Title: How to store energy permanently?

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What is the phase transition? You may have been taught in science class that there are three states of matter: liquid, solid, and gas. For example, water becomes ice at 0°C and water vapor at 100°C. This change in the appearance of the same substance in response to changes in the external environment, such as temperature and pressure, is called the phase transition. The phase transitions from solid to liquid and from liquid to gas should be familiar to everyone. However, do you know that there is also the phase transition from solid to solid? For example, when we consider the example of water, the crystalline structure of ice actually changes and becomes a different phase when high pressure is applied. According to recent research, there are more than 10 different types of ice. Let us consider another familiar example. The pencil lead we use in our daily lives is made of a substance called graphite, which undergoes a phase transition to diamond when exposed to high temperature and pressure. Moreover, the same substance can have completely different properties in different phases. Graphite is fragile because its two-dimensional network is layered by intermolecular forces, while diamond is very tough because its three-dimensional network is formed by covalent bonds between carbon atoms. Another difference is that graphite is an excellent electrical conductor because it has electrons that are not involved in bonding, while diamond is an insulator. If we can manipulate the changes in these two materials with completely different properties, we can create very interesting materials, can't we? This is my research theme.

Among phase transition materials, I am working on a ceramic called lambda titanium pentoxide (λ-Ti_3O_5), which can store thermal energy. This material has a β phase, the most stable state at room temperature, and a λ phase, the second most stable state. It then has the interesting property of switching between the two states when the temperature is raised, pressure is applied, or light is shone on it. In addition, the switching between two phases can be repeated. Using this property, energy can be stored semi-permanently by absorbing thermal energy from the β-phase state and storing it in the λ-phase. The stored energy can also be extracted by applying pressure or light. Materials with this property are called long-term heat storage materials.

By the way, renewable energy is becoming increasingly popular recently, but did you know that a lot of energy is being thrown away because of this? Basically, electricity must be generated in balance with demand or power outages will occur. However, since the output of renewable energy is affected by weather and other factors, the amount of power generated by thermal power and other sources must be controlled to match demand. If they still cannot be adjusted, they will have no choice but to shut down renewable energy generation. As such, shutting down power generation in order to match electricity supply with demand is called output control. In effect, this can be seen as a form of energy dumping. In fact, in Japan, approximately 1 billion kWh of renewable energy was output-controlled in FY2022. (Since the average annual power consumption of a Japanese household is 4,000 kWh, this value is equivalent to 250,000 households.) If the spread of renewable energy continues to accelerate, the portion of output that can be adjusted by thermal power generation, etc. will become smaller and smaller, resulting in frequent energy surpluses and conversely, shortages. Although there are currently attempts to store excess energy produced in excess by reusing old EV (electric vehicle) batteries, etc., further development of low-cost energy storage technology is awaited.

If long-term heat storage materials are put into practical use, it will be possible to store overproduced energy as thermal energy and retrieve it at any time, thereby significantly reducing wasted energy. Not having to throw away energy will help reduce the progression of global warming, and the electricity bill we pay will be lower. The advent of lithium-ion batteries and the ability to charge small devices was a revolutionary event for mankind, but our lives could change dramatically if heat recharging becomes possible as well.

I learned about this long-term heat storage material in a class during my third year of undergraduate studies. I was shocked to learn that this material could store heat semi-permanently and could be used repeatedly, which had never existed in the world before. At that time, I realized that scientists are in a profession where they can use their own creativity to make the impossible possible. Living in a time when we are facing a mountain of challenges on a human scale, including global warming, and when we tend to feel helpless about the future, such a profession seemed very appealing to me. This is why I decided to become a scientist.

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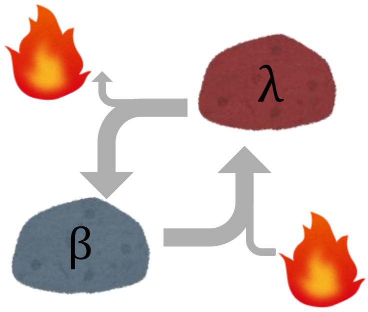
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