AA01

Low Temperature Heat Assisted Magnetization Reversal and Its Application to MRAM

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Conventional magnetoresistive random access memory (MRAM) and spin torque transfer (STT) MRAM designs require sufficient current magnitude either to generated magnetic field or spin torque to be able to reverse storage layer magnetization of a memory element. In this memory element design, heat is used to induce an antiferromagnetic to ferromagnetic phase transition in the interlayer of a sandwiched trilayer storage layer structure for memory state switching. This novel memory element, referred to as the binary anisotropy structure, consists of a magnetic storage layer with relatively high perpendicular anisotropy, an interlayer that changes from antiferromagnetic to ferromagnetic a temperature slightly higher than ambient, e.g. FeRh[1], and a thin magnetic layer with strong uniaxial anisotropy in the film plane. When heated over the transition temperature, the interlayer becomes ferromagnetic, providing ferromagnetic exchange coupling between the two magnetic layers with orthogonal easy axes and yielding significant reduction of the switching field for the storage layer. Systematic theoretical analysis of the switching field reduction and area storage density capability will be presented.

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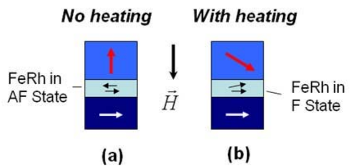

Fig. 1 Illustration of recording mechanism for the binary anisotropy media (BAM).

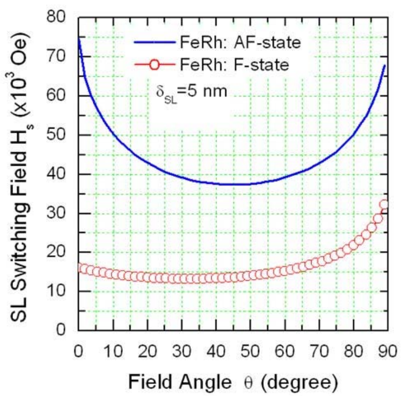

Fig. 2 Calculated switching field threshold for BAM with FeRh interlayer in the AF (solid line) and F (circles) states.

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AA02

Nonlocal Self-Spin-Transfer Torque Induced by Lateral Spin Diffusion in Magnetic Layers with Inhomogeneous Magnetization

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Initial spin torque theories derived the spin torque term within the macrospin assumption [1]. However, micromagnetic studies [2] and recent time-resolved imaging experiment [3], have revealed that the spin torque generates incoherent spin-waves and thus non-uniformities in the magnetization. Therefore it is essential to consider a possible feedback mechanism between the inhomogeneous magnetization and the spin-transfer torque. Several authors proposed that the lateral diffusion of spin-dependent reflected electrons at a NM/FM interface can induce a stabilizing or destabilizing effect on the local magnetization of the FM layer depending on the direction of the current due to local spin-transfer effects [4]. This effect can be named *self-torque* since it allows a single FM layer with inhomogeneous magnetization to exert spin transfer effects on itself. To quantitatively study this phenomenon, we developed a 3-dimensional numerical model to *self-consistently* solve both Landau-Lifshitz-Gilbert and time-dependent spin diffusion equations. The study was carried out on 3-dimensional structure of Cu(10 nm)/Co(t nm)/Cu(52-t nm) patterned to nanopillar of 60 x 30 nm^2 where t varies from 2 to 8 nm. As in the experiment [5], magnetic excitations were observed only at negative currents (electrons from thick to thin Cu). The critical current for the excitation linearly depends on the out-of-plane field. Even when $H_z > 4\pi M_s$ we observed high frequency precession motions of magnetizations at negatively large currents instead of the out-of-plane saturation. Our result confirms the existence of *self-torque* effects and allows investigating the interplay between the lateral spin diffusion currents and the magnetic excitations in the FM. Numerical studies on spin-valve structures were also performed. The *self-torque* significantly changes the current-induced dynamic modes and more strikingly, can reduce the linewidth of microwave power spectrum. In the presentation, the current-induced magnetization dynamics affected by the *self-torque* will be presented in detail.

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