MAGNETORESISTIVE DETECTION OF PERPENDICULARLY MAGNETIZED DOMAINS

U. Lieneweg, K. R. Heim, and R. R. Katti
Center for Space Microelectronics Technology, Jet Propulsion Laboratory,
California Institute of Technology, Pasadena, California 91109, USA

Magnetoresistive (MR) thin-film permalloy strips are used to detect magnetic domains in data storage and memory devices [1]. Domains in epitaxial garnet films with perpendicular magnetization, which are propagated with a current-access line, provide a non-uniform stray field. A model for the design of permeable MR detectors operating in such fields is presented and compared to experimental results.

Detector Design and Modeling

Permalloy strips (Pe) were designed to sense flux from propagated stripe domains (Gu), see Fig. 1. As the domain approaches the permalloy from a distance $X_p > 0$, the garnet domain's fringing field induces the magnetization vector M_p of the uniaxial permalloy to rotate in-plane, from being parallel to the long, easy-axis (z-direction) to being orthogonal, and hence change the magnetoresistance. A 2-urn garnet film was assumed with strong perpendicular (y-directed) uniaxial anisotropy, a magnetization of either $4\pi M_g = 350$ G (Sample S) or 470 G (Sample M), a permeability of unity, and uniformly up-or down magnetized domains. The permalloy was modeled piecewise linearly with an initial rotational permeability of $1+4\pi M_p/H_k = 4000$, $4\pi M_p = 10$ kG, $H_k = 2.5$ Oe, and a saturated permeability of unity. A two-dimensional magnetostatic simulator [2] was used to calculate B-fields in the x-y plane, assuming all z-dimensions to be infinite. The MR ratio, MRR, was computed with $(\Delta R/R)/(\Delta R/R)_{max} = \langle \sin^2 \phi \rangle$, where ϕ is the angle between M_p and the current in z-direction and where the brackets denote averaging over the permalloy's cross-section. In close approximation is $\sin\phi = B/4\pi M_p$, hence MRR $\propto \langle B^2 \rangle$. Since the model neglects exchange forces, it is valid only in regions where M_p does not change abruptly, as in thin-film permalloy.

Results and Conclusions

Field values $B_{rms} = \langle B^2 \rangle^{0.5}$ in the permalloy and the horizontal force F_{xgu} exerted on a 2-μm wide garnet "up"-domain by the permalloy were calculated as a function of domain position, see Fig. 2. Equilibrium positions, at $F_{xgu} = 0$, and maxima of MR response are found near the permalloy strip edges. Shown in Fig. 3 is the maximum B_{rms} as a function of permalloy width w for different permalloy thicknesses d and vertical permalloy-garnet spacings Y_p. For a design of d = 25 nm and w = 3 μm, Sample M reaches a response close to the maximum of 9 kG with a maximum separation of $Y_p = 1$ μm and sample S with one of $Y_p = 0.5$ μm. (The separation should

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D Dr. Udo Lieneweg
JPL 300-329
Pasadena, CA 91109
(818) 354-3444, Fax: 3934820, Email: udo.lieneweg@jpl.nasa.gov
Subject *Category* = ?????????????, *presentation* preference = ????????????

be maximized to minimize the **restoring force** $|F_{xgu}|_{max}$.) **For the two optimum cases** **we** calculated MRR = 0.49 for Sample M and 0.62 for S. A simulation of the MRR in a uniform horizontal field reproduced closely our experimental data obtained on a detector on a nonmagnetic test substrate as well as curves published by Pant [3], see Fig. 4.

References and Acknowledgments

[1] A. Eschenfelder. "Magnetic Bubble Technology," 2nd cd., Springer-Verlag, 1981.

[2] QuickField, **Finite Element Analysis System, Tera Analysis, Granada Hills, CA.**

[3] B. B. Pant, "Scaling in thin magnetoresistive films", J. Appl. Phys. 67,414 (1990).

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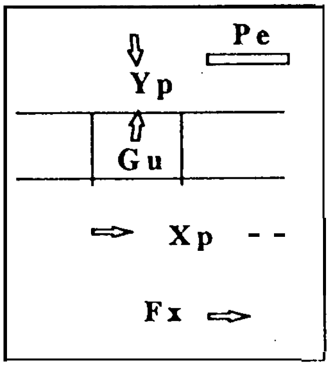

Fig. 1: Cross-sectional view

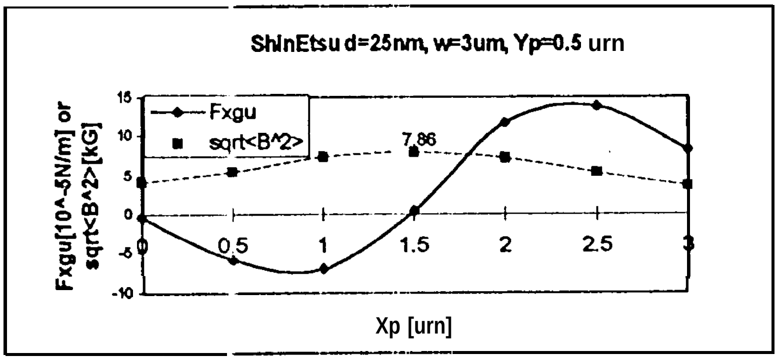

Fig. 2: Permalloy rms induction and force on domain

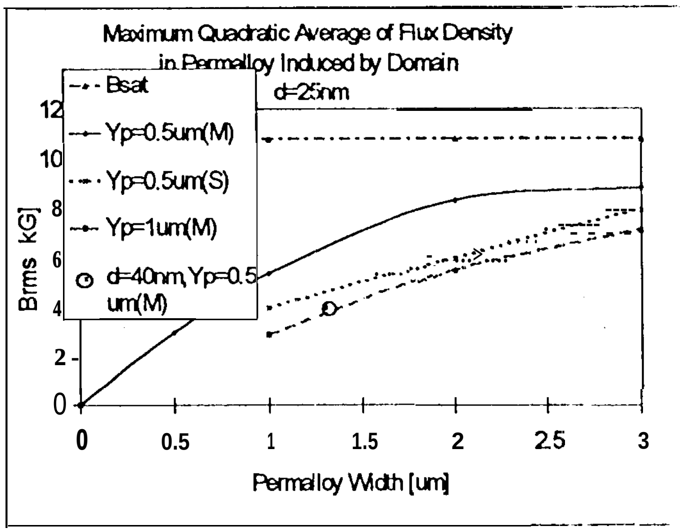

Fig.3: Maximum rms induction vs. geometry

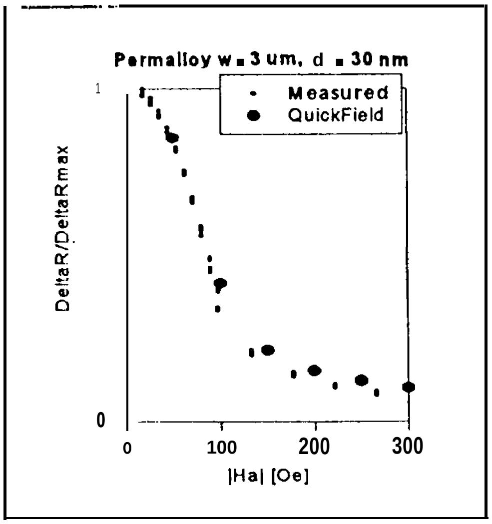

Fig. 4: (1 - MRR) in uniform field