Contact geometry dependent spin-valve signal from spin injection devices with (Ga,Mn)As/GaAs spin Esaki diode contacts

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Generation of a spin accumulation in non-magnetic semiconductors by means of electrical spin injection and its subsequent electrical detection is one of the key issues in semiconductor spintronics. One of the basic experimental methods used to study spin injection is measurement of the non-local spin valve (NLSV) effect. In such measurement one monitors non-local voltage at the detector contact, resulting from spin injection at the nearby injector, while sweeping magnetic field along the magnetic easy axis of the both contacts. As a result of switching between parallel (P) and antiparallel (AP) alignment of magnetizations in the contacts, one observes a switching in the non-local voltage leading to a typical spin valve signal [1]. From the amplitude of the NLSV one can extract such important parameters as spin injection efficiency or spin diffusion length.

We previously reported on realization of an all-semiconductor GaAs-based scheme for a spin injection/detection with (Ga,Mn)As/GaAs spin Esaki diodes as spin injecting/detecting contacts [2]. From our experiments it became clear that a switching observed in NLSV signal was not caused by a typical mechanism described above but it originated from vanishing of a total spin signal in a certain range of magnetic field instead.

Here we present the results of systematic study of the switching behavior in NLSV signal from such devices. We investigated a dependence of the signal on the geometry of the contacts, i.e., their crystallographic direction, as well as their dimensions. For contacts oriented along [110] we typically observed the antiparallel-parallel (AP–P) switching in NLSV signal, even for the same width of injector and detector contacts [3]. Situation was different however for contacts along [010] direction, geometry used also in experiments described in [2]. Typical results for this geometry are shown in Fig.1. As one can see there exists always a range of magnetic field where spin signal is equal zero. For the case of injector and detector contacts of equal widths (the top panel in Fig.1.) the existence of this "zero spin signal" is a sole origin of the SV-like feature observed in measurements. AP–P switching is observed additionally when one of the contacts is very narrow (bottom panel of Fig.1.) We discuss the observed behavior of the NLSV signal in terms of magnetic anisotropy of narrow (Ga,Mn)As stripes and resulting variation of the angle between direction of injected spins, detector's magnetization and the external magnetic field.

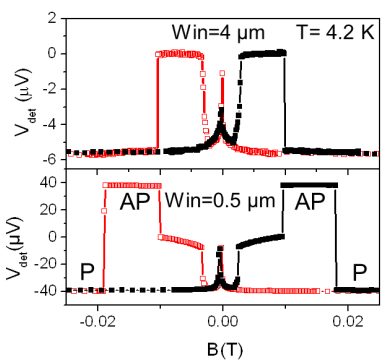

Figure 1 Non-local voltage (with background removed) measured at 4 μm wide detector for different injector widths. All contacts were 50 μm long, oriented along [010] direction.

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[1] F. J. Jedema et al., Nature **410**, 345, (2001)
[2] M. Ciorga et al., Phys. Rev. B **79**, 5321(2009)
[3] M. Ciorga et al., AIP Adv. **1**, 022113 (2011)