

08-06 Study of spin transfer torque in serially-connected-pillars by means of ferromagnetic resonance

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It is well known that a spin polarized current in a ferromagnet exerts a torque on the magnetic moments by spin-momentum transfer [1, 2]. This current can be used to switch the magnetization of one ferromagnetic layer in a ferromagnetic metal/nonmagnetic metal/ferromagnetic metal spin valve device [3]. We use ferromagnetic resonance (FMR) to detect the effect of spin transfer torque on the magnetization of the ferromagnetic layer. A current flowing perpendicular through a pillar structure (Fig. 1 left) is spin polarized by one ferromagnetic layer – in this case the hard-magnetic Co layer – and exerts a torque on the magnetization of the soft-magnetic Py layer. The sign of the torque depends on the angle between the magnetization and the polarization direction of the current given by the direction of magnetization of the polarizer and is zero if both magnetizations are orientated parallel or antiparallel.

The pillars are prepared and electrically contacted by high-resolution electron beam lithography (HR-EBL) and electron beam evaporation in a multi-step process. The FMR measurements are carried out on a pillar array, in which all pillars are connected in series, so that we are able to increase the current density to a value that is sufficient to observe the effect of the spin transfer torque. The temperature rise due to the high current density is avoided by a cooling set-up. Calculations of the distribution of magnetic moments by object oriented micro magnetic framework (OOMMF)[4] for our square-shaped structures show that they exhibit mono-domain behaviour at the resonance field.

In the FMR measurements, the magnetization precesses around the effective magnetic field. Due to different magnetizations of Co and Py (permalloy), the resonance field of the metals is also different which gives the possibility to investigate the precession of magnetization of Py individually. The spin-polarized current which passes the pillar structure and hits the Py layer causes an increase or decrease of the magnetic damping in Py depending on the current direction. By analysing the FMR line-width, which corresponds to the damping in the ferromagnetic system, the additional damping due to the

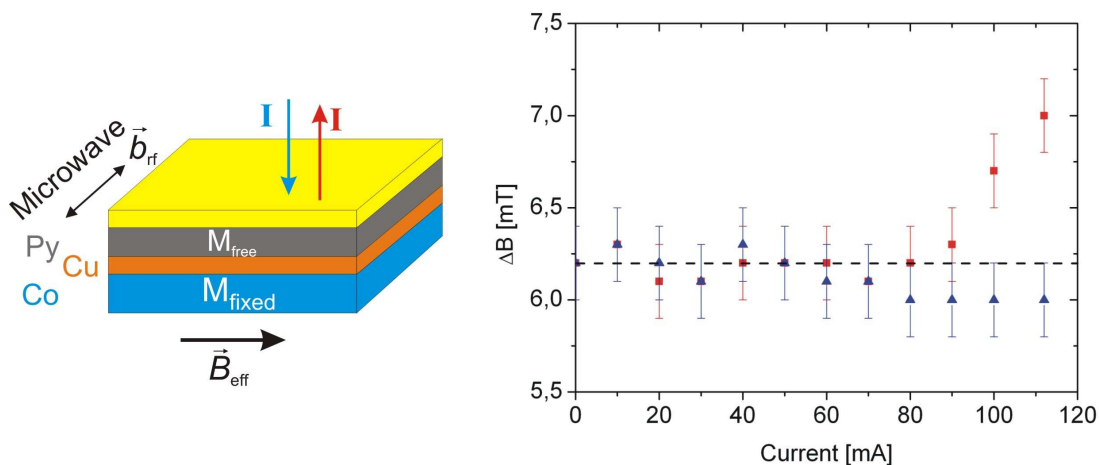


Fig. 1: One measurement geometry for the investigation of the spin transfer torque (left). The external magnetic field lies in the film plane. The FMR line-width, which corresponds to the damping in the magnetic film, increases for one current direction (the electrons flow from Co into Py) and decreases for the opposite current direction (right).

spin-transfer torque effect can be separated from the intrinsic damping if the line-width is measured as a function of current. If the external magnetic field is applied in-plane, the angle between polarization direction and the magnetization of the Py-layer is given by the angle between the magnetization of Co and the angle of the precession cone from the Py-magnetization. This angle is very small and a high current density is necessary to observe an effect. If the magnetic field is applied perpendicular to the film-plane the magnetization of the Co layer lies almost in the film-plane because its high sharp anisotropy, however the magnetization of Py points out-of-plane. In this case, the angle between the two magnetizations increases, and even for small currents, a change in the FMR line-width due to spin transfer torque can be observed.

Figure 1 shows the line-width as a function of injected current for the Py-signal. The external field lies in the film-plane. A current of 100 mA corresponds to a current density of $4 \times 10^5 \text{ Acm}^{-2}$. Above a threshold current of 80 mA, an increase in the line-width for one current-direction can be seen, which means that in this case, the damping is enhanced. In the other current-direction only a small decrease of the damping can be observed.

Additionally, the influence of the Oersted-field is estimated. We find that the Oersted-field leads to a broadening of the FMR line-width. However, this broadening is independent of the current direction. Thus, by an analysis of the line-width for both current directions, the increase in the line-width due to the Oersted-field can be separated. This work is supported by the Deutsche Forschungsgemeinschaft within SFB 491.

References

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