SII

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APPLICATION BRIEF

SPI no.61 Evaluating MRAM with the Applied Horizontal Magnetic Field Option

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SII has developed technology to measure and analyze surface nano-structure properties such as viscoelasticity, friction and electromagnetism under various environments, such as air, liquid, vacuum, controlled temperatures, controlled humidity and applied magnetic fields. Its scanning probe microscope (SPM) system can be used in a wide range of fields, from basic research to industrial applications. In this brief, we will use the applied horizontal magnetic field option of an atomic force microscope (AFM) to evaluate Magnetoresistive Random Access Memory (MRAM), which is considered to be the next generation of universal memory.

Figure 1 shows an overview of the applied horizontal magnetic field option. The option has the following features.

1) It is easy to set the strength and polarity of magnetic field because it is applied by an electromagnet.
2) The distance between magnetic poles is 10 mm. A magnetic field with a maximum of approximately 5000 oersteds can be created at the sample stage located between the poles.
3) Coils are located away from the test sample stage and are water cooled so that heat from the coils does not influence the measurements.
4) It is possible to perform lengthy measurements in a stable, fluctuation-free magnetic field because the generated magnetic field is stabilized by a feedback mechanism that uses a Hall device to detect the magnetic flux density.

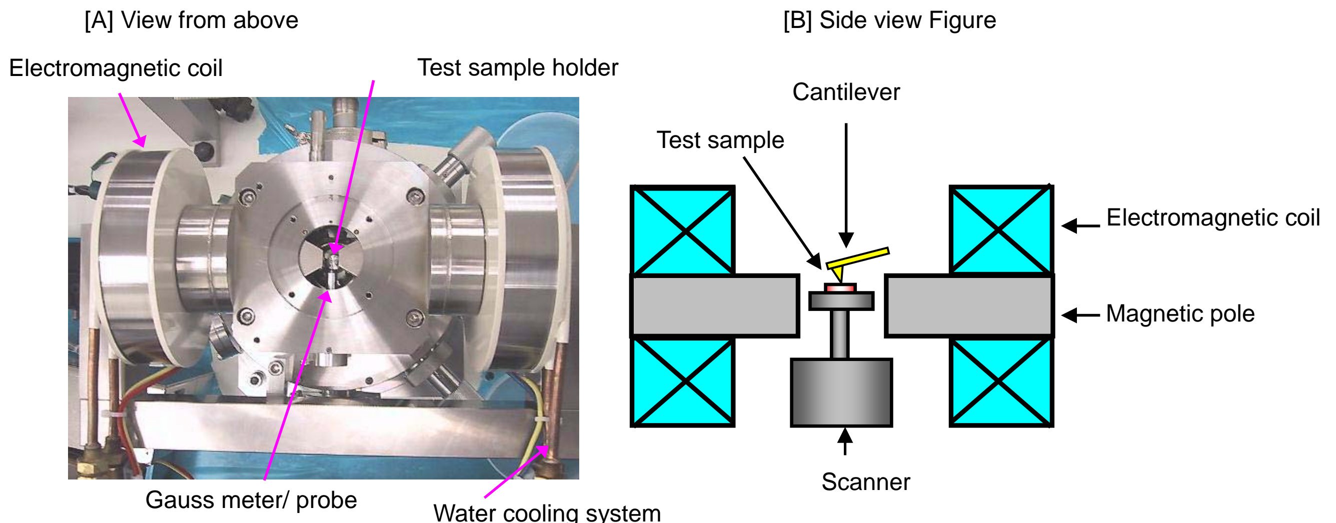

Figure 1 – Overview and side view of the applied horizontal magnetic field option

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Figure 2[A] shows the operational principles of MRAM. One MRAM memory cell is composed of two small magnetic entities with different coercitivity separated by insulating layer. In other words, it is a tunnel magnetoresistance (TMR) device. If the magnetization of the two ferromagnetic layers is parallel, electrical resistance is reduced. Conversely, if the magnetization is anti-parallel, electrical resistance is increased. These changes in resistance are used to read digital signals of “0” and “1”. To write data, the magnetization of one of the small magnetic entities is reversed by a magnetic field.

Figure 2[B] shows how the resistance of TMR device is measured by Conductive AFM.

