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Spin Torque Oscillator using a Perpendicular Polarizer and a Planar free Layer

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Spin electronics materials have recently been considered for radio frequency applications by exploiting the concept of transfer of angular momentum between a spin polarized electrical current and the magnetization of a nanostructure. This angular momentum transfer is equivalent to a (spin) torque exerted on the local magnetization and which counteracts the damping torque. As a result it is possible to stabilise steady state oscillations of the magnetisation on trajectories that arein many situations close to constant energy trajectories defined onlyby the system energy. For an in-plane magnetised thin film with uniaxial anisotropy, two types of constant energy trajectories exist which are commonly called in-plane (IP) precession, where the magnetisation oscillates around the in-plane easy axis, and out of plane (OP) precession where the magnetisation oscillates around the out of plane energy maximum.

From an applications point of view it will be of interest to excite OP precessions with a small out of plane magnetization component at the threshold current and in zero field. Such OP precessions will lead to a larger output signal than IP precessions that are usually excited in 'planar' spin valve structures that use an in-plane magnetised polarizer and free layer. In contrast to this, we will present herea spin torque oscillator that combines an out of plane magnetised polarizer with an in-plane magnetized free layer [1]. Using static and dynamic transport measurements, we will show that OP precessions are induced at the threshold current for moderate current densities of 9×10^6 A/cm². These OP precessions manifest themselves as discrete steps in the resistance-field transfer curves whose field range increases as a function of current. The experimental current-field state diagram as well as the frequency vs. current and applied bias field is well explained by macrospin and micromagnetic simulations.

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Magnetic Field Dependence of Current-induced Magnetization Reversal with Perpendicularly Magnetized FePt Layers

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Recently, current-induced magnetization reversal in a perpendicularly magnetized nanodevice is one of the topical issues on spin-transfer phenomena because of its high thermal stability of magnetization, negative shape anisotropy, and specific magnetic field dependence of current-induced magnetization reversal. [1-3] Although we previously reported current-induced magnetization reversal in perpendicularly magnetized $L1_0$-FePt layers, large external magnetic field was required to observe the current-induced magnetization reversal because of the high magnetic anisotropy ($K_u = 5 \times 107$ erg/cm³). [2] In this study, we prepared current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) pillars with changing the growth temperature for FePt layers to control the magnitude of K_u, and investigated the magnetic field dependence of current-induced magnetization reversal using current pulse measurement.

The stacking structure of Fe (1) / Au (100) / $L1_0$-FePt (20) / Fe (1) / Au (5) / L10-FePt (4) / Au (25) / Pt (100) (in nanometers) was deposited on a MgO (001) single crystal substrate using ultrahigh vacuum sputtering system. The bottom 20 nm-thick $L1_0$-FePt layer was deposited at 300°C, and subsequently annealed at 500°C for 15 minutes, which is a spin-polarizer for current-induced magnetization reversal. On the other hand, the top 4 nm-thick $L1_0$-FePt layer was deposited at 300°C and annealed at various temperatures (T_{ann}). CPP-GMR pillars with the area of 0.1×0.2 μm² were fabricated through the use of electron beam lithography and Ar ion etching.

The magnetization curves for 4 nm-thick FePt layers annealed at T_{ann} indicate that $T_{ann} \geq 400$°C is required to obtain high remanent magnetization in the perpendicular direction to the film plane. For the CPP-GMR pillar with the 4 nm-thick FePt layer annealed at $T_{ann} = 450$°C, clear current-induced magnetization reversal is observed in a wide range of external magnetic field. The current densities for the magnetization reversal from the antiparallel alignment to the parallel one ($J_c^{AP\text{-}P}$) in a low magnetic field region are consistent with the results of theoretical calculation, which assumes the coherent magnetization rotation. [4] These results imply that the value of K_u is related with $J_c^{AP\text{-}P}$ in a low magnetic field region. However, the experimental values of $J_c^{AP\text{-}P}$ deviate from the theoretical calculation with increasing the external magnetic field, which is not interpreted by the conventional theory. Furthermore, $J_c^{AP\text{-}P}$ in a high magnetic field region seems to be determined by H_c rather than K_u. The magnetic field and angular dependences of $J_c^{AP\text{-}P}$ suggest that magnetization reversal mainly occurs through the incoherent rotation mode at a high magnetic field. For the current densities from parallel to antiparallel ($J_c^{P\text{-}AP}$), on the other hand, the experimental results show quite smaller values than the theoretical calculation, which is attributable to the thermal effect induced by current because of the required large current densities for the transition from parallel to antiparallel.

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