DOI: 10.1017/S1431927604882679
Microsc Microanal 10(Suppl 2), 2004

Development of a STEM-EBIC/CL System for Structural, Compositional, Electrical, and Optical Characterization of Quantum Well Devices

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This work involves the development and application of Scanning Transmission Electron Microscopy (STEM) techniques for nanometer structural, compositional, electrical and optical characterization of quantum well devices using Electron Beam Induced Current (EBIC) and Cathodoluminescence (CL). The optoelectronic properties in InGaN-based quantum well devices may be influenced by localization effects due to In fluctuations, piezoelectric effects, or a combination of both. Therefore, the ability to characterize these devices on the nanometer scale can provide valuable insight into the emission mechanisms in single and multiple quantum well devices. STEM-EBIC can provide information on the electrical properties of these devices including nanometer resolution of the p-n junction position. STEM-CL can provide information on the luminescence homogeneity and spectroscopic variations within the quantum wells.

A STEM-EBIC system was designed and implemented in a Hitachi HD-2000 dedicated Field Emission STEM in order to characterize InGaN quantum well heterostructures. The simultaneous collection of Z-contrast images, EBIC images, and elemental x-ray linescans allowed for the determination of the p-n junction location, AlGaN and GaN barrier layers, and thin InGaN quantum well layer within the device. The relative position of the p-n junction with respect to the thin InGaN quantum well was resolved with the STEM-EBIC technique with nanometer precision [1].

A custom sample holder and sample preparation techniques have been developed for full structural, compositional, and electrical characterization of fully packaged quantum well devices at the nanometer scale (Fig. 1). Commercially packaged AlGaInP MQW devices were deprocessed while maintaining full optical and electrical activity [2]. The samples were embedded in glue, mechanically polished into a wedge, and placed between two 3mm half Cu grids. Focused ion beam micromachining was adapted to create an electron-transparent membrane ~ 100 nm thick in the active region.

A CL spectroscopy setup is currently being implemented in the STEM using a miniature spectrometer coupled via a fiber optic light collection system (Fig. 2). The custom sample holder will also make it possible to positively and negatively bias the fully prepared device in the STEM and observe any effects in the electrical and optical properties of the device. The simultaneously acquisition of CL spectroscopy and x-ray analysis at the nanometer scale allows for investigations into the emission mechanisms in quantum well InGaN-based devices. The CL setup has been implemented in the Hitachi S-3200N and CL spectroscopy and the effects of biasing are currently being studied in InGaN-based devices (Fig. 3).

[1] K.L. Bunker et. al., *GaN and Related Alloys: 2002*: (MRS Boston, 2002), Vol. 743, L10.10.
[2] K.L. Bunker et. al., '*Current Issues on Multidisciplinary Microscopy Research and Education*', Vol. 2, edited by A. Méndez-Vilas: (FORMATEX, Badajoz, Spain), in press.

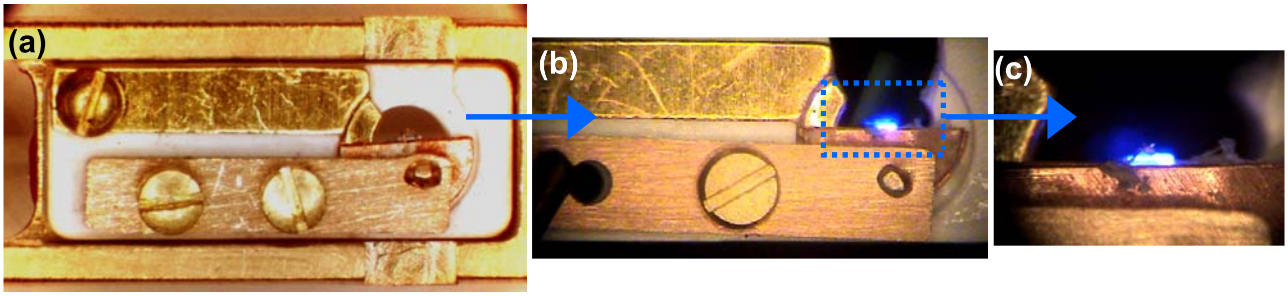

Fig.1 (a) Fully assembled custom STEM-EBIC sample holder for the HD-2000 STEM. (b) STEM-EBIC sample holder insert holding a fully prepared InGaN-based LED. (c) Fully prepared InGaN-based LED emitting under bias in the custom STEM-EBIC sample holder.