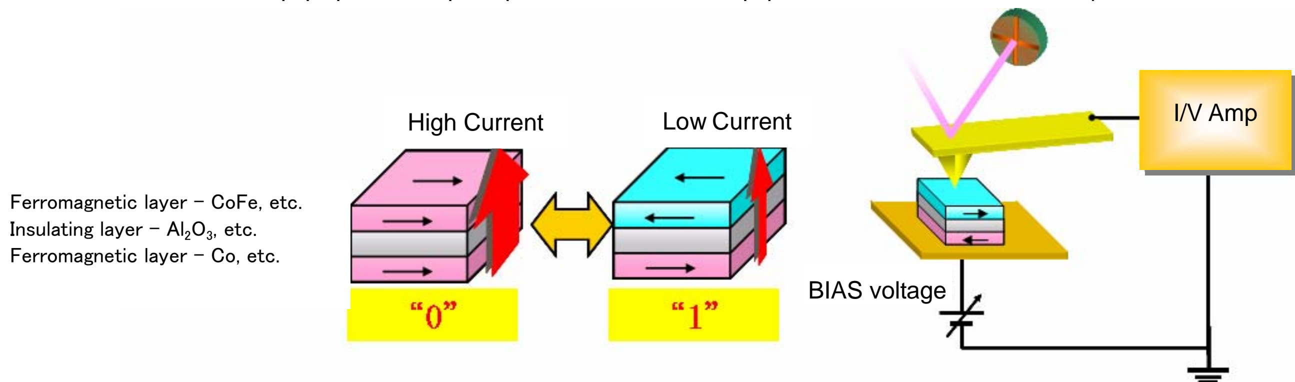

Figure 2 – MRAM operation principles and measurement of TMR device resistance by AFM

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Figure 3[A] and 3[B] are a microphotograph of a TMR array and the results of AFM observation of one device. A probe was placed in the center of a device to measure the electrical current and voltage characteristics under the following two conditions. The applied horizontal magnetic field option applied 100 oersteds in the right direction to change the magnetization of the magnetic layers to parallel. The option applied 100 oersteds in the left direction to change the magnetization of the magnetic layers to anti-parallel.

Figure 3c displays the results of these two conditions. We can see that when the magnetization is parallel, the electrical current is high and the resistance is low.

