UV aging behavior of AlGaN and SiC UV photodiodes

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Introduction

The applications of UV photodiodes are quite varied and include use and survival at high radiation and high temperatures. Such applications are e.g. the UV source monitoring in UV water purifiers (high radiation) and UV curing machines (high radiation and eventually high temperatures). For such applications the photodiode's output current is the technical base of important decisions, e.g. to set a water purifier or a curing machine into failure mode or to replace expensive UV lamps. Thus, it is crucial that a UV photodiode does not degrade even exposed to high UV radiation and high temperature. The present paper reports about the results of UV aging experiments of different commercially available UV photodiodes by means of measurement of the spectral responsivity and the photoluminescence before and after UV exposure. The measurement of the spectral responsivity is a good means to reveal wavelength resolved damages caused by the UV exposure and to predict how these damages will influence the photodiode's output current at a given irradiation spectrum. The results of the photoluminescence measurements before and after stressing of a photodiode do not give a direct information about the aging behavior. However, significant changes in photoluminescence mean that the amounts of defects within semiconductor changed, e.g. by creation of new defects within the crystal lattice or at the interface of the PIN device structure.

Experimental setup

Two different commercially available UV photodiode types were used for this analysis. These are SiC based photodiodes from sglux (model SG01D-18) and AlGaN based photodiodes from GenUV (model GUVA-T11 and GUBV-T11). The aging experiments were done with an UV aging chamber at a UV radiation level of up to 130mW/cm^2 and temperatures from room temperature up to 350°C. Picture 1 shows the aging chamber. Both photodiode types had been exposed for 90 hours to an irradiation of 60mW/cm^2 and a temperature of 80°C. A Hg medium pressure lamp was used as the UV light source.
sglux produces a SiC photodiode type that is specified to work at temperatures of up to 350°C. This photodiode was exposed for 192 hours to an irradiation of 130mW/cm^2 and a temperature of 350°C. Furthermore, photoluminescence measurements had been done at room temperature and at low temperature (15K) using the SiC photodiode before and after irradiation (80 hours, 130mW/cm^2 Hg medium pressure lamp, 80°C).

Fig. 1 UV aging chamber

Results

Figure 2 shows the spectral responsivity of the SiC photodiode (blue curve), the UVA AlGaN photodiodes (red and black line) and the UVB AlGaN photodiodes (green and yellow line) before and after 90h at 60 mW/cm² UV irradiation. The SiC photodiode shows no measurable degradation. Both AlGaN photodiodes show a strong degradation of approx. 85%.

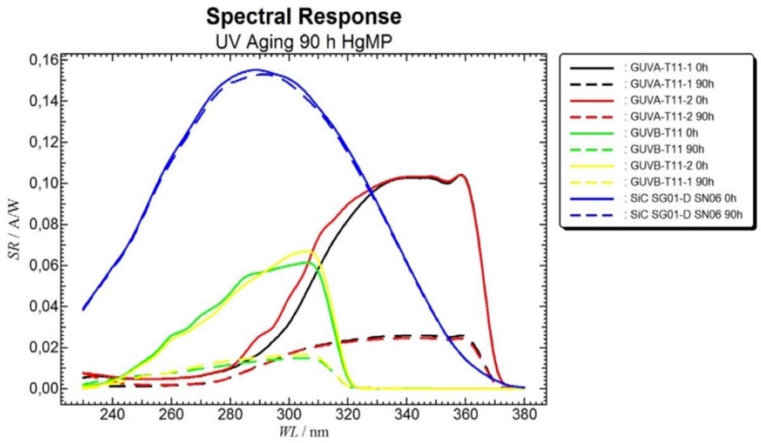

Fig. 2 Spectral response of SiC and AlGaN before and after 90h irradiation

Figure 3 shows the spectral responsivity of the SiC photodiode before irradiation, after 60 hours, after 120 hours and after 192 hours at a constant temperature of 350°C. The graph shows that the material shows an initial sensitivity decrease of approx. 12% within the first 120 hours of irradiation. After that 120 hours no further changes could be observed.

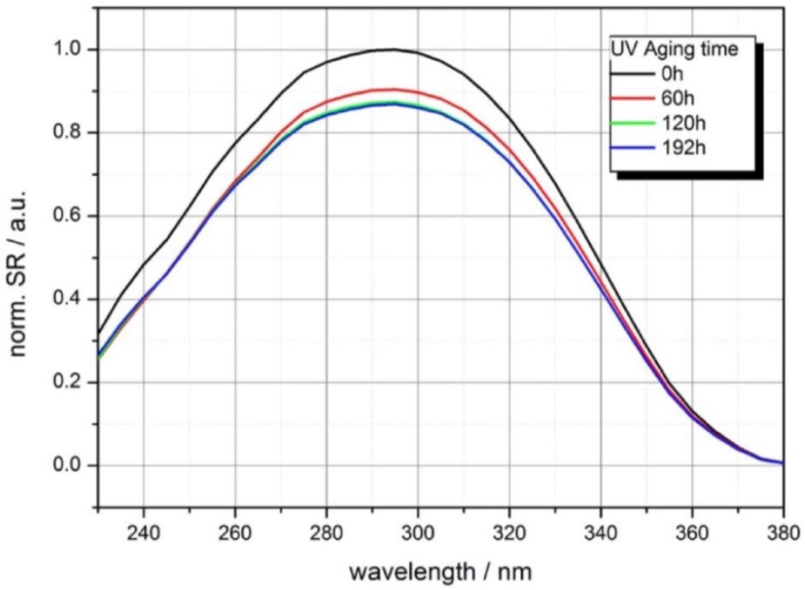

Figure 3 spectral response of the SiC photodiode before and after irradiation with 130mW/cm2 at a temperature of 350°C

