Plasmon-enhanced photoluminescence of quantum dot-like PbTe/CdTe heterostructures

M. Szot[1], K. Karpińska[1,2], S. Chusnutdinow[1], L. Kowalczyk[1], S. Kret[1], T. Wojciechowski[1,3], S. Schreyeck[4], T. Story[1], G. Karczewski[1]

[1] *Institute of Physics, Al. Lotników 32/46, 02-668 Warsaw, Poland*
[2] *Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland*
[3] *International Research Centre MagTop, Institute of Physics Polish Academy of Sciences, Warsaw, Poland*
[4] *Universität Würzburg, EP III, Am Hubland, D-97074, Würzburg, Germany*

The coupling of surface plasmons (SPs) with photons is the alternative method, which similarly to the resonant cavities or photonic crystals, may be used to improve the spontaneous emission rate (SE) from semiconductor quantum well (QW). Strong plasmon-photon coupling can be achieved if optically active region of the emitting device is placed within SP fringing field penetration depth [1]. To meet this condition, the capping of the QW by appropriate metallic nanolayer via thin spacer can be useful. Then the emission of photons into SP modes occurs instead of into free space, giving even six-fold improvement of spontaneous emission rate as it was shown for GaAs or InGaN/GaN QWs coated with Ag or Al layer [2].

In this paper we study the quantum dot-like (QD) crystal structure-mismatched heterostructures based on rock-salt narrow gap PbTe ($E_{g,L}$=190 meV at 4K) and zinc-blende wide gap CdTe ($E_{g,\Gamma}$=1.6 eV at 4K). Using molecular beam epitaxy technique, a variety of samples containing hexagonally-shaped PbTe nano-structures with complicated morphology embedded in CdTe were obtained. Photoluminescence (PL) measurements were performed in a wide range of temperatures 4-300 K and for different power of excitation (up to 1.4 mW) with 1064 nm line of Nd:YAG pulsed laser.

We have observed that investigated PbTe/CdTe samples exhibit surprisingly narrow (≈5 meV) and unusually strong mid-infrared emission (250 meV) as compared to the luminescence of a typical ensemble of PbTe/CdTe quantum dots with different sizes measured in similar temperature (about 100 K) and excitation power conditions (400 μW). Moreover, for higher excitation power (over 500 μW) additional emission in energy about 10 meV, (i.e. energy of LO phonon in PbTe), lower than previous one appears, which dominates PL spectrum for excitation higher than 800 μW. This line, not reported for such kind of QDs yet, exhibit non-linear, laser-like dependence of amplitude on excitation power. Observed photoluminescence behavior we discuss considering presence two-dimensional electron gas (2DEG) at QDs CdTe/PbTe interfaces. The spontaneous formation of 2DEG with high electron mobility and carrier density up to 10^{19} cm^{-3} closed to the polar CdTe/PbTe interface was predicted theoretically and confirmed experimentally for single CdTe/PbTe heterojunction [3]. As estimated plasmon energy in our samples Ep≈240 meV matches well the energy of observed emission, non-resonant interface plasmon coupling mediated by LO phonon is most possible explanation of unusual enhancement of PL from studied heterostructures.

The research was partially supported by the National Science Centre through Grant No. UMO 2017/25/B/ST3/02966

[1] Neogi *et al.* Phys. Rev.B, **66,** 153305 (2002)
[2] Okamoto *et al.* Nature Mater. **3**, 601 (2004)
[3] Cai *et al*. Appl. Phys. Lett. **100**, 182104 (2012)