Investigation of light-hole/heavy-hole mixing in self-assembled quantum dots emitting in telecommunication spectral range

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The confinement potential anisotropy driven by the nanostructure's shape and strain effects induces a symmetry breaking affecting the mixing of valence band states of light- and heavy-holes (LH and HH, respectively), directly reflected in the polarizing properties of the emission [1]. Light-hole excitons confined in semiconductor quantum dots (QDs) are interesting excitations in view of both fundamental properties as well as due to their potential advantages in quantum information science and technology [2] because of the total momentum and optical selection rules, which allow coherent conversion of photons into electron spin and thus direct tomographic measurement of the spin state or spin coherence [3,4]. In particular, there are very few reports on light-hole excitons in the structures emitting in the telecommunications range (O- and C-band).

In self-assembled Stranski-Krastanow QDs the ground state has a heavy-hole character and the light-hole exciton is not easily accessible. To enable observation of the valence band mixing and to distinguishing the light- and heavy-hole-like excitons we have employed an especially prepared experimental setup with two perpendicular optical axes, both equipped with microscope objectives, providing high spatial resolution for polarisation-resolved single quantum dot spectroscopy at low temperatures. Here, we present the valence band mixing study based on the results of polarization-resolved microphotoluminescence (μPL) of single QDs emitting in the application-relevant near-infrared spectral range.

The heavy vs light hole character of the emitting excitonic states is determined based on the polarization-resolved μPL measurements from both the surface and the sample edge. In this way, the degree of linear polarization (DOLP) can be determined for both geometries. In the surface emission, both the HH and LH excitons are similarly active, and only the DOLP compared with decent band structure calculations allow to derive the LH-HH mixing. The situation becomes significantly different when measuring the polarization-resolved emission from the structure edge – the HH excitons emission is predominantly TE-polarized, whereas the LH emission is dominating in the TM polarization.

Access to the edge emission allows for better understanding and quantitative description of the level of mixing between HH and LH states in QDs, indicating the ways of the intentional control of the QD emission polarization, e.g. by biaxial strain engineering.

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