How Can Material Science Change the World?

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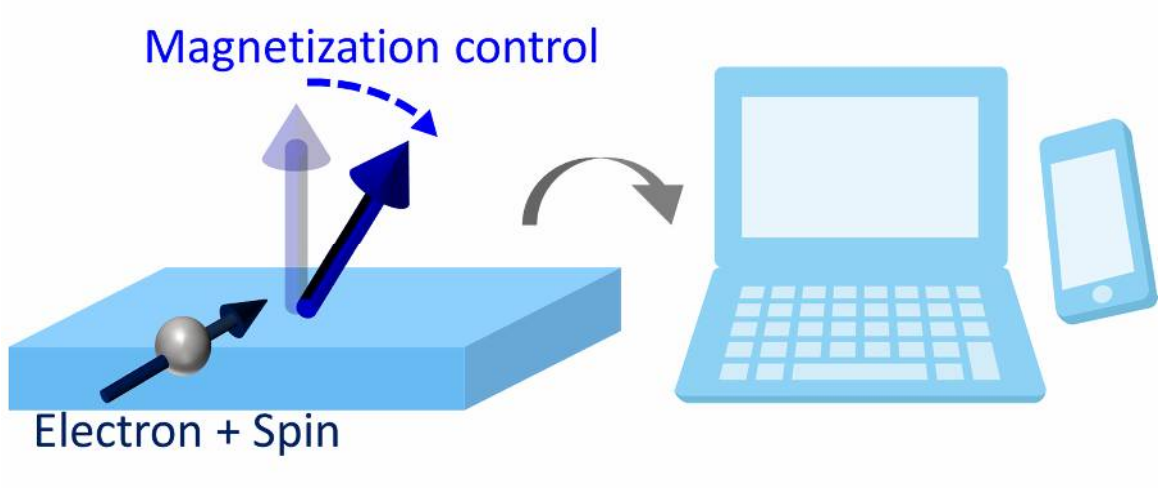

Today, all of you use computers, smartphones, tablets and other devices to take notes, call your friends, play video games, or do various other things. Moreover, the recent advancement in artificial intelligence will change our future lives. These electronic- and information-technologies have been developed based on **material science** to physically realize them. Material science is a field studying material properties in the electronic, magnetic, thermal, or other aspects. By utilizing the maximal potential of these material properties, we can expect the further improvement of the technologies and our daily lives, changing the whole world. Here, you might have a question: How can material science change the world? To answer this, we need to start from atomic scale.

Every material is composed of a tremendous number of small particles: atoms and electrons. In solid-state materials, atoms are arranged in a regular pattern, forming a crystal. One of the most important aspects of a material's physical properties is **magnetism**. A familiar example is when magnets attract materials such as iron, cobalt, or nickel.

This kind of magnetic behavior results from the **spins** of electrons. Each electron has a spin, which acts like a tiny magnet. Under certain conditions, the spins of many electrons become ordered, giving rise to macroscopic magnetism. Once the spins in a material align in some order, the magnetism it gains is preserved robustly unless a large electromagnetic field or heat is applied. Therefore, materials with magnetism behave as if they have a kind of **memory**.

More interestingly, these spins can be used to intentionally control the magnetism of a material. In some materials, the spin of the electrons is correlated with their motion, allowing spins to be directed in a specific way—this is known as a **spin current**. Spin currents can be used to control the magnetic state of materials and are already being applied in electronic devices in industry. And as I mentioned above, this memory can be rewritten by electrical control of magnetism. In this way, magnetic materials can retain and rewrite **information**, enabling data storage and computation.

This kind of information processing is expected to enhance our technology. Here, one of the most important aspects of applying materials to information processing is their size. Because the length scale of atoms and electrons is 10^{-9} m or smaller, the materials used as memory units can be miniaturized to the micro- or nano-scale. This is a major advantage in efficient processing using magnetism even in industrial level. Although the technology of control magnetism by spin current is yet to be commercially used, this certainly has a potential to realize next-generation technology enabling low power consumption and high integration.

Moreover, even more sophisticated technologies for computation are being investigated to achieve higher efficiency recently. Materials that have short-term memory expressed in continuous values can also be applied to **reservoir computing**—a computational technique that classifies input signals into specific patterns. This technology has a significance in the framework of machine learning, which has computers to learn a large amount of data and act as if they understand it. Nowadays machine learning is becoming more and more important because of the today's prevalence of **artificial intelligence (AI)**. Thus, magnetism and spin current in materials, which can be applied to this, have gained a larger importance.

This leads to the focus of my current research: I investigate the electronic properties of materials, specifically the **electrical control of magnetism**. In this field, *heterostructures* of thin films—where a magnetic material is stacked on top of a material which generates spin current—are particularly useful. They allow us to design systems that are optimal for controlling magnetism, paving the way for further advancements in **spintronics**, the field that explores practical uses of electron spins. Therefore, in response to the initial question, I would say that material science can further advance electronic devices, computing technologies, and artificial intelligence through studying spintronics.

My interest in material science dates back to my high school years. I was good at physics and confident in my ability to understand its theoretical aspects. However, I didn't know how to apply that knowledge in a meaningful way. Then I came to realize that all

modern technologies are fundamentally supported by materials that make their physical implementation possible. I also learned that the properties of these materials can be understood through the physics that describes the behavior of electrons. Since then, I have been driven by the desire to use my abilities to make a positive impact on the world.

So, what I want to tell my 12-year-old self is to find how to **maximize my value to the world**. When I was really 12 years old, I thought about things like, “What do I really want to be in the future?” I had already realized that my abilities were unique at the time, but I had not yet found the best way to use them throughout my life. Would I be happy if I became a doctor, a lawyer, a politician, or an entrepreneur? That was the biggest question for me at that time. Adults around me said that I could and should be whatever I wanted to be, but that was meaningless because there were too many choices to decide.

Thus, I want to tell myself at that time that I should have analyzed my suitability for various fields. It is essential to thoroughly analyze which abilities you excel in and which ones you lack, understand the domains in which they are most effectively demonstrated, and think deeply about the kind of life you should lead in order to maximize your true value. For example, if you have a great ability to grasp abstract concepts and calculate fast but a poor ability to memorize a lot of names of people or cities, probably you are suitable for mathematics or physics rather than politics or history.

While people don't live solely for others, as individuals who benefit from being part of society, it is both an important responsibility and one of life's true joys to give back to society by using our abilities. Now I have a strong desire to change the world through scientific and technological innovation, supported by my theoretical thinking skills. This is the result of carefully assessing my abilities and aptitudes. Therefore, my personal answer to the original question would be: Material science changes me. I change the world. Therefore, material science changes the world

Chat-gpt is used to check the grammar of sentences above.

Free images of a PC and a smartphone downloaded at *illustAC* are partly used in the figure.

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