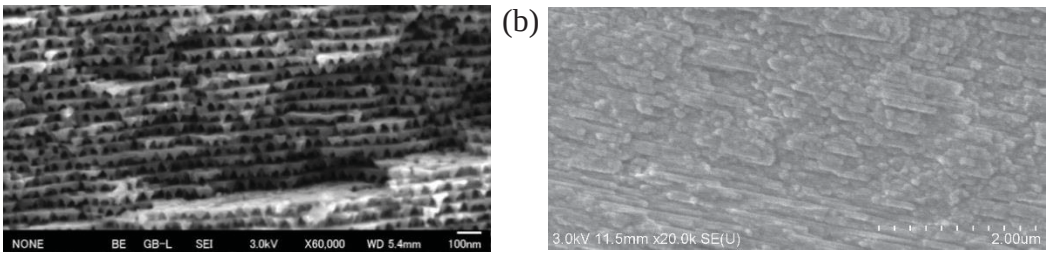

Fig. 2 Cross-sectional SEM images of porous SiC, (a) before the passivation and (b) after the passivation with 20nm-thick Al_2O_3.

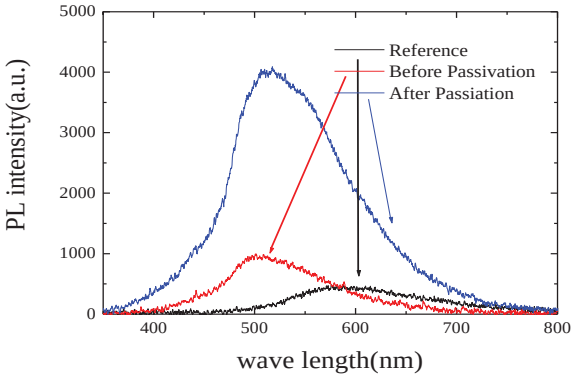

Fig. 3.PL spectra of porous SiC samples before and after passivation with 20nm-thick Al_2O_3 deposited at 160 °C.