Lift-off process for II-VI semiconductor microcavity and for optical transmission studies of exciton-polaritons

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Monocrystalline substrate is a key component for growth of thin layers by molecular beam epitaxy (MBE). The choice of the substrate is typically determined by the lattice constant and crystalline structure of the designed layer. However physical properties of substrates may significantly affect the experiments performed on epitaxial layers, e.g. opaque substrate limits the light transmission and contributes to the absorption. The problem of opaque substrate can be solved by a lift-off of epitaxial layers. The purpose of this work was to develop and verify a new method of producing free-standing semiconductor microcavities containing semi-magnetic (Cd,Zn,Mn)Te quantum wells (QW).

On the GaAs substrate the 1 μm thick CdTe buffer and 1 μm MgTe layer were deposited. The MgTe layer was introduced here for the first time and is of particular importance. The structure is followed by 22 pairs of Bragg mirror based on (Cd,Zn,Mg)Te with 40% and 8% of Mg in low and high refractive index layers, respectively. The width of layers was optimized to reach cavity resonance at emission wavelength of QWs (about 760 nm). Inside λ cavity we have grown three (Cd,Zn,Mn)Te QWs containing about 0.3% of manganese. Finally we have grown 22 pairs of top Bragg mirror. Except of MgTe buffer the structure was similar to the first exciton-polariton sample based on (Cd,Zn,Mg)Te [1].

Despite hygroscopic MgTe layer, our structure is stable in ambient atmosphere. Reflectance, at both room and helium temperatures, shows characteristic stopband with sharp cavity mode interacting with a QW excitons and forming exciton-polaritons.

To separate the microcavity epitaxial layer from the rest of the structure, the sample was glued to a quartz glass and immersed in a deionized water for 2 hours. After rinsing, MgTe layers was removed by water and the glass plate with microcavity containing QWs was lifted-off from the substrate. The images of the sample on the glass shows continuous surface of the area exceeding 10 mm^2. Low temperature photoluminescence and reflectivity spectra of the microcavity demonstrate the existence of strongly coupled exciton-polariton modes, what confirms that Mg in Bragg mirror and cavity was not harmed despite long contact with water.

Only after lift-off it was possible to measure optical transmission through the microcavity. The observation of lower and upper polaritons is consistent with the results obtained using other experimental configurations, such as back illuminated photoluminescence or angle resolved reflectivity. Moreover, the magnetooptical measuremtents allow us to observe giant Zeeman effect of polaritons, observed previously only on non-transmitting microcavities [2]. Our new design of microcavity structures opens possibility of experiments on resonantly excited exciton-polariton superfluids with magnetooptical properties enhanced by the presence of Mn in quantum wells.

[1] J.-G. Rousset et al., Appl. Phys. Lett. 107, 201109 (2015).
[2] R. Mirek et al., Phys. Rev. B 95, 085429 (2017).