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Extended Abstracts of the 2012 International Conference on Solid State Devices and Materials, Kyoto, 2012, pp1019-1020

Development of magnetic field microscopy for interconnection testing inside passivation layer

Kenjiro Kimura[1], Yuki Mima[1], Noriaki Oyabu[2], Noriaki Kimura[3] and Takeshi Inao[4]

[1] Kobe Univ.
1-1 Rokkodai-cho, Nada-ku, Kobe 657-8501, Japan
Phone: +81-78-803-5702 , E-mail: kimura@gold.kobe-u.ac.jp
[2] Kyoto Univ.
Katsura, Nishikyo-ku, Kyoto, 615-8510, Japan
[3] Osaka Univ.
2-1, Yamadaoka, Suita-shi, Osaka, 565-0871, Japan
[4] Murata Manufacturing Company, Ltd.
1-chome 10-1, Higashikotari, Nagaokakyo-shi, Kyoto 617-8555, Japan

1. Introduction

Magnetic field imaging has been widely used for examining the living organisms or electric devices[1]. This is because magnetic field is suitable for visualizing internal structures inside biological materials or electric parts owing to their uniform magnetic permeability. In magnetic field imaging using a solid magnetic sensor[2, 3], placing a magnetic sensor far from magnetic sources degrades spatial resolution of the image due to field broadening. Additionally, stray magnetic fields originated from various surrounding electric parts or mechanical parts have negative effects on its spatial resolution and sensitivity. Therefore, we have developed a magnetic field microscopy with magnetic field reconstruction capable of producing a magnetic field image near above the sources with stray magnetic field effect reduced.

2. Experimental setup and results

In this study, we adopted a magnetroresistance (MR) sensor among various solid magnetic sensors because MR sensor has a promising potential about the spatial resolution because they can be miniaturized by most-advanced nanometer-scale fabrication techniques. Furthermore, tunneling magnetroresistance (TMR) sensor has extremely higher sensitivity than the other MR sensors such as anisotropic MR sensor and Giant MR sensor [4, 5].

TMR sensor is composed of a first ferromagnetic layer (free layer), a tunneling layer formed over the first ferromagnetic layer and a second ferromagnetic layer (pin layer) formed over the tunneling layer. The band structure of pin layer and free layer in their parallel magnetization is symmetrically different from the one in their anti-parallel magnetization. That induces difference of tunneling probability, and thus, TMR sensor can produce the signal corresponding to the magnetic field.

Figure 1 shows a block diagram of the magnetic field microscopy. We used a commercially available TMR sensor (STJ-220: Micro Magnetics, Inc.). The change of the resistance is detected and amplified by a preamp composed of a bridge circuit and a differential amplifier, and this signal is send to the Analog – Digital (AD) converter. TMR sensor and the preamp are mounted at the end of a long aluminum cantilever illustrated in FIG.1 to reduce the stray magnetic field from the XYZ stages. 2D scanning is conducted by X-stage and Y-stage equipped with stepping motors, and Z-stage, which is used for the adjustment of the distance between sensor and the sample surface, is mounted on the X stage. This magnetic field microscopy is controlled by the motion regulation software, which allows us to acquire couple of magnetic field data matrices at different heights from the sample surface automatically. These data matrices are utilized for after-mentioned magnetic field reconstruction.

After acquiring couple of magnetic field data matrices, a magnetic field image inside materials is produced by the reconstruction software. In the software, the magnetic field near above the magnetic sources inside the passivation

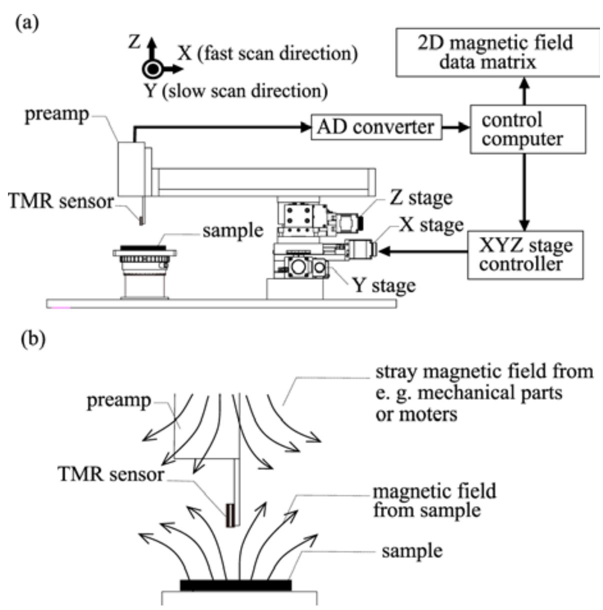

Figure 1: (a) Schematic illustration of magnetic field microscopy., (b) Magnetic fields surrounding TMR sensor.