Figure 4 shows the photoluminescence response of the SiC photodiode before and after having been stressed with UV radiation (130 mW/cm^2, 80 hours, 80 deg. C). The figures before stressing of the photodiodes show a typical photoluminescence spectrum of a high quality crystal structure. In the band-gap region the N bound exciton emission (NBE) is visible as well as the donor-acceptor-pair recombination emission (DAP) that typically changes with temperature. Another peak can be recognized at a wavelength of 670 nm for each sample. This peak is associated with a C antisite-vacancy pair (CAV) in 4H-SiC [1]. At 450nm and 15K temperature a phonon replica is visibile that corresponds to longitudinal optical (LO) phonon branches [1]. After having been stressed with UV radiation the room temperature photoluminescence spectrum shows no significant change. At 15K a slight increase of LO and DAP emission could be observed. It is unclear if this is caused by variations of the measurement setup or by changes of the crystal structure.

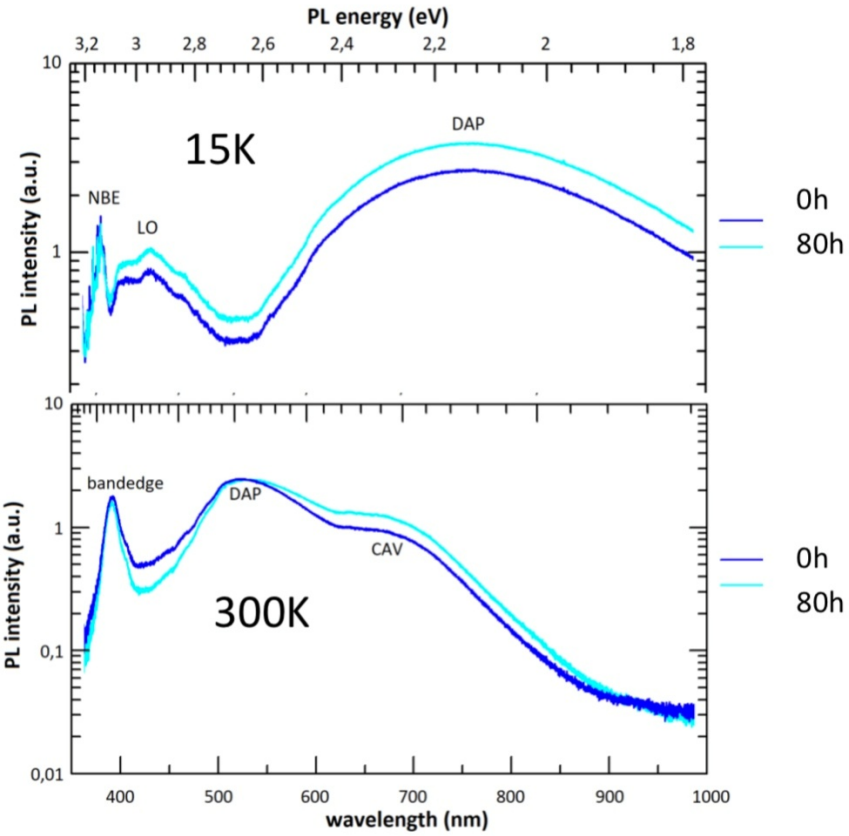

Figure 4 photoluminescence of the SiC photodiodes before and after UV-stressing.
(Source: Krueger, J., Diploma Thesis 2020, Technical University of Freiberg)

Conclusion

The present paper confirms previous publications [2] that at moderate temperature levels SiC photodiodes does not degrade while irradiated with ultraviolet light. Furthermore photoluminescence measurements do not give hints of any UV radiation induced crystal damage. The evaluated AlGaN photodiodes do strongly degrade. SiC photodiodes operated at 350°C need a burn-in of 120 hours and are stable afterwards.

Literature

[1] J. Krueger, *UV-induced degradation of SiC based PIN-photodiodes,* Diploma Thesis Technical University of Freiberg, 2020

[2] D. Prasai, W. John, L. Weixelbaum, O. Krüger, G. Wagner, P. Sperfeld, S. Nowy, D. Friedrich, S. Winter, and T. Weiss. Highly reliable silicon carbide photodiodes for visible-blind ultraviolet detector applications. Journal of Materials Research, 28(1):33–37, 2013.

Acknowledgements

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