Microsc. Microanal. 8 (Suppl. 2), 2002
DOI 10.1017.S1431927602106192

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Study of self-assembled InAs quantum dots on InP nano-templates by low voltage scanning electron microscopy cathodoluminescence

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Semiconductors quantum dots (QDs) are expected to lead to major development for high-speed electronic and optoelectronic devices. The performances of devices based on QDs are still limited by the fabrication technology. To overcome this difficulty, we need not only the well-developed growth technique but also the proper method of characterization of QDs performance. A powerful technique of high spatial resolution for the investigation of the optical and structural properties of QDs is the cathodoluminescence, which consist in collecting the light emission associated with excitation of material by electron beam. The electron beam excitation may be focused to a spot to excite a small region or defocused to illuminate a large area of the sample.

In this study, we have mainly employed CL Imaging and spectroscopy technique for the characterization of self-assembled InAs QDs grown on patterned InP(100) nanotemplates (figure 1). This SEM micrograph shows clearly the individual InAs QDs on top of the pyramid. To ensure good quality of those structures, the QDs are capped with further InP. This study will investigate the formation of QDs and try to relate the size/thickness of such dots to their emission wavelength. The CL experiments were performed on a LEO 1530 FESEM equipped with the MonoCL2 cathodoluminescence system and a liquid helium stage (down to temperature lower than 5 K) from GATAN Instruments. The light emitted from the material was collected by a retractable modified paraboloidal mirror and amplified with a dry ice cooled infrared photomultiplier tube (Hammamatsu R5509-72). Spectra can be acquired with this system in the wavelength range of 300nm up to 1.8μm. The measurements were carried by low beam energies (2 keV- 5 keV) to increase spatial resolution by reducing the interaction volume of the electrons. Our studies have also included the dramatic effect of low voltage charging on CL properties.

Figure 2, present a micrograph recorded using secondary electron mode and simultaneously in monochromatic CL mode. This low magnification inspection is used to investigate the quality of individual pyramid and allows the selection of proper structure for further analysis. A CL spectrum, shown in figure 3, was recorded at T= 5K using a focused electron beam scanning the top of a pyramid. From this spectrum, the InAs wetting layer (WL) can be identified (1100 nm) and several other peak corresponding to QDs of different energy are also shown. Monochromatic CL imaging at 5 K was employed to study the spatial distribution of luminescence and identified the presence of the QDs. Figure 4, shows such image recorded at 1100 nm. Interpretation of CL image needs careful attention because of electron diffusion within the analyse structure. In this semiconductor system the high electron mobility and high purity of material increase dramatically the carrier diffusion length, which degrade the spatial resolution of CL images. In this work, different techniques will be investigated to reduce this drastic effect and increase the lateral resolution of CL imaging to allow the characterization of single quantum dot.

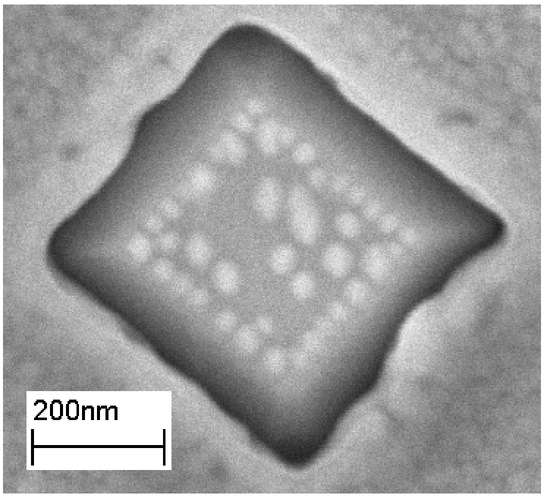

Figure 1 Secondary electron image showing the uncapped InAs quantum dots on top of a InP pyramid template. EHT = 3 kV

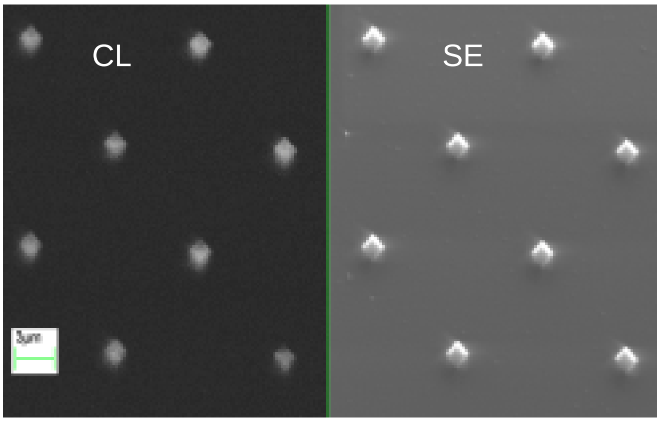

Figure 2 Cathodoluminescence image acquired at 1066nm (left) and secondary electron image of the same region of similar pyramid shown in figure 1. EHT = 2 kV, T = 5K.

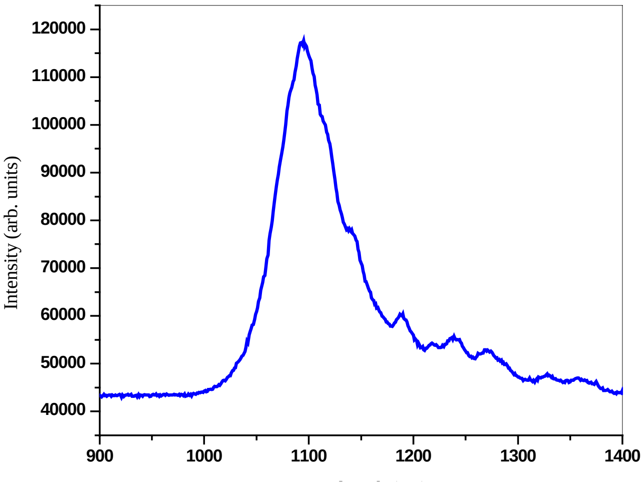

Figure 3 Cathodoluminescence spectrum acquired on a single pyramid. EHT = 2 kV

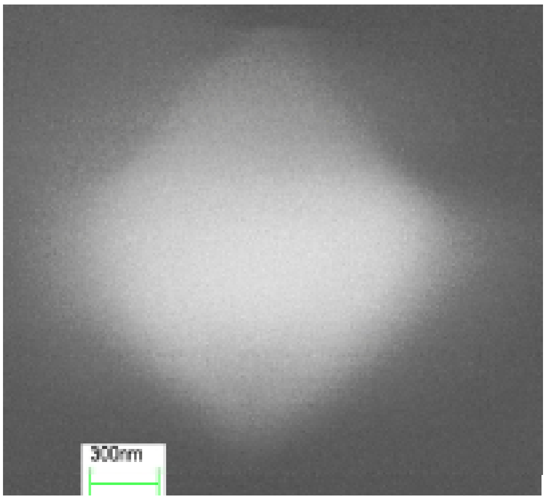

Figure 4 Cathodoluminescence image (1100 nm) of a single pyramid. EHT = 2kV.

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