Noise characteristics of tunnel magnetoresistance sensors under AC modulation field

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Suppression of 1/*f* noise is the central issue for achieving tunnel magnetoresistance (TMR) sensors with ultrafine magnetic field resolutions. Recently, a new AC modulation method by external magnetic field to suppress the 1/*f* noise in TMR and giant magnetoresistance sensors was proposed.[1, 2] This method requires an even-function type resistance-magnetic field (*R*-*H*) response curve symmetric with respect to the sign of *H*, which was not established for TMR sensors. In this work, we developed TMR sensors exhibiting even-function *R*-*H* curves and characterized their noise properties under AC modulation magnetic field.

Figure 1(a) shows the schematic layer structure of the TMR sensor.[3] The CoFeB-based magnetic free layer (FL) is "softly" pinned unidirectionally by the IrMn antiferromagnetic layer, which is called "soft-pined FL". To control the pinning strength of the FL, we utilized the weak ferromagnetic coupling (orange-peel coupling) through a AgSn (2.6 nm) spacer layer. The layers above the MgO tunnel barrier are the standard synthetic antiferromagnetic pinned layer structure. As shown in Fig. 1(b), the *R*-*H* curve along the easy axis (EA) showed a shift by 2.15 mT, corresponding to the soft-pinning strength of the FL. When *H* was applied along the hard axis (HA), the *R*-*H* curve showed an even-function shape with a negligible magnetic hysteresis.

Figure 1(c) shows the noise spectra under AC modulation field (f_{ac} = 10 kHz, $\mu_0 H_{ac}$ up to 0.68 mT_{rms}) applied in the HA from a 6-turn coil fabricated on a printed circuit board (inset). As the amplitude of H_{ac} increased, noise with a flat spectrum ("flat noise") increased, which is considered to be due to random telegraphy noise. In addition, "noise skirt" appeared around the peak at f_{ac}. A detailed analysis revealed that the noise skirt was due to the transfer of the 1/*f* noise originated form a thermal magnetization fluctuation, indicating that magnetic 1/*f* noise cannot be suppressed by this AC modulation method.

Ref. [1]Bocheux *et al*. in IEEE Sensors Applications Symposium, 2016. [2]Shirotori *et al*. IEEE Trans. Magn. 57, 4000305 (2021). [3]Nakatani *et al*. Appl. Phys. Lett. 121, 192406 (2022).

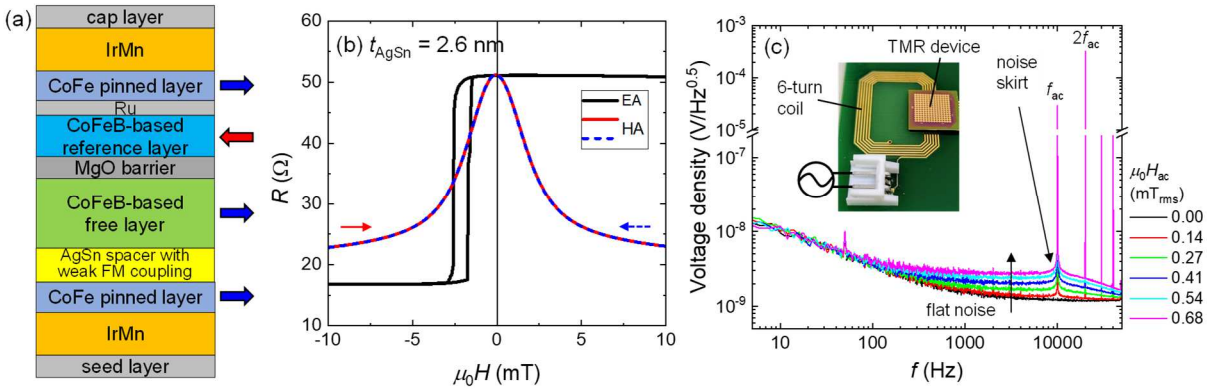

Fig. 1(a) Layer structure of the soft-pinned FL TMR device, (b) *R*-*H* curves along easy axis (EA) and hard axis (HA), (c) noise spectra of the TMR device under AC modulation magnetic field.