Structure and state analysis with Spectrometric Full-color Cathodoluminescence Microscopy

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Scanning electron microscopy (SEM) with cathodoluminescence (CL) detection can draw distribution of electronic states and chemical information in the specimen. The energy of CL photons of visual light region gives information of Band Gap of semiconductors or the highest occupied molecular orbital (HOMO)-lowest unoccupied MO (LUMO) of organic materials. Our new spectrometric full-color CL microscope [1] displays CL spectra of each observing point and provides full-color CL map and SEM image of 512 x 512 pixels in 8 s, which enabled us to observe irradiation-sensitive materials such as organic or biological materials. The block diagram of the system and its performance are shown in Fig. 1.

Since the CL excitation is given by the incident electron beam, deep UV emission down to 200 nm can be detected and the spatial resolution of CL micrographs may reach that of the secondary electron images, which makes CL to exceed PL (photoluminescence) microscopy. The spatial resolution of CL micrographs generally may become worse than that of SEM due to bulb-shape spread of incident electrons in solids. Delayed CL emission is another cause of poor resolution. Both result practical CL resolution around 100 nm. However, lower incident energy and slow image scan improve the resolution significantly, and in our system 25 nm resolution was verified with 6 kV beam and 40 s/frame, which is comparable to or better than that of scanning near-field optical microscopy.

With the high sensitivity and high spatial resolution in hand, we studied grain boundaries of ZnO varistors, growth of GaN/InGaN layers for laser diode, cyanine dye J-aggregates, and composite materials for UV emission.

Fig. 2 is a study of grain boundaries of ZnO varistor [2]. CL observation across the boundary revealed that, from the boundary, 500 nm peak appears first, then 510 nm peak rises slightly inside the grain. Then, 490 nm peak appears forming twin with 510 nm peak. Thus, the high-resolution CL study provides tools for the detailed structure analyses.

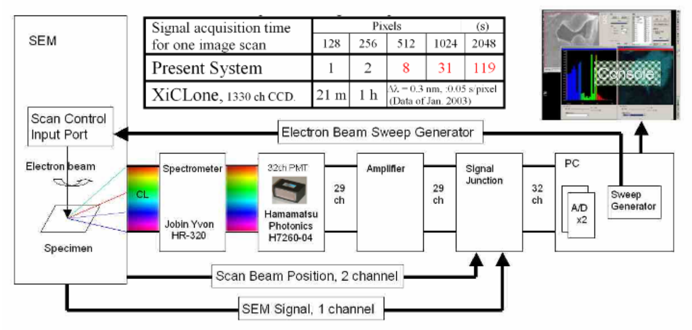

Fig. 1. Block Diagram and the performance of CL Microscope.

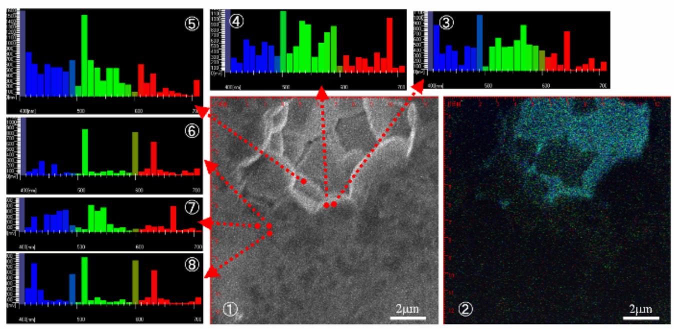

Fig. 2. CL observation of SnO_2 10% and Bi_2O_3 1% doped ZnO varistor. ①; SEM image, ②; CL micrograph of ①, ③-⑧; CL spectra of points marked in ①.

References

1. H. Saijo and M. Shiojiri, in "Proc. 16th IMC. Sapporo", Vol. 2 (2006), p. 883.
2. H. Saijo, N. Daneu, A. Recnik, and M. Shiojiri, in "Proc. EMC2008. Aachen", (2008).