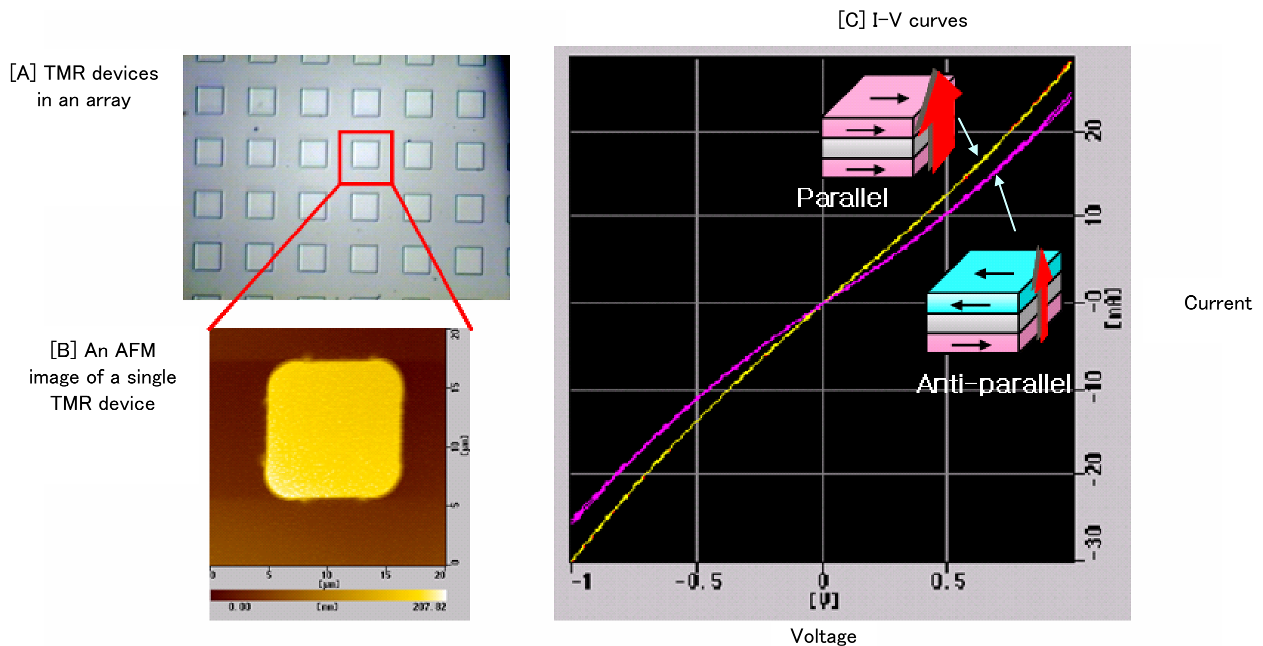

Figure 3 – Measurement of the electrical current and voltage characteristics of a TMR device by AFM with magnetic field application

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Figure 4 shows the magnetic resistance characteristics as electrical current and voltage characteristics are changed by an external magnetic field, as in Figure 3c. Number 1 shows when 100 oersteds has been applied in the right direction. The resistance has lowered because the magnetization is parallel. If a magnetic field is applied in the left direction, the resistance rises because the magnetization is anti-parallel, as seen in Number 2. If the magnetic field applied in the left direction is strengthened, the magnetization of the magnetically fixed layer (the third layer from the top) reverses and the resistance lowers because the magnetization of the two magnetic layers has become parallel again.

Acknowledgements
The TMR test sample was provided by Prof. Chung of Sungkyunkwan University.

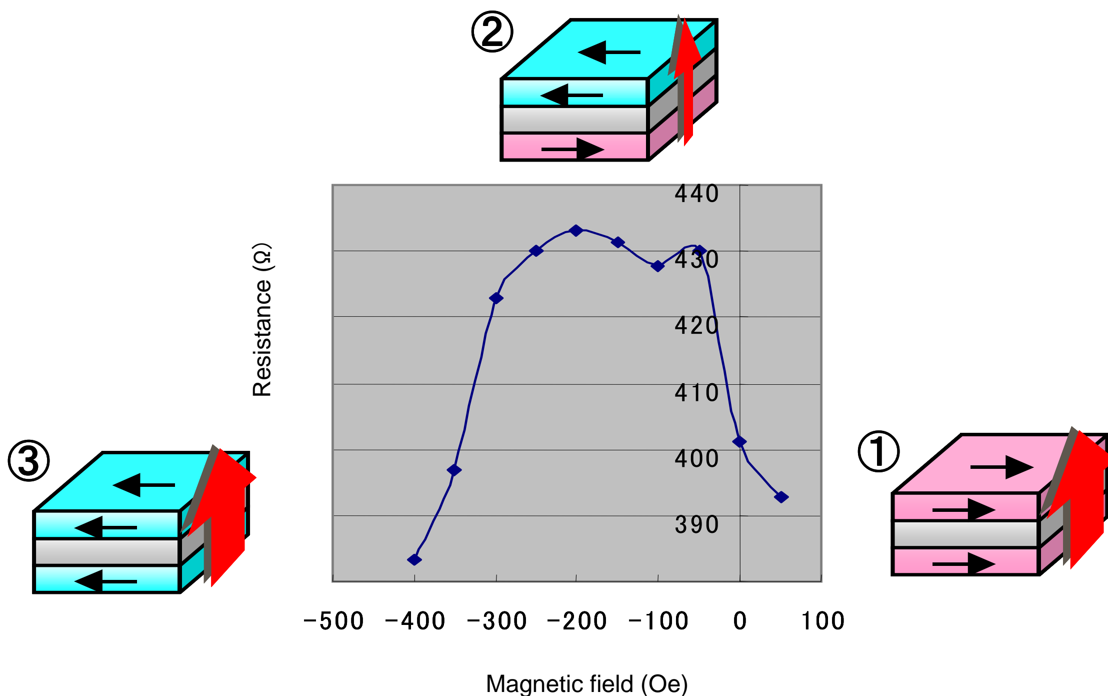

Figure 4 – Measurement of magnetic resistance of a TMR device by AFM with magnetic field application

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