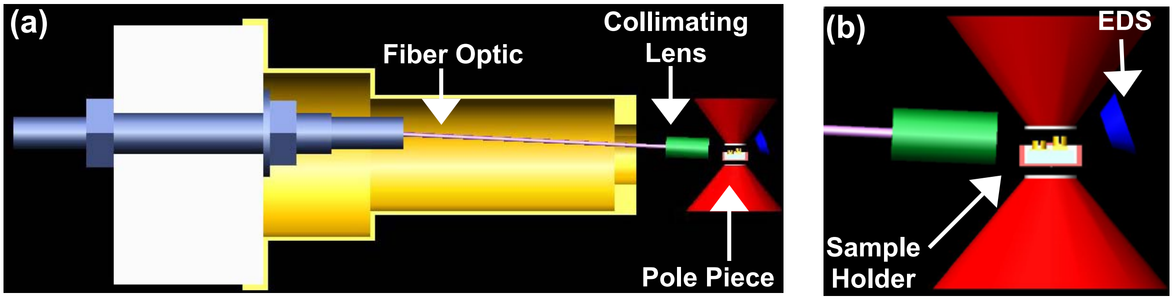

Fig.2 (a) STEM-CL design using a fiber optic light collection system in the Hitachi HD-2000 STEM. (b) Sample holder placed between the two pole pieces of the Hitachi HD-2000 STEM.

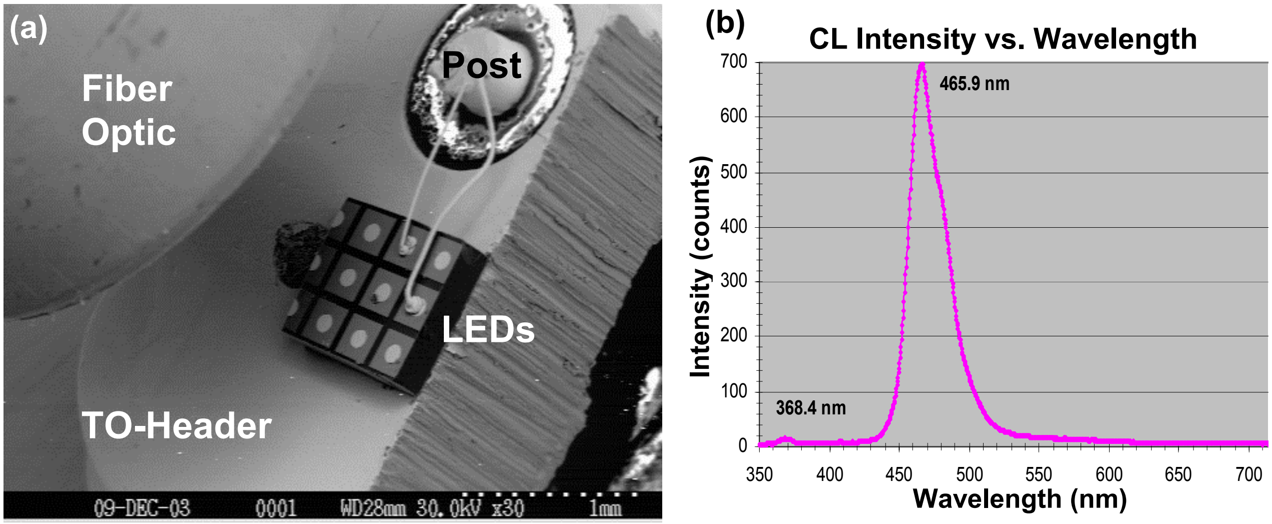

Fig.3 (a) Secondary electron image acquired in the Hitachi S-3200N showing the fiber optic of the CL setup and a cleaved portion of a wafer mounted unpackaged on a TO header. (b) CL spectrum of one LED showing the InGaN peak at 486.9nm and the GaN peak at 388.4nm.