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Etching of InGaAs/GaAs layered structures by neutral beam etching for quantum dot laser applications

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III-V semiconductors are widely used to fabricate optoelectronics devices such as light emitting diodes, quantum dot (QD) lasers, or solar cells [1]. Particularly, QD lasers are one of the most promising light sources because of their theoretically improved performance compared to quantum well and bulk lasers. Because of the three-dimensional confinement, the density of states is modified and enables better temperature stability, lower threshold currents and higher speed. InGaAs QDs are usually fabricated by Stranski-Krastanov growth mode but it is still a big challenge to achieve high QD density, with high uniformity and multi-stacked QD layers.

Therefore, a novel top-down process has been developed combining a bio-nano process (BNP) and a neutral beam etching (NBE) process for QD fabrication. The BNP consists of making a sub-10 nm etching mask by forming a two-dimensional array of metal oxide nanoparticles embedded in a cage-like protein called ferritin [2]. The NBE consists of an inductively coupled plasma (ICP) source separated from the process chamber by a carbon electrode made of high-aspect ratio apertures [3]. Therefore, charged particles coming from the plasma are efficiently neutralized by collision with the inner walls of the apertures while UV photons are screened, avoiding any drawback of usual dry etching processes.

After forming etching mask array of iron oxide nanoparticles, multi- quantum well (MQW) samples were treated by hydrogen radical to remove oxide layer on their surface. NBE was carried out at different substrate temperature, ranging from -20 ºC to +80 ºC, and for different neutralizer bias power. Nanopillars embedding InGaAs QDs were successfully fabricated for a substrate temperature of +50 ºC and a bias of 13 W. After regrowth of barrier layer, photoluminescence of QDs was detected, with an emission wavelength blue-shifted from MQW emission (Figure 1).

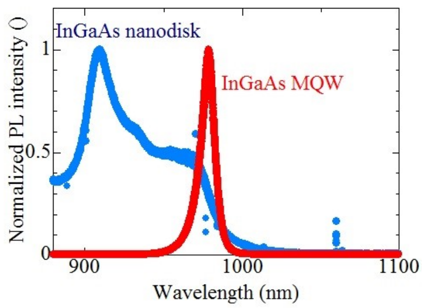

Fig. 1: Photoluminescence of fabricated InGaAs QDs (nanodisks) and InGaAs MQW as reference. Emission peak is blue-shifted with respect to MQW emission, due to the quantum confinement in QDs.

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