For a more comfortable life: spintronics semiconductor integrated circuits

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What are you using to read this report? Is it a smartphone, or a PC? These devices are built-in semiconductor integrated circuits, which are composed of hundreds of electric elements and semiconductors. They are possible to control turning on or off a current freely and have some functions as our brain. Thanks to semiconductor integrated circuits, it is possible to apply them with AI (Artificial Intelligence), IoT (Internet of Things), automatic driving without controlling by a handle, and so forth. In our brain, we can activate our life by signals communicated by a lot of nerves. How about semiconductor integrated circuits? They communicate with electrons. Electrons are tiny particles that have a little negative electricity (charge) and turn on their axis like the earth (spin). In particular, the charges are used to communicate lots of electric signals in the semiconductor integrated circuits at present. Therefore, we called them electronics semiconductors.

In the advanced information society today, a lot of information surrounds us because of the development of IT (Information Technology). Therefore, an ability to deal with information that you need properly and rapidly are necessary to survive in society. However, it is too complicated to gain the ability! That is why we demand new semiconductor integrated circuits of which a speed dealing with plenty of information are faster than that of electronics semiconductor integrated circuits, instead of you. In 1998, Albert Fert and Peter Grünberg discovered Giant Magnetoresistance. Giant Magnetoresistance is a phenomenon that an electronic resistance of a structure in which a magnetic material sandwiched between non-magnetic materials with applying a magnetic field is about 10 times larger than that of a conductor. This result is caused by spins of the magnetic material and many researchers were interested in this phenomenon because it was expected to detect faint magnetic fields. Therefore, researchers thought that it is possible to reach the goal to use not only the charges but also the spins and started to research [1]. Those devices are called spintronics semiconductors.

Compared with electronics semiconductors, one of the most prominent characters of spintronics semiconductors is saving used electricity. To improve the performances of components used in integrated circuits, to be smaller the size of the components and to assemble using them a lot are needed. However, in electronics semiconductors, electricity always must flow all over to keep information in the semiconductors because information is exchanged through the charges. On the other hand, in spintronics semiconductors, information is continued to retain without flowing electricity because the spins also exchange it. Therefore, electricity is needed only in exporting data and reading out. In addition, used electricity can be saved largely because it flows not all over the integrated circuits but used parts.

Also, electronics semiconductors need a large amount of electricity due to improving their performance. However, because they radiate heat by applying a lot of electricity, their performance should be suppressed to prevent heating. On the other hand, in spintronics semiconductors, this matter is solved, and their performance can be progressed more. For example, the density of memory is 10 times to 20 times larger than that of electronics semiconductors and calculation speed is about 1000 times faster, and so forth. And surprisingly, nano-sized components of spintronics semiconductors can be achieved, it is expected development of high performance and small-sized devices.

As written above, spintronics semiconductors are materials that can be more comfortable life in the future. However, researchers discuss what ingredients of them are the best up to now, and the answer is unknown. Investigation of directions of spins of each element is important to understand whether the candidates are the best or not.

One of the main measurements to understand whether the directions of the spins of each element are clockwise or anti-clockwise is Magneto-Optical Kerr Effect. This measurement method is based on the Kerr effect, which is discovered by John Kerr in 1875 [2].

Kerr effect is a phenomenon that the reflected light is changed to ellipsoidal circular polarized light when line polarized light is irradiated to materials that have a magnetization because of an interaction between the light and magnetization (See Figure). Polarized light is light controlled to vibrate only along a specific direction. Especially, in polarized light, light vibrated along one direction is called line polarized light, and vibrated drawing like ellipsoidal spiral is called ellipsoidal circular polarized light. Using the measurement method, we can understand what kind of magnetizations the element in the materials has by observing the polarization of reflected light.

For a more comfortable life, spintronics semiconductor integrated circuits are necessary for our future. If the semiconductor integrated circuits were to complete, devices and machines which are more compact and high-performance would be the foundations of our lives. To realize them, what kind of magnetizations the element has is important. The world that devices that spintronics semiconductor integrated circuits are built-in are surrounded us is, maybe, near the future.

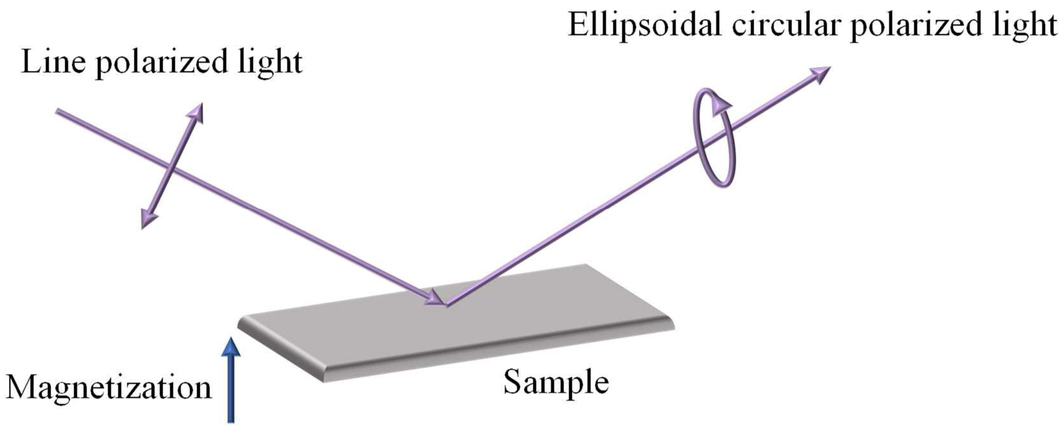

Figure. Schematic of Magneto-Optical Kerr Effect.

Reference

[1] W. Patrick McCray, *Nature Nanotechnology*, 4, 2 (2009).

[2] P. Weinberger, *Philosophical Magazine Letters*, 88, 12, 897 (2008).