Photoelectrical properties of p-i-n diodes with PbSe quantum wells

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Lead selenide (PbSe) is a widely recognized material for infrared photodetectors which can be employed in infrared spectroscopy, gas and flame analysis, medical diagnostics etc. Due to favorable physical and chemical properties of PbSe, such as a narrow and direct band gap and a large Bohr radius, the PbSe-based detectors are very sensitive and can operate in the 1–5 μm spectral region. In addition, due to the large Bohr radius the quantum confinement effect in PbSe nanostructures is much stronger than in II-VI or III-V materials. On the other hand, PbSe exhibits a few drawbacks, such as high Auger recombination, high electrical permittivity, and very high thermal expansion coefficient. However, the rate of Auger recombination can be decreased by surrounding the PbSe structures by wide-gap material barriers. Introduction of PbSe nano-inclusions into wide-gap photodetectors would lead to an extension of the detection range toward lower energies, since the energy gap of PbSe is just 0.28 eV at 300 K. CdTe and PbSe has close value crystal lattice parameters, thus the lattice mismatch is ~ 5.5%. However, CdTe and PbSe crystallize in the zinc blend and rock salt, respectively. As a result of the difference in crystal structures these materials are almost immiscible. Limited miscibility allows creation of high-quality quantum size inclusions.

Here we report on photoelectrical investigations of p-CdZnTe/i-CdTe/n-CdTe thin-film diodes with PbSe nano-inclusions introduced into the intrinsic CdTe absorption layer. The thin-film heterojunctions were grown by molecular beam epitaxy (MBE) from elemental sources on monocrystalline, semi-insulating (100) GaAs substrates. The n-type CdTe films were produced by iodine doping. Depending of the growth parameters either PbSe quantum dots or PbSe quantum wells were formed in the intrinsic CdTe layer. The p-type CdZnTe layers were doped with nitrogen supplied from nitrogen-plasma source. The investigated structures exhibit very good diodes characteristics. The current-voltage characteristics of p-CdZnTe/i-CdTe/n-CdTe diodes were measured in darkness and under infrared illumination. The dark forward-to-reverse current ratio for this diode is equal to 1×10^4 at ±0.5V voltage bias and the diode ideality factor is about ~ 1.1 at 295 K. With the decreasing temperature the ideality factor increases to 44 at 13 K. This is probably due to the change in the carriers transport mechanism through the heterojunction. Electron Beam Induced Current (EBIC) measurements confirmed the formation of the junctions at the p-CdZnTe/i-CdTe interface. EBIC scan on cross-sectional indicated that the maximum of the EBIC current was occurring in the PbSe layer. The diffusion length and activation energy of charge carriers have been extracted from EBIC scan profiles.

The spectral response curves of the diodes reveal two peaks located at about 800 nm and 3000 nm. These peaks are related with absorption in CdTe and PbSe QW, respectively. Intensity of second peak very strongly depends on temperature and reaches maximum intensity at about temperature 200K. The investigated p-CdZnTe/i-CdTe/n-CdTe structures with PbSe nano-inclusions proved to be very promising for IR sensor applications.

This work was partially supported by the Foundation of Polish Sciences by the Master program № Mistrz5./2013