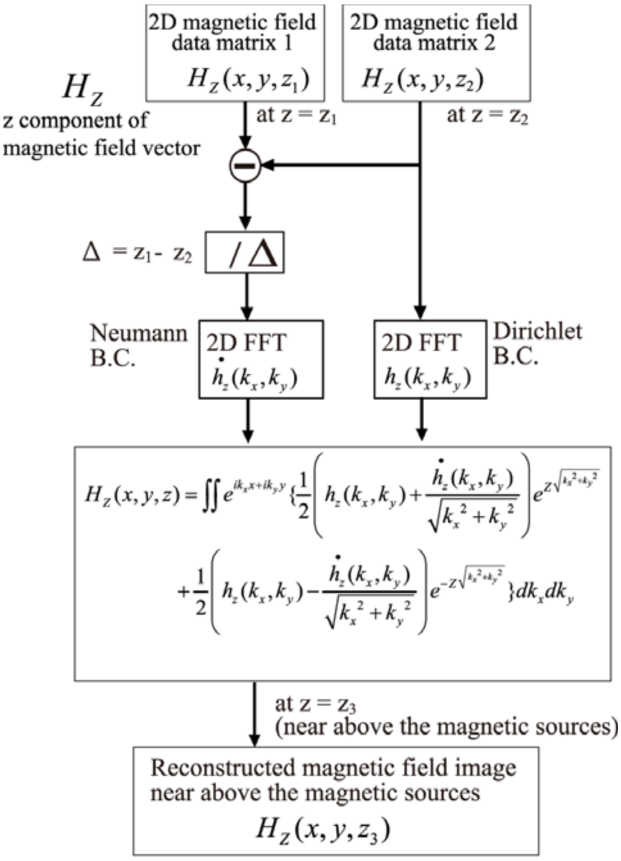

Figure 2: Procedure of magnetic field image reconstruction.

layer or IC package is calculated by solving Laplace equation[6]. The image data processing in the reconstruction is shown in figure 2. In this procedure, we utilize couple of magnetic field data matrices for making a data matrix of the Z derivative of magnetic field. This data matrix enables us to solve the Laplace equation when there are magnetic field sources at both upper side and lower side, and the effect of stray magnetic field behind the magnetic sensor schematically illustrated in FIG. 1 can be reduced.

We demonstrated current flow imaging on a test printed wiring board (PWB). Figure 3(a) shows a photograph of the test PWB. A constant current source is connected to through hole A and B. Current flow is schematically shown by red arrows in FIG. 3(a). FIG. 3(b) shows the position of the TMR sensor and the test PWB in this experiment. The TMR sensor is two-dimensionally scanned twice over the sample at difference heights. After twice 2D scanning, couple of data matrices is utilized to produce a reconstructed magnetic field image near above the magnetic sources. In this experiment, we used a commercially available TMR sensor (STJ-220: Micro Magnetics, Inc.), whose sensor size is 0.89 mm square. Sensor scan speed was 5 mm/s. The measurement time per one data matrix was about 10 minutes. Applied current to the test PWB was 100 mA DC. FIG. 3(c) shows a reconstructed magnetic field image at 0.2 mm from the PWB surface. The color

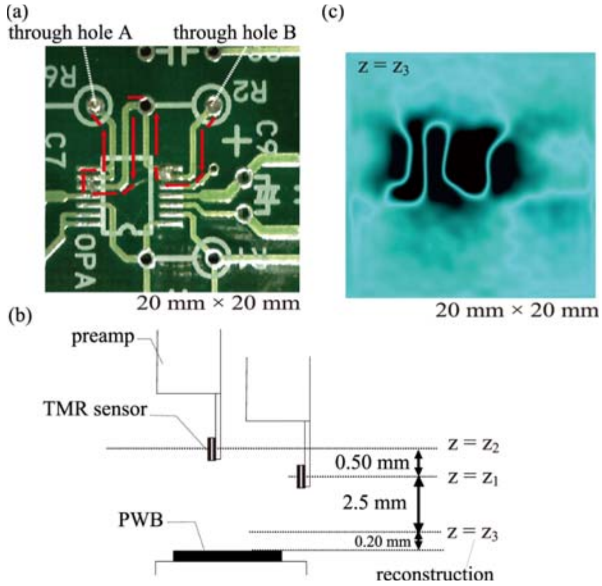

Figure 3: (a) Photograph of the test PWB., (b) Positions of the TMR sensor and the test PWB., (c) Reconstructed magnetic field image at 0.2 mm from the test PWB surface.

scale of FIG. 3(c) means the absolute value of Z component of magnetic field vector, and the bright and dark contrasts reflect small and large magnetic field, respectively. The reconstructed magnetic field image at 0.2 mm displays the current pass clearly. We confirmed that this microscopy has promising potentials to apply various electric devices and circuits.

3. Conclusion

In this study, we presented a brief overview of TMR microscopy with magnetic field reconstruction software. In the demonstration, current flow was clearly visualized. We believe that this microscopy would achieve higher spatial resolution using a more miniaturized TMR sensor since both field broadening and stray magnetic field can be reduced effectively by the magnetic field reconstruction.

Acknowledgements

This work was supported by Adaptable and Seamless Technology Transfer Program through Target-driven R&D, JST.

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