Magnetic field response characteristics of anomalous Hall magnetic recording reader

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The recent progress in energy assisted magnetic recording technologies are pushing the areal recoding density of hard disk drives (HDDs) to beyond 2 Tbit/in^2. Consequently, the size of HDD read head sensor (reader) must shrink to obtain the required resolution. The physical size of the reader for 4 Tbit/in^2 is predicted to be 17 nm in shield gap (G) and 9 nm in reader width (W).[1] However, achieving G < 20 nm using the present tunnel magnetoresistance (TMR) based reader is a challenging task owing to its multilayered structure as shown in Fig. 1(a). We recently proposed a new reader structure using anomalous Hall effect (AHE), which consists of only one layer of AHE material as shown in Fig 1(b).[2] In this work, we present finite element simulation studies of AHE reader and compare the results with the conventional TMR reader.

Figure 1(c) shows the simulated output voltage *vs.* magnetic field curves for TMR and AHE readers. The simulations were carried out by fixing the stripe height (the reader dimension in the z-direction) and W to 9 nm, and thicknesses of TMR free layer (t_{FL}) and AHE layer (t_{AHE}) to 4 nm and 13 nm, respectively. The external bias field of H_x = 50 mT was applied in the direction of W. The voltage of AHE reader was calculated from the resistivity tensor of the AHE material, which was defined as a function of its magnetization. For TMR readers, we considered TMR ratio = 120%, RA = 0.25 Ω μm^2, and pinned layer magnetization along z-direction. The output curve of the TMR reader is asymmetric with respect to H_z = 0 due to the nonlinear angular dependence of the resistance of TMR device.[3] Figure 1(d) shows the asymmetry of the output curve defined as $A = (|V_{+Hz}-V_0|-|V_{-Hz}-V_0|) / (|V_{+Hz}-V_0|+|V_{-Hz}-V_0|)$, where V_{+Hz}, V_{-Hz}, and V_0 are the output voltages at magnetic fields $+H_z$, $-H_z$, and 0, respectively. Owing to the asymmetry of the output curve for TMR readers, the sensor utilization is limited typically to 30%. On the other hand, the output curve of the AHE reader is perfectly symmetric because the anomalous Hall voltage is proportional to the magnetization component in the z-direction. The symmetric output curve of AHE readers enables us to increase the sensor utilization, thus higher SNR can be obtained. Therefore, AHE sensor is an attractive candidate for the readers for beyond 2 Tbit/in^2.

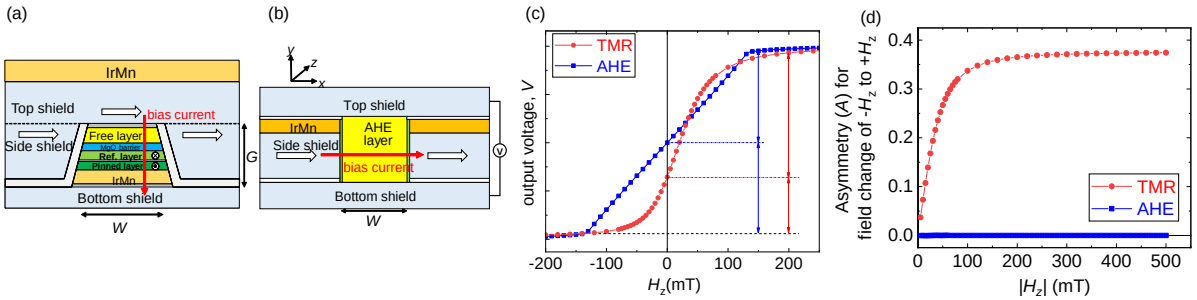

Figure 1. Schematic structures of (a) TMR reader and (b) AHE reader. (c) Reader outputs *vs* media field H_z. (d) Asymmetry in reader output for various media field range ±H_z.

Ref.: [1] Albuquerque, IEEE Trans. Magn. 58, 3100410 (2022). [2] Nakatani et al. JSAP Autumn Meeting 2022, 20p-B101-12. [3] Slonczewski, Phys. Rev. B 39, 6995 (1989).