Magnetoresistive Effects in Nanostructures Tailored from (Ga,Mn)(Bi,As) Dilute Magnetic Semiconductor

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The aim of our work is to unleash the potential of (Ga,Mn)(Bi,As) quaternary compound as a prospective dilute ferromagnetic semiconductor. Nearly two decades of intensive studies of the (Ga,Mn)As ternary compound accumulated experience and successful achievements in both theory and experiment, proving that this prototype dilute ferromagnetic semiconductor provides a basis for developing novel spintronic functionalities [1]. As verified in our recent investigations [2], incorporation of a small fraction of bismuth into (Ga,Mn)As layers results in a strong enhancement of magneto-transport effects, owing to increased spin-orbit coupling. Appropriate nano-structurization of thin (Ga,Mn)As layers results in patterning-induced strain relaxation, which introduces into narrow stripes of the material a shape-dependent magnetic anisotropy in addition to the magneto-crystalline anisotropy of the layers. This patterning-induced magnetic anisotropy offers an additional degree of freedom that can be used in device operation. Our recent studies on several types of nanostructures tailored from (Ga,Mn)As layers, pointed to their utility for spintronic applications [3].

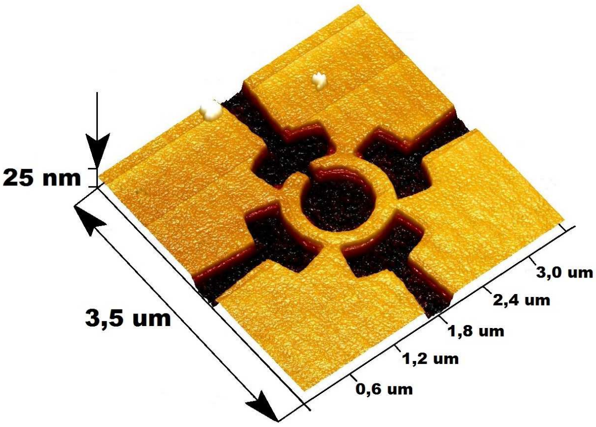

Fig. 1: Atomic force microscopy image for the ring-shaped nanostructure, consisting of a ring with a slit and four large contact areas connected to the ring periphery.

In the present study we have designed and investigated two types of nanostructures, of the cross-like and ring-shape geometries, tailored using electron-beam lithography patterning and chemical etching from 10-nm thick (Ga,Mn)(Bi,As) epitaxial layers with 6% Mn and 1% Bi contents. In the ring-shape nanostructures, shown in Fig. 1, the easy axis of magnetization is along the ring periphery. It results in two different stable magnetic states in the ring: the flux-closure "vortex" state and the "onion" state with a single domain wall (DW), located across from the slit, which contribute an extra resistance to the ring total electrical resistance, owing to spin-dependent scattering of charge carriers passing through the region of DW. For the two types of nanostructures their resistance, measured under a weak in-plane magnetic field at low temperatures, displays hysteresis-like behaviour, controlled by rearrangement of DWs in the nanostructures, which could be utilized in a new class of nonvolatile two-state memory cells.

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[3] T. Wosinski, T. Andrearczyk, T. Figielski, J. Wrobel and J. Sadowski, *Physica E* **51**, 128 (2013).