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# ABSTRACTS

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**DS-12. High sensitivity magnoise measurement for characterizing internal magnetic states of a small magnetic tunnel junction.**

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As various nano-scale magnetic devices emerge, it is becoming increasingly important to obtain detailed information about the internal magnetic states of small magnetic tunnel junctions (MTJ). The internal magnetic states are strongly affected by the device size and shape, thus must be measured after patterning. Magnoise is a powerful probe for this purpose [1], as it gives thermally excited ferromagnetic resonance (FMR) signals, whose frequency depends on the effective magnetic field in the layer. We have developed a highly sensitive magnoise measurement system using a bias voltage ($V_B$) chopping and synchronous data acquisition technique. As shown in Fig. 1, a MTJ device is biased by a chopped voltage source, and a spectrum analyzer (SA) acquires the noise power in synchronization with the chopped $V_B$. Then the odd and even indexed data points are separately averaged and the difference between them is numerically calculated. This is equivalent to the lock-in detection [2,3], but with less hardware components needed. Fig. 2 shows the magnoise spectra on a MTJ based spin torque oscillator (STO) having an in-plane magnetized free layer and out-of-plane magnetized reference layer under the application of $V_B$ = -100 mV as a function of out-of-plane bias field ($H_B$) using this technique. The diameter of this STO is estimated to be 21 nm from the resistance-area product and the device resistance. It clearly shows FMR signals from both the free and reference layers, which show different dependencies on $H_B$ reflecting the magnetic states of these layers. When $H_B <$ -300 mT, the free layer is fully perpendicularly saturated, thus the FMR frequency is proportional to $H_B$. When -300 < $H_B$ < 700 mT, the FMR signal from the free layer shows a convex dependence typical for in-plane magnetized layers, while the FMR signal from the reference layer shows a linear dependence as it is perpendicularly magnetized. This work is supported by the JST strategic innovation promotion program, "Development of new technologies for 3-D magnetic recording architecture."

[1] S. Tamaru et al, J. Appl. Phys. 115, 17C740 (2014). [2] J. Cho et al, Phys. Rev. B, 94, 184411 (2016). [3] S. Tamaru et al, Rev. Sci. Inst., 84, 054704 (2013).

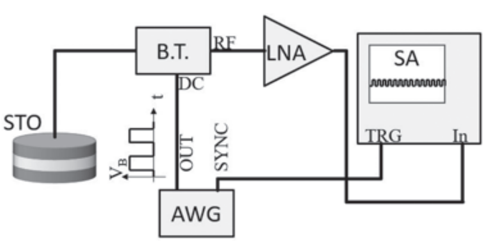


**Fig. 1, Block diagram of high sensitivity magnoise measurement setup.**

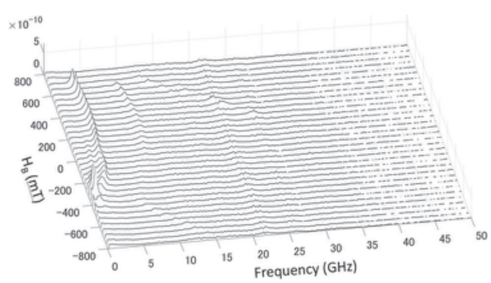


**Fig. 2, Magnoise spectrum of a MTJ based STO as a function of $H_B$.**

**DS-13. Rotating Magnetizations in Electrical Machines: Measurements and Modelling.**

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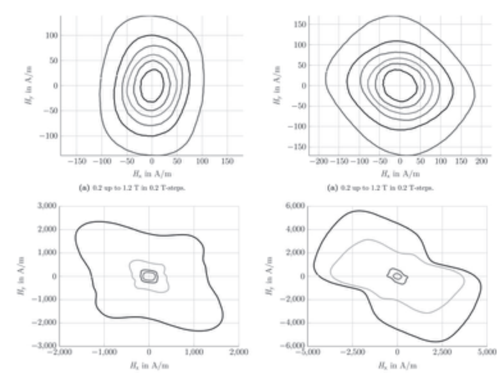
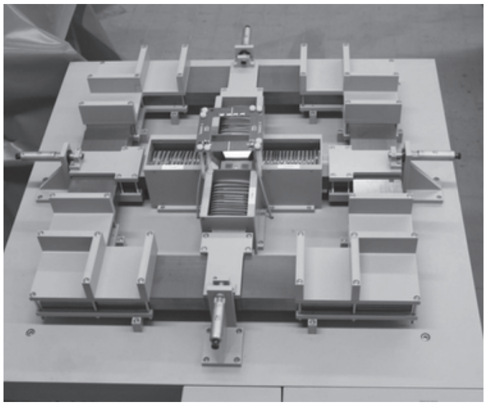
The increasing requirements for modern high performance electrical machines call for suitable loss and magnetization models for the highly utilized soft magnetic materials. Current approaches to this problem aim for a vectorial description of the magnetizing process, which is capable to accurately predict the hysteretic nature of these materials [1, 2]. Although concepts for two-dimensional measurement devices, known as rotational single sheet testers (RSST), are known [3, 4], their usage is not very common compared to unidirectional methods [5]. There are several reasons for this, e.g. that uniaxial methods are standardized, or the more complex control of rotational magnetizations. Therefore, most models are based on unidirectional measurement data and occurring rotating flux in the later application are treated e.g. by introducing correction factors. Only few efforts have been made so far to use RSST measurements, e.g. for model parametrization [6]. In this work, RSST measurements are used for a more comprehensive examination. By analyzing the effects of rotational flux on different materials, a better understanding of the material behavior can be achieved. This knowledge can then be used in the machine design process to take advantage of specific material properties. Due to the complex control of rotational fields, RSST measurement are time consuming. In order to improve the usability, a field oriented control scheme is developed. Quantities are transformed to a coordinate system aligned to the fundamental component of the rotating magnetic flux. Thus, separate controllers can be conveniently implemented for generating the fundamental component and the required harmonics for any given arbitrary rotating reference flux density inside the sample. Field strength and losses measurements are taken for circular and elliptical *B* loci with different axis orientations. The measurements cover rotating frequencies from 10 to 800 Hz and flux densities up to 1.6 T. The magnetic anisotropy is evaluated by analyzing the *B*-*H* lag angle. Fig. 1 shows as an example two measured *H*-loci sets for circular polarizations. The used RSST is shown in fig. 2.

[1] S. Steentjes, F. Henrotte, and K. Hameyer, *Journal of Magnetism and Magnetic Materials*, vol. 425, pp. 20–24, (2017). [2] E. Cardelli and A. Faba, *Physica B: Condensed Matter*, vol. 486, pp. 130–137, (2016). [3] Y. Guo, J. G. Zhu, J. Zhong, H. Lu, and J. X. Jin, *IEEE Trans. Magn.*, vol. 44, no. 2, pp. 279–291, (2008). [4] F. Fiorillo and I. D. Mayergoyz, *Characterization and Measurement of Magnetic Materials*. Burlington: Elsevier, (2004). [5] E. Cardelli, A. Faba, M. Pompei, and S. Quondam Antonio, *AIP Advances*, vol. 7, no. 5, p. 56112, (2017). [6] E. Cardelli, E. Della Torre, A. Faba, and M. Ricci, *IEEE Trans. Magn.*, vol. 46, no. 8, pp. 3465–3468, (2010).



***H* loci for M330-50A (left) and M400-50A (right).**



**The used four-pole RSST.**