Toward a brighter tomorrow, colored by big data with magnets

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The widespread use of smartphones has transformed our lives. We can not only access a variety of articles and videos anytime, anywhere but also calculate and write documents with smartphones. Digital technology has brought about a revolution in our personal lives and, now, is about to transform the entire society. In Japan, it is also called "Digital Transformation" (DX), and various companies are beginning to work on it all at once. It's not just about phones anymore. Everything around us is changing. Wearable devices will automatically check your health and give you advice like a doctor. Cars will be able to get you to your destination without your operation. Based on weather data aggregated from all over the world, anyone on a farm will be able to grow food as accurately as a craftsman. Private shops, warehouses, transportation, factories, and raw material production centers will all be connected by data. Waste in production and consumption will be close to zero. This is the era of big data and artificial intelligence.

To make these a reality, we need vast amounts of electronic devices and places to store data on a cosmic scale. Both consume enormous amounts of energy. How much of this is there?

A tremendous amount of data is managed in data centers around the world. The energy consumed by these data centers is enough to power 20 nuclear power plants. In the future, the amount of data will increase at an accelerated rate. As the number of data increases, the energy consumed by the data centers will also increase. Yes, this is a global energy problem that is just around the corner.

Recently, one good news and one bad news for data centers were reported in the prestigious U.S. scientific journal “Science”[1]. Over the last decade, the amount of work done in data centers has increased by 550%, while the amount of energy used has only increased by 6%. Advances in technology have reduced energy consumption. However, the energy reduction came from the power supply to the devices and the cooling of the devices. The energy consumption of the devices, which is the heart of the matter, has continued to increase. In other words, to overcome the challenges ahead, we need to improve the power consumption of devices that handle data.

To store data, magnets have long been used. Can you remember the days when we used

cassette tapes and floppy disks? All of the above record information in the direction of the magnet. However, their operation is, unfortunately, slower than that of electrical recording devices (SSD, DRAM, SRAM), which consume more power. For this reason, magnetic recording devices can only be allocated where they are slow enough. The use of magnetic recording devices everywhere will also greatly reduce power consumption.

What would the world be like if we could create magnetic recording devices that are faster and consume less power than electric recording devices? A discovery leading to the answer to this question was made in 2015[2]. Here, a magnet that doesn't stick to a refrigerator, an antiferromagnetic body, attracted attention.

An antiferromagnet is known to change direction much faster than ordinary magnets. However, it was difficult to determine the direction of an antiferromagnet. With ordinary magnets, all the small magnetic elements either point up or all point down, and it is easy to tell from a distance which direction they are facing. So, you can put shopping notes on the refrigerator with a magnet. This is because the refrigerator reacts to the magnet. On the other hand, an antiferromagnet is made up of magnetic elements that are oriented in different directions from each other to cancel out the magnetic force. Therefore, from a distance, it appears as if there is nothing there.

The researchers of Ref. [2] discovered the antiferromagnet which can electrically read the direction of magnetism. Even though it can be read out electrically, the power consumption is expected to be much lower than that of conventional electrical devices.

Recording devices using antiferromagnets have the advantage of reducing the device size. Have you ever brought the N and N poles of an ordinary magnet close together? If you have, you'll know immediately that they repel each other. This is why your refrigerator friend can't be placed very close to another magnet. It is said that this does not happen with antiferromagnetic materials. Therefore, it is possible to make a device that can record more data in a smaller area. Now you can be free from the worry of being chased out of your home by an overgrowing mountain of data.

Although the above benefits are expected, there are still some issues to be solved. It is still in the research stage, so research and development by researchers and companies are essential. Also, the price difference from existing recording devices will be an issue. It will take a lot of human will, including government support, corporate investment, and ultimately the awareness of our consumers, to bring this technology to widespread use.

One by one, the spread of devices will erase the reasons why people hesitate to go digital for reasons of energy and land. Tomorrow, this world will be bright again, illuminated by your smartphone.

[1] E. Masanet et al., Science **367**, 6481 (2020).
[2] S. Nakatsuji et al., Nature **527**,7577 (2015).