Spatially Resolved Photoluminescence and Laser Annealing of GaBiAs Epitaxial Layers and Quantum Wells

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Dilute bismide semiconductor compound GaBiAs is a promising material for ultrafast infrared light emitters and detectors for optical fiber systems and terahertz applications. Introducing a small percentage of bismuth into gallium arsenide significantly reduces the band gap of the compound. However, growth of high quality GaBiAs is still a challenge. GaBiAs epitaxial layers with Bi content of up to 10% can be grown at low temperatures (~240-380°C). Post-growth rapid thermal annealing at high temperatures (~600-700°C) improves the crystalline structure of GaBiAs layers and, as a result, nonradiative recombination rate decreases [1].

In this work, the PL properties of GaBiAs epitaxial layers and GaBiAs/GaAs quantum wells were investigated with spatial resolution. The GaBiAs structures used in this study were grown by molecular beam epitaxy (MBE) technique on GaAs substrates at the Center for Physical Sciences and Technology, Vilnius, Lithuania. Four low-temperature grown samples were investigated: three epilayers with different Bi content and a quantum well (QW) structure.

The PL spatial distribution of the samples was investigated using *WITec Alpha 300S* confocal microscope coupled to *Andor* spectrometer, equipped with *iDus* InGaAs CCD detector array. The spatial distributions of photoluminescence parameters were investigated by raster scanning randomly selected areas on the sample top surface. The surface morphology of the samples was studied by the atomic force microscope integrated in the *WITec* system. All the measurements were performed at room temperature.

The epitaxial layers exhibited a PL band peaked at 1060 nm, 1140 nm, and 1210 nm in the epilayers containing 4%, 5.5% and 6.5% of Bi, respectively. The highest PL intensity was recorded in the sample with the lowest Bi content. The PL band experienced a red shift and a decrease in intensity with increasing Bi content. The epilayers with Bi content of 4% and 6.5% have a striped pattern of PL intensity spatial distribution, which is most probably related to the stripes of different roughness observed on the layer surface. The epilayer with 5.5% of Bi showed a spotted pattern of PL intensity distribution. This epilayer also exhibited the largest density of dislocation-related pits.

The PL spectrum of the sample with QWs containing approximately 5.5% of Bi exhibits a single PL band peaked at 1050 nm. The PL intensity distribution in this sample is homogeneous except for dark spots or lines, which are associated with crystal defects. Moreover, a peculiar response to prolonged laser exposure was observed in this sample. The spectrally integrated PL intensity in the spots exposed to a highly focused laser beam for time periods of up to 30 min increased by up to 75%, while the PL band was slightly blueshifted. The changes of PL parameters indicate that the crystal structure is locally modified by laser annealing. It is feasible that Bi-rich clusters are decomposed during the laser annealing process, like they were shown to do under thermal annealing. AFM images revealed that the laser annealing results in formation of humps, up to 40 nm in height, at the annealed spots.

The results show that the laser annealing can be used to improve the GaBiAs crystal quality and enhance the emission efficiency.

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