Virtual crystal approximation versus valence band anticrossing model of the band structure in the (Ga,Mn)As and (Ga,Bi)As epitaxial layers.

O. Yastrubchak[1*], J. Sadowski[2,3], J. Z. Domagala[2], Ł. Gluba[1], J. Żuk[1] and T. Wosiński[2]

[1]Institute of Physics, Maria Curie-Skłodowska University in Lublin, Pl. Marii Curie-Skłodowskiej 1,20-031 Lublin, Poland
[2]Institute of Physics, PAN, 02-668 Warsaw, Poland
[3]MAX-Lab, Lund University, 22100 Lund, Sweden
yastrub@hektor.umcs.lublin.pl

The GaAs semiconductor alloy compounds containing Bi or Mn have emerged as potential candidates for novel microelectronic and spintronic applications. The band gap of the (Ga,Bi)As epitaxial layers red shifted considerably upon the addition of only a few atomic percent of Bi and exhibits other anomalous properties, such as a reduced temperature dependence as well as giant spin-orbit splitting. To explain these unusual features of the electronic structure of the (Ga,Bi)As epitaxial layers the band anticrossing (BAC) model was developed [1]. It was suggested in [2], that in the (Ga,Mn)As the valence band anticrossing interaction is observed as well.

We have investigated (Ga,Bi)As and (Ga,Mn)As layers and, as a reference, undoped GaAs layer, grown by LT-MBE. All the epitaxial layers were grown pseudomorphically on semi-insulating (001) GaAs substrates. The alloy compositions were determined from high resolution X-ray diffractometry (XRD) measurements. The photoreflectance (PR) spectroscopy enabled the determination the of the band gap values (E_0) and spin-orbit split-off (E_{SO}) band to conduction band optical transition in (Ga,Mn)As and (Ga,Bi)As epitaxial layers. Photoreflectance studies were supported by Raman spectroscopy.

The very large valence band anticrossing interaction is observed for (Ga,Bi)As epitaxial layers with 1% of Bi content. This interaction caused the strong red shift the of the energy values of E_0 as well as E_{SO} for this film with respect to that in reference LT- GaAs epi-layer.

In (Ga,Mn)As with a low (1–2%) Mn content and hole density close to that of the metal-insulator transition, the E_0 interband transition energy was blue shifted with respect to that in reference LT-GaAs. On the other hand, a substantial red shift, of 40 meV, of the E_0 energy was revealed in (Ga,Mn)As with the highest (6%) Mn content and a hole density corresponding to metallic side of the metal-insulator transition [3]. Nevertheless for all investigated (Ga,Mn)As epitaxial layers no energy value changes at E_{SO} optical transition are observed. These results support the idea assumes mobile holes residing in the valence band of GaAs and the Fermi level position determined by the concentration of valence-band holes. The blue shift of the E_0 in the (Ga,Mn)As with a low Mn content was interpreted as a result of the Moss-Burstein shift of the absorption edge due to the Fermi level location below the top of GaAs valence band. On the other hand, a substantial red shift of the E_0 in (Ga,Mn)As with the highest (6%) Mn content was interpreted in terms of a disordered valence band, extended within the band-gap, formed in highly Mn-doped (Ga,Mn)As as a result of merging the Mn-related impurity band with the host GaAs valence band.

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