Nanocomposites and nanomaterials

Low-temperature investigation of diluted ferromagnetic semiconductor nanolayers

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Semiconductor alloy compounds of GaAs containing Bi and/or Mn have emerged as potential candidates for novel photonic and spintronic applications.

In the present paper we report on the results of extensive study of ternary and quaternary compound (Ga,Mn)As and (Ga,Mn)(Bi,As). We have investigated 20-100-nm-thick (Ga,Mn)(Bi,As), Ga(Bi,As) and (Ga,Mn)As layers, and, as a reference, undoped GaAs layer, grown by LT-MBE at a temperature of 230°C in the MBE machine attached to the angle-resolved ultraviolet photoemission spectroscopy (ARUPS) end station of the MAX-Lab synchrotron radiation facility. The ARUPS results revealed two-dimensional energy dispersion maps $E(k_x,k_y)$ for both the fundamental band-gap E_0 and spin-orbit split E_{SO} optical transitions near the Γ point of the Brillouin zone. In addition, the PR spectroscopy enabled determination of the E_0 critical point energy and electro-optic energy values and their temperature dependences. Magnetic properties and the Curie temperatures for the (Ga,Mn)As and (Ga,Mn)(Bi,As) layers were inspected using SQUID magnetometry. Micro-Raman spectroscopy was employed to estimate the free-hole concentrations in the layers and their structural properties were characterized with high-resolution X-ray diffractometry.

The presence of a small amount of Bi atoms in (Ga,Mn)(Bi,As) significantly increased the spin-orbit splitting and electro-optic energy in the layers, similarly to those in the Ga(Bi,As) ones. On the other hand, the annealing treatment of the (Ga,Mn)As and (Ga,Mn)(Bi,As) layers resulted in an increase in their Curie temperature, hole concentration, as well as the band-gap transition and electro-optic energies and a degrease in the compressive strain. Our results demonstrate that homogenous (Ga,Mn)(Bi,As) epitaxial layers can be produced using standard procedures of LT-MBE growth and post-growth annealing treatment. This material combines the properties of (Ga,Mn)As and Ga(Bi,As), and is very promising for band structure engineering for both spintronic and photonic applications.