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Hello, everyone. I’m Mizuguchi Yoshikazu. "Superconductivity" is attracting a lot of attention as a physical phenomenon that will lead the way for a sustainable society. Among all, it is one of the most expected technologies that has the potential to solve the world’s energy problems. What exactly is superconductivity? I’d like to start by talking about electrical resistance.

Video 1: What is Electrical Resistance?

There are many electrical appliances that use electrical resistance. These include irons, electric griddles, hair dryers, and electric heaters. These appