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Direct measurement of the field from a magnetic recording head using an InAs Hall sensor on a contact write/read tester

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Abstract

At 1 Tbit/in^2 areal density magnetic recording dimensions, reliable magnetic field metrology does not exist. One technique to map the spatial profile of the magnetic field of a write head is to use a contact read/write tester. A magnetic recording head is brought into contact with a Hall sensor, and is subsequently scanned with nm resolution. For a 300 nm track width longitudinal recording head, the magnetic field of the head was mapped. Measurements include the down track field gradient and cross-track field profile and the current-field transfer curve. These results suggest this technique offers a viable write field metrology.

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Keywords: Devices; Hall effect; Information storage—magnetic recording heads; Magnetic imaging

1. Introduction

Recent large increases in magnetic data storage areal density have been achieved by spatially scaling the size of the bit cell used to store information on a magnetic disc, and consequently the physical dimensions of the magnetic recording heads. For 1 Tbit/in^2 magnetic recording, the bit cell is proposed to be 38 nm wide by 15 nm long [1]. As these dimensions push the capabilities of even the most advanced integrated circuit fabrication techniques, the recording industry does not currently possess the metrology necessary for establishing component performance at these length scales [2]. Measurement techniques such as scanning kerr-effect microscopy [3,4], and magnetic force microscopy [2] fail to provide quantitative metrology for sensor dimensions below 100 nm (100 Gbit/in^2 dimensions).

Magnetizing a recording medium at Tbit/in^2 dimensions will require a magnetic write width (MWW) of less than 40 nm and a write field of 1.36 T [1]. These key parameters are typically inferred from the process of recording data, using the industry-standard spin stand where the result is a convolution of the write head, the media and the read head. The MWW is measured by writing a single track on AC-erased media, which is subsequently read back while changing the reader offset to obtain the track profile. The field of the writer is deduced by how well it magnetizes the media, leaving field determination fully contingent on a thorough understanding of media properties. This paper describes a method to measure the MWW and the writer field independently of media and read head properties.

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2. Method

The method utilizes a contact write/read tester, or scanning magneto-resistive microscope (SMRM) [5]. This tool has found application for studying advanced magnetic media, as well as the recording process on unflyable media and sliders [6–8]. The contact write/read tester is operated by placing a recording head on a vertical lift stage (z-stage) and raising it into contact with a media disc such that the transducer, mounted on a conventional head-gimbal-assembly (HGA), is within the flying height of the disc [9]. Here, the media disc is replaced with a chip carrier for holding the Hall sensor and attaching electrical probes to detect the sensor output. The Hall chip is sufficiently large ($5\times5\,mm^2$ in this case) such that the electrical connections near the edge of the chip do not interfere with the HGA (which is less than 2 mm wide). The head is subsequently scanned using a nm-resolution piezoelectric stage with scan ranges from 10 to 100 μm. Similar sub-micron resolution measurement systems that have scanning capabilities [10] and that do not have scanning capabilities [11,12] have been previously demonstrated. Eliminating the media in the measurement process reduces the complexity of the measurement, allowing for a more direct measurement of MWW and a quantitative measurement of the magnetic field. The write head is scanned in X and Y directions over the patterned InAs 2DEG Hall sensor with the write head energized, while monitoring the Hall output as a function of scan position.

The Hall sensors were fabricated using molecular beam epitaxy on a GaAs substrate. First an AlSb buffer layer was deposited followed by an AlGaSb insulator/charge donor. On top of the AlGaSb, 150 Å InAs was deposited, where the 2DEG resides. The 2DEG was capped with an additional layer of AlGaSb and SiO_2. The total capping layer thicknesses bury the 2DEG approximately 100 nm underneath the surface adversely affecting the device/head spacing. The Hall sensors were subsequently lithographically defined to $4\times4\,\mu m^2$. Using a focused ion-beam (FIB) trimming process the sensors were further reduced in size. The smallest working Hall sensor was $1.0\times0.7\,\mu m^2$. The Hall resistivity of this sensor was 16.93 Ω/kOe, only slightly less than the 19.49 Ω/kOe for a sensor that was not "trimmed".

