Band gap engineering of PbSe by doping with Cd

S. Chusnutdinow[1], M. Szot[1], S. Schreyeck[2], I.V. Kucherenko[3], A.V. Muratov[3], V.A. Yakovlev[4], W. Zaleszczyk[1,5], T. Wojtowicz[1,5] and G. Karczewski[1,2]

[1]Institute of Physics, Polish Academy of Sciences, Aleja. Lotników 32/46, PL-02-668 Warszawa, Poland

[2]Physikalisches Institute, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

[3]Lebedev Physical Institute, Russian Academy of Sciences, Leninskii pr.53, Moscow, 119991 Russia

[4]Institute of Spectroscopy Russian Academy of Sciences, ul. Fizicheskaya 5, Troitsk, Moscow 10884 Russia

[5]International Research Center MagTop, Aleja Lotników 32/46, PL-02-668 Warszawa, Poland

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. The band structures of lead salts are unique due to narrow and direct band gaps located at four equivalent L-points of the Brillouin zone, strong non-parabolicity and small and anisotropic effective masses of holes and electrons. 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. Formation of solid solutions in semiconductors leads to enriching of their physical properties and thus their possible applications. Very different band gaps of PbSe (0.278 eV) and CdSe (1.66 eV) and very close lattice constants (6.124 and 6.077 Å, respectively) make the ternary alloy of PbSe and CdSe ($Pb_{1-x}Cd_xSe$) unique for band-gap engineering and for applications.

We report the growth and characterization of Cd doped PbSe thin films prepared by molecular beam epitaxy (MBE) from elemental sources on monocrystalline, hybrid GaAs/ZnTe (100) substrates. From the high resolution x-ray diffraction studies it was found that the films are good crystalline quality without any phase segregation up to 12% of Cd doping. The lattice constants obtained from XRD data decreases proportionally to Cd concentration supporting the Vegard's law. From photoluminescence studies confirmed that with increase in Cd concentration the band gap of $Pb_{1-x}Cd_xSe$ thin film increases systematically. Other important parameters of the $Pb_{1-x}Cd_xSe$ films are determined from infrared (IR) reflectance spectra. The experimental spectra are compared with simulations of the Fresnel formulas for IR reflection from a multilayer structure. The transport measurements reveal the most intriguing feature of the investigated set of samples. The $Pb_{1-x}Cd_xSe$ samples are all p-type, however, the room temperature hole concentration significantly decreases with the increasing Cd concentration, x. The hole concentration decreases from a typical value of $3x10^{18}$ cm^{-3} for pure PbSe down to $3\cdot10^{16}$ cm^{-3} for the layer containing 5.2% of Cd. The significant reduction of hole concentration in $Pb_{1-x}Cd_xSe$ layers makes the material very attractive for infrared detector applications. Spectral photoresponse of a photoresistor made of $Pb_{1-x}Cd_xSe$ layer covers the range from 1500 to 3000 nm.

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