Spatially Resolved Cathodoluminescence Analysis of ZnO Infiltrated into Porous Anodic Alumina Pores

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Zinc oxide (ZnO) is widely used as an electron transporting layer in various types of solar cells, particularly perovskite solar cells. Its primary function is to efficiently collect and transport electrons from the photoactive layer to the electrode while simultaneously blocking holes, thereby minimizing recombination losses. In this context, investigations into the electronic properties of ZnO, especially the spatial distribution of free carriers, are essential for optimizing device performance.

In this study, porous anodic alumina (PAA) with a periodic structure was fabricated using a two-step anodization of aluminum under time-controlled voltage conditions. ZnO thin films were then deposited onto the PAA templates via atomic layer deposition. Following deposition, the ZnO-coated PAA structures were bonded to glass substrates, after which the aluminum substrate was removed and the PAA templates were selectively dissolved. This process yielded vertically aligned ZnO nanotubes.

To probe the emission characteristics and spatial variation of free carrier concentration within the nanotube walls, cathodoluminescence (CL) depth profiling was employed. Using the established relationship between emission energy and free carrier concentration in ZnO [1], the carrier densities were estimated from the energy positions of the CL emission peaks. The results revealed a non-uniform distribution: carrier concentration increased from the outer surface toward the interior of the ZnO layer, followed by a decrease near the inner surface of the nanotube. This behavior is attributed to the inhomogeneous distribution of donor-like defects and the presence of surface-induced band bending, likely due to surface states such as dangling bonds that trap free carriers.

References

[1] N. C. Giles; Chunchuan Xu; M. J. Callahan; Buguo Wang; J. S. Neal; L. A. Boatner, Appl. Phys. Lett. 89 (2006) 251906.

Figures

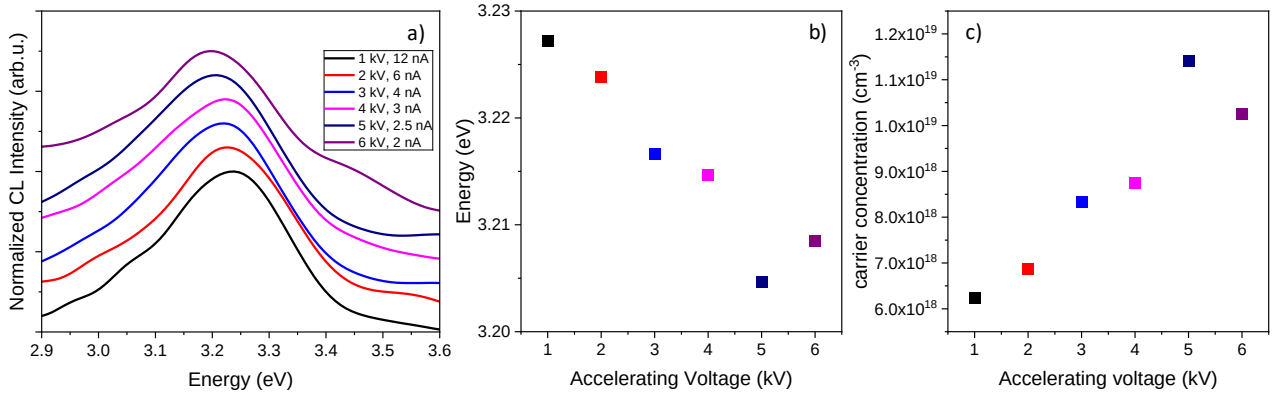

Figure 1. a) CL spectra acquired from the 70 nm-thick top wall of a ZnO nanotube with an outer diameter of approximately 400 nm at 300 K. b) Responses of the CL peak positions. c) Local carrier concentration determined from the CL peak positions.