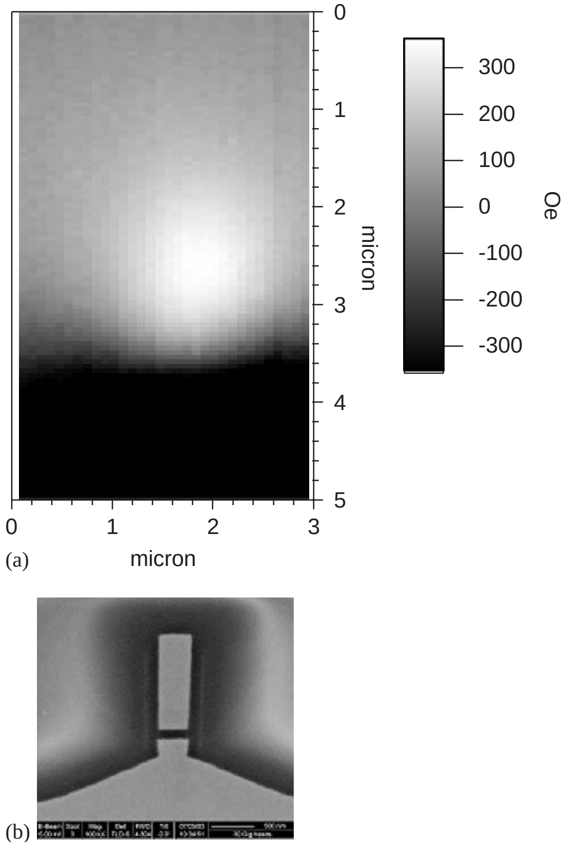

Fig. 1. (a) Magnetic field map as measured on the contact write/read tester and (b) scanning electron microscope image of a write head with a 320 nm wide pole and 130 nm long gap in the same scale.

3. Measurements

Maps of the Z-component of the magnetic field were obtained by scanning the write head over the Hall sensor. Fig. 1(a) was obtained with the sensor biased with 1 μA AC current and the write head energized with a 25 mA DC current. The Hall sensor field sensitivity was 14.65 μV/kOe. From Fig. 1(b), taken with a scanning electron microscope, the write head had a 320 nm wide top pole (P2), and a 130 nm long gap between bottom (P1) and top poles. The cross-track field profiles of P2 as a function of DC write head current are shown in Fig. 2. The average P2 magnetic FWHM is 1.5 μm. This width is a convolution of the actual P2 field distribution with the Hall sensor spatial response width, and the spacing between the two, which is >100 nm. While flying in an actual recording operation, the head is significantly closer to the media, and thus this measurement detects a broadened write field profile compared with that seen in an actual recording environment.

It is also possible to obtain a magnetic field versus current transfer curve of both write head poles. This measurement is important, as it can reveal saturation and side writing issues in write head operation. By scanning the write head over the Hall sensor on the contact tester at a range of drive currents, a series of images, each similar to Fig. 1(a) is obtained. The locations of P1 and P2 are readily identified, but to obtain the correct magnitudes of both the P1 and P2

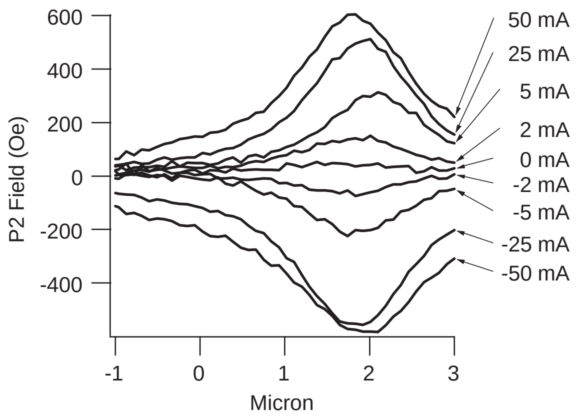

Fig. 2. Cross track profile of the vertical magnetic field of a 320 nm wide P2 as measured by an InAs Hall sensor at various coil currents.

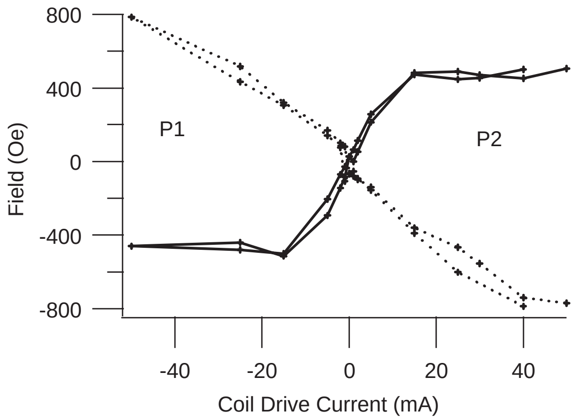

Fig. 3. Transfer curve of both P1 and P2 as measured by an InAs Hall sensor after subtracting the far-away background.

fields the background far away from either pole (8 μm away in this case) needs to be subtracted. Fig. 3 shows P2 saturating at ~15 mA, while P1 does not saturate within the limits of our current supply. Different saturation currents are expected since P2 has a very small cross sectional area compared to P1.

Using this method, it is possible to directly map the field of the writer with only the convolution of the field sensor by using the write/read contact tester. A Hall device was chosen as a field sensor because of its linear field response. However, the required barrier on top of the 2DEG sensor will need to be reduced significantly to get the write head within the recording fly height distance (6.5 nm [1]) of the sensor. Further, surface roughness of the Hall sensor is also likely to be worse than a typical media. Lastly, to obtain an accurate value for the local field, the physical size of the Hall sensor needs to be deconvolved properly from the image, requiring accurate spatial metrology.

4. Conclusion

The feasibility of using a nano-patterned field sensor to characterize the magnetic write width and the magnetic field quantitatively has been demonstrated using an InAs Hall sensor. While this technology can likely be scaled to the sub-100 nm spatial dimensions required to perform metrology on recording heads targeted at areal densities $>100\,\text{Gbit/in}^2$, preserving the integrity of the sensor while scanning in contact on the contact tester with a head-to-sensor spacing of the order of 10 nm will be a formidable challenge.

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