Field sensing via Spin Hall Magnetoresistance

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We analyse the performance of a Wheatstone bridge type magnetic field sensor based on spin-Hall magnetoresistance (SMR) by modelling the sensitivity, taking into account different magnetoresistance contributions. We aim to propose an optimal design considering different materials combinations and geometries for a low-power device.

Keywords: spintronic sensors, spin Hall effect, spin orbit torque, FeCoB

1. Introduction

Next generation spintronic sensors aim to exploit the Spin Orbit Torque (SOT), which allows for a manipulation of magnetization by relatively low electrical currents. In particular, the use of SOT simplifies the magnetic structures and helps to avoid bias magnetic fields. Spintronic sensors, such as tunnel magnetoresistance (TMR) sensors, are attractive for their higher sensitivity and miniaturization potential. Current problems of field immunity and offset compensation might be tackled by novel SOT structures.

An alternative to sensing by TMR was recently proposed in the form of a Wheatstone bridge Spin Hall Magnetoresistance (SMR) sensor with a detectivity of $1\mathrm{nT/Hz}^{1/2}$ and working temperatures of up to 150°C [2]. Its simpler device structure, consisting basically of two thin film layers, and the improved signal-to-noise ratio - one of the major issues still to be solved for TMR sensors - compensate for the lower sensitivity.

2. Results and discussion

In order to optimize such a sensor it is of utmost importance to consider the various magnetoresistance contributions, such as anisotropic (AMR) and spin Hall magnetoresistance (SMR). In this paper we study Hall bar and Wheatstone bridge structures of Pt/FeCoB, Ta/FeCoB and W/FeCoB bilayers with in-plane anisotropy by performing spin Hall magnetoresistance (SMR) measurements. The bilayers with various heavy metal (HM) thicknesses (wedge d_{HM}=5-10nm), and a ferromagnetic (FM) layer ($Fe_{60}Co_{20}B_{20}$) thickness of 2nm were prepared at Singulus Technologies AG and patterned at AGH.

We develop a model of a SMR sensor considering the current density distribution in the multilayer system based on a Fuchs-Sondheimer approach [3], the different magnetoresistance (MR) contributions are taken into account by a thermodynamical approach [5]. The hysteretic dependence of the resistance signal on the magnetisation is considered through a Stoner-Wohlfarth model for structures at different angles with respect to the applied magnetic field. The output voltage is given by eq.1, where I is the applied current, α is the angle between current and magnetization, $R_{HM/FM}$ are the resistances of the two layers and $\Delta R_{AMR/SMR}$ are the magnetoresistive contributions.

$$V_{out} = \frac{I}{2} A \, cos2\alpha$$

$$A = \frac{R_{HM}^2 \Delta R_{AMR} - R_{FM}^2 \Delta R_{SMR}}{(R_{HM}+R_{FM})^2}$$

Fig. shows the output voltage of the sensor structure for two different configurations.

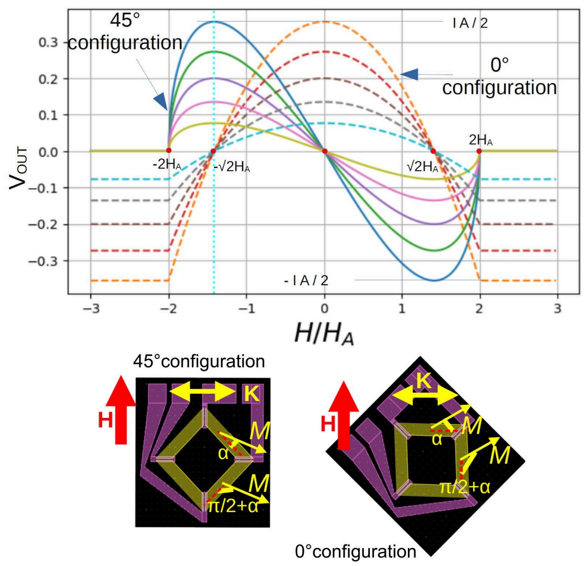

Figure 1: Top: modelled output voltage of the two Wheatstone bridge configurations as a function of applied field. H_A is the anisotropy field. Bottom: 45° configuration: Wheatstone bridge branches at 45° to the applied field H; 0° configuration (right): Wheatstone bridge branches parallel or perpendicular to the applied field H.

The results are compared with SMR measurements and indications for optimizing the sensor performance also in terms of power consumption are given.

References

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