Optimizing the cap thickness in fabrication of quantum dot photonic structures by focused ion beam

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In recent years, much attention has been paid to the fabrication and investigation of various photonic structures, such as micro-mesas, micro-lenses, micropillar cavities or photonic crystal slabs integrated with quantum dot emitters to optimize the performance in terms of non-classical light sources for quantum technology applications. There exists different fabrication methods of such structures. In this work, we use a focused xenon ion plasma beam (Xe-PFIB), which on one hand can suffer from a possible destructive influence on the crystal structure due to ion implantation, thus reducing the internal quantum efficiency of the source, i.e. intensity of photoluminescence from quantum dots.

Therefore, the goal of this study is to find the optimal range of cap layer thickness which assures efficient emission. The processes have been made on an exemplary QD material system of InGaAs/GaAs with the emission in the application-relevant range of the 2nd telecommunication window. By using wet chemical etching process, first we prepared samples with the cap thickness in the range from above 600 nm down to approx. to 50 nm. Next, a series of cylindrical micro-mesas of 4 μm in diameter were fabricated using the Xe-PFIB. The ion beam energy of 30 keV and the beam current of 1nA were selected according to our preliminary tests. The fabricated pillar-like photonic structures in function of the cap thickness were then characterized by low-temperature micro-photoluminescence (μ-PL) measurements. Based on the single dot emission intensity dependence on the decreasing of the cap layer thickness, we found that the minimum cap thickness lies between 200 nm and 150 nm, for the given beam parameters and the chosen material system. Last, we considered further optimization steps, which relied on the carbon layer deposition to protect from the unwanted ion implantation, could potentially allow for the Xe-PFIB processing for even thinner cap layers.

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