Reversal magnetization dynamics of the flip-flop transitions in CoFeB/Ta/CoFeB trilayer with perpendicular anisotropy

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This work is focused to the time-resolved measurements of magnetization reversals in artificial antiferromagnets based on two perpendicularly magnetized CoFeB layers of different width separated by Ta non-magnetic interlayer (fig.1, right insert). The following measurement sequence was used: 1) the sample was magnetized in H_S = 1 kOe magnetic field exceeding saturation field, perpendicular to the film plane (i.e. along easy magnetization axis); 2) magnetic field was switched to $H^* < H_S$ and immediately after stabilization of the H^* value, recording of the time dependence of the magnetic moment M was started. This measurement cycle was repeated for different H^* fields +600 Oe and -600 Oe. Magnetic relaxation curves are presented in the Fig.1. Four stable magnetic states F^+, AF^+, AF^- and F^- correspond to four stable mutual orientations of CoFeB magnetization in trilayer structure. Flip transitions F^+ to AF^+ and AF^- to F^- are reversible and give no magnetic after-effect (fig.1). AF^+ to AF^- flip-flop transition (simultaneous remagnetization of thin and thick CoFeB layers) is irreversible. Threshold magnetic field initiates gradual leaving of magnetization from AF^+ state until it reaches AF^- state. The straightening of the ($\ln(\Delta M)$; t) curves (fig.1, left insert) reveals exponential dependence $\Delta M(t) \sim \exp(-\Gamma t)$. Accordingly with [1], exponential relaxation of the magnetic moment is typical of the crossing of a potential barrier by an assembly of quasi-identical and independent objects. The field dependences of the relaxation frequencies Γ (fig.2) were described in terms of the model proposed in [2]:

$$T\ln(\Gamma_0/\Gamma) = \Delta E_0 \cdot (1 - H^*/H_P)^{\alpha} \quad (1),$$

Γ_0 is frequency factor, $\Delta E_0 \cdot (1 - H^*/H_P)^{\alpha}$ is activation energy of domain wall pinning, ΔE_0 is height of potential barrier in the absence of magnetic field, H_P is threshold magnetic field of pinning, $\alpha = 3/2$ is constant. We have considered typical values $\Gamma_0 = 10^6$ Hz and $\alpha = 3/2$ mentioned in the literature [1,2]. Pinning field H_P was determined from approximation of field dependence $T\ln(1/\Gamma)$ by formula (1) for each temperature separately. The temperature dependence of the pinning field is shown in the fig. 2, left insert. The height of potential barrier ΔE_0 = 0.72 eV was temperature independent.

In contrast with previous works [2], pinning field was temperature dependent in our experiments. For that reason, field dependence of the $T\ln(\Gamma_0 / \Gamma)$ value was plotted versus H^*/H_P to normalize magnetic field at different temperatures. Straightening of the $T\ln(\Gamma_0/\Gamma)$ *vs* H^*/H_P dependence (Fig.2, right insert) confirms correctness of chosen approach. Thus, exponential dynamics of the flip-flop transition corresponding to single barrier depinning of the domain walls was revealed. The temperature dependence of critical field of domain wall pinning as well as height of the potential barrier were determined.

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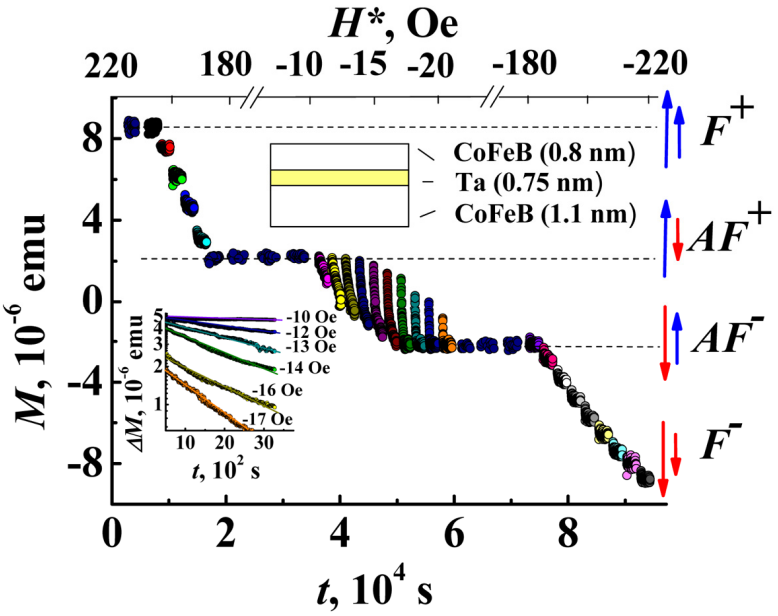

Fig. 1. Time dependences of the magnetic moment M of the sample recorded at T = 300 K in reversal magnetic fields H* lying in the range from -210 Oe till +210 Oe. Blue and red arrows on the right panel indicate directions of magnetizations of the ferromagnetic layers in different magnetic states. Left insert: time dependences $\Delta M(t)$ in semi logarithmic coordinates. Right insert: scheme of CoFeB/Ta/CoFeB trilayer structure.

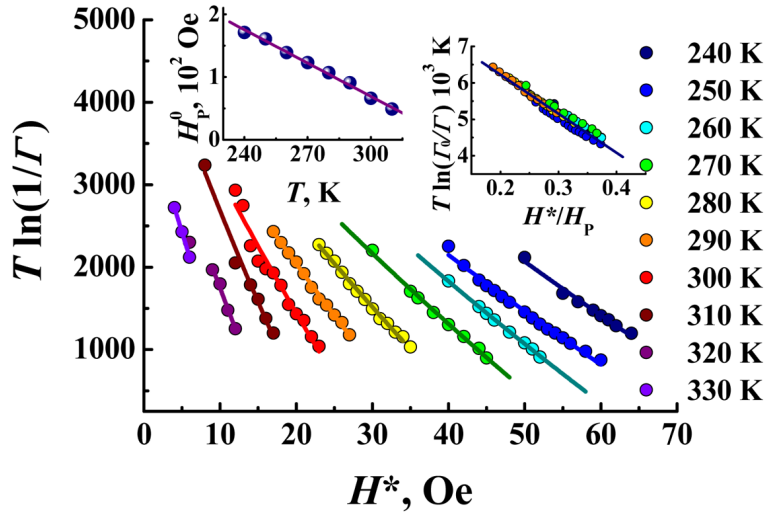

Fig. 2. Field dependences of the magnetic relaxation time constants $1/\Gamma$ at different temperatures in the range 240 -350 K. Approximations by formula discussed in the text are shown by solid lines. Left insert: temperature dependence of H^0_P critical pinning field. Solid line is linear approximation. Right insert: dependences of the magnetic relaxation time constants unified into a single curve in normalized coordinates ($\ln(\Gamma_0/\Gamma)$; H/H_P) at different temperatures below T = 290 K.

References

[1] D. B. Gopman, D. Bedau, S. Mangin at al. Journ. Appl. Phys. **115**, 113910 (2014).

[2] S. Mangin, A. Sulpice, G. Marchal et al. Phys. Rev. B, **60**, 1204 (1999).