Spin-filter Tunneling Magnetoresistance in Bicrystal $Zn_{1-x}Mn_xTe$

Le Van Khoi, R.R. Gałązka and W. Zawadzki
Institute of Physics, PAS, al. Lotników 32/46, 02-668 Warsaw, Poland
*E-mail: lkhoi@ifpan.edu.pl

Wide bandgap Mn-based II-VI diluted magnetic semiconductors (DMS) are attractive materials for fabrication of spin filters due to the large Zeeman splitting of the conduction and valence bands. Recently, we have reported that, below 77 K, the application of a bias voltage 4V to a $Zn_{1-x}Mn_xTe$ bicrystal causes the Zener or avalanche breakdowns in the grain boundary junction (GBJ) [1]. In post-breakdown regime the bicrystal becomes highly conductive and emits intense circularly-polarized green light [2]. Here we report results of the inter-band tunneling magneto-resistance (TMR) measurements for the GBJ and crystal grains (CGs) which compose the bicrystals. We show that when the magnetic field-induced Zeeman splitting of the conduction and valence bands in $Zn_{1-x}Mn_xTe$ reaches saturation value, the resistance of the GBJ exhibits two-step switching (Fig. 1(a)), while the resistance of the soft CG shows one-step switching (Fig. 1(b)). The resistance ratio, TMR = $(R_{high} - R_{low})/R_{low}$, of GBJ is 9.2 %, while it reaches 96 % for the soft CG. It shows a strong suppression of the conductivity of one of the spin-tunnel channels.

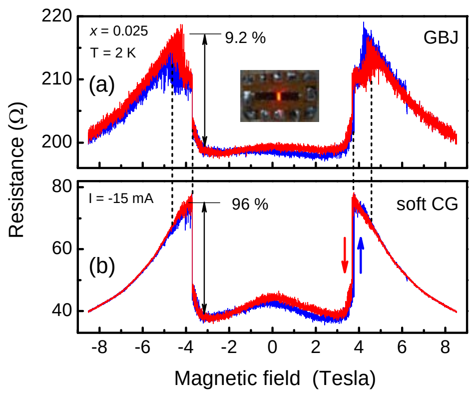

Figure 1

In our experiments, the $Zn_{0.97}Mn_{0.03}Te$ bicrystal was p-type, doped with phosphorus to a level of 8×10^{18} cm^{-3}. The *I-V* and *C-V* measurements have revealed a symmetrical electric barrier with a height of 0.50±0.05 eV and a width of 150 Å at the GBJ, within the ZnMnTe bicrystal. Figure 1(a) presents the magneto-resistance (MR) of the $Zn_{0.97}Mn_{0.03}Te$ GBJ under a current bias of -15 mA. Electrons flow from the soft grain to the hard one. The CG with low (high) B_{sw} are called soft grain and hard grain, respectively. B_{sw} is the field at which the MR jumps. It is seen that the MR curve exhibits a two-step switching at magnetic fields B_{sw} = ±3.72 T and ±4.58 T. Also, the amplitude of the first switching is larger than that of the second switching by a factor of 2.4. The total TMR of the GBJ is 9.2 %. These features show that: (i) for current bias of -15 mA there is no inter-grain exchange coupling, (ii) the CGs have different switching fields for complete reorientation of Mn spins. Figure 1(b) shows MR of the soft CG which exhibits an one-step switching. The curve shows negative MR in the field range -3.72 T ≤ B ≤ +3.72 T caused by the suppression of the magnetic fluctuation potential. This feature implies that both the electrons with spin-down and spin-up contribute to the electrical conduction of the bicrystal. Above 3.72 T the Mn spins completely align to the field direction due to the exchange interaction. As a consequence, the -3/2 and -1/2 valence states in the soft CG can tunnel to the conduction +1/2 and -1/2 states in the hard CG, whereas valence states +3/2 and +1/2 have no corresponding states in the hard CG. This leads to filtering of the spin-up valence electrons and the TMR of the soft CG increases reaching 96 %. After the switching the negative MR occurs again. The comparison of the values of TMR for GBJ and the soft grain shows that the spin polarized tunneling electrons are strongly scattered by the structural defect in the GBJ giving rise to its spin depolarization. In summary, we have measured the transverse magnetoresistance of the $Zn_{1-x}Mn_xTe$ bicrystal acting as a spin filter.

[1] Le Van Khoi and R.R. Gałązka, Appl. Phys. Lett. **98**, 112103 (2011).
[2] Le Van Khoi, et al., J. Appl. Phys. **106**, 036102 (2009).