Effect of Misfit Strain in (Ga,Mn)(Bi,As) Epitaxial Layers on their Magnetic and Magneto-Transport Properties

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Highly mismatched ternary semiconductor compound Ga(Bi,As) has recently emerged as promising material for possible applications in a new class of photonic and spintronic devices. The replacement of a small fraction of As atoms by much larger Bi atoms in GaAs, that requires highly non-equilibrium growth conditions, results in a large decrease in its band gap and a strong enhancement of the spin-orbit coupling [1]. On the other hand, (Ga,Mn)As, in which a few percent of Ga lattice atoms have been substituted by Mn impurities, has become a prototype diluted ferromagnetic semiconductor, combining semiconducting properties with magnetism. In this communication we report on an effect of misfit strain in thin epitaxial layers of (Ga,Mn)(Bi,As) quaternary compound on their magnetic and magneto-transport properties.

We have investigated (Ga,Mn)(Bi,As) thin layers of 10 to 50 nm thicknesses, with 6% Mn and up to 1% Bi contents, grown by the low-temperature MBE technique at a temperature of 230°C on either semi-insulating (001)-oriented GaAs substrate or the same substrate covered with a thick $In_{0.2}Ga_{0.8}As$ buffer layer. High-resolution X-ray diffraction characterization of the layers pointed at their high structural perfection and showed that all of them were grown pseudomorphically, on GaAs substrate – under compressive misfit strain and on the InGaAs buffer – under tensile misfit strain. An addition of a small amount of Bi to the (Ga,Mn)As layers resulted in a distinct increase in their lattice parameters. Magnetic properties of the layers were examined with the magneto-optical Kerr effect (MOKE) magnetometry. Hall-bar shaped samples, supplied with Ohmic contacts to the (Ga,Mn)(Bi,As) layers, were subjected to low-temperature magneto-transport measurements. The obtained results show the in-plane and out-of-plane easy axis of magnetization in the layers grown under compressive and tensile misfit strain, respectively. Incorporation of Bi into the (Ga,Mn)As layers results in significant decrease in their Curie temperature, T_C, and the hole concentration, which, however, can be enhanced during the low-temperature post-growth annealing performed in air at 180°C. The main effect of the annealing is outdiffusion of self-compensating Mn interstitials. The T_C enhancement caused by the annealing is accompanied with a decrease in the magnetic coercivity of the layers, which results mainly from an increase in the hole concentration in annealed layers [2]. On the other hand, the revealed larger magnitudes of magneto-transport effects for the (Ga,Mn)(Bi,As) layers, with respect to those for the (Ga,Mn)As layers, indicate for an increase in the spin-orbit interaction upon the addition of Bi into the layers, which is especially favourable for spintronic materials where spin precession can be electrically tuned via the Rashba effect.

This work was supported by the Polish National Science Centre under grant No. 2011/03/B/ST3/02457.

[1] M. Usman, C. A. Broderick, Z. Batool, K. Hild, T. J. C. Hosea, S. J. Sweeney and E. P. O'Reilly, *Phys. Rev. B* **87**, 115104 (2013).
[2] O. Yastrubchak, J. Sadowski, L. Gluba, J. Z. Domagala, M. Rawski, J. Żuk, M. Kulik, T. Andrearczyk and T. Wosinski, *Appl. Phys. Lett.* **105**, 072402 (2014).