Technical Digest of

Frontiers in Electronic Materials

A collection of extended abstracts of the Nature Conference

Frontiers in Electronic Materials, June 17th to 20th 2012, Aachen, Germany
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ISBN 978-3-527-41191-7
(2012, Wiley-VCH, Weinheim)
ELECTRICAL SPIN INJECTION AND SPIN TRANSPORT IN ZINC OXIDE

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The wide bandgap semiconductor ZnO is interesting for semiconductor spintronics because of its small spin-orbit coupling implying a large spin coherence length. This is a prerequisite for the successful creation, transport, and detection of spin-polarized currents over hundreds of nanometers in typical spintronic devices. In this context, the spin dephasing time of mobile charge carriers - and the associated length scale for coherent spin transport - are fundamental parameters. While other semiconductors like GaAs and related III-V compounds have been studied extensively, only very few reports on the spin coherence in ZnO exist. Using time-resolved optical techniques, electron spin coherence at 30 K was observed in epitaxial ZnO thin films with a spin dephasing time of 20 ns [1]. Reports on electrical spin injection are rare [2,3] and focus on technical aspects like the improvement of GMR read heads rather than the fundamental spin-dependent properties of ZnO.

We investigate the injection, transport, and detection of spin-polarized charge carriers in ZnO utilizing all-electrical, vertical spin valve devices with ferromagnetic electrodes. Using pulsed laser deposition and electron-beam evaporation, we fabricated epitaxial multilayers of TiN/Co/ZnO/Ni/Au on (0001)-oriented Al₂O₃ substrates with different thicknesses of the ZnO spacer layer ranging from 5 nm to 100 nm. The multilayers were patterned into vertical mesa structures with junction areas between 100 µm² and 400 µm². Magnetotransport (MR) measurements with the magnetic field and the current applied in and perpendicular to the plane, respectively, show a clear spin valve behavior (Fig. 1). The

![Figure 1: Magnetic moment m (circles, left axis) and magnetoresistance MR (squares, right axis) of a Ni/ZnO/Co spin valve device at 2 K as a function of the magnetic field H applied in-plane. Closed symbols represent data taken with increasing field, open symbols with decreasing field. The m(H) and MR(H) hystereses nicely correspond to each other with regard to their coercive fields (vertical grey lines), evidencing a spin valve behavior of the MR.](image-url)
switching fields correspond to the coercive fields of the ferromagnetic layers as determined by SQUID magnetometry (Fig. 1). For a ZnO thickness of 20 nm, the magnetoresistance (MR) increases from 0.8% at 200 K to 8.5% at 2 K (Fig. 1). We systematically analyze the maximum MR values as a function of the ZnO thickness in the framework of a two spin channel model with a spin-dependent interface resistance [4,5]. From our fits, we obtain spin diffusion lengths for ZnO of 12.3 nm (2 K), 9.2 nm (10 K) and 8.3 nm (200 K). This corresponds to a spin dephasing time of 110 ns at 2 K which exceeds previously published data determined from optical experiments. Here, we electrically create and detect a spin-polarized ensemble of electrons and demonstrate the transport of the spin information across several nanometers in ZnO.

This work was supported by the Deutsche Forschungsgemeinschaft via SPP 1285 (project no. GR 1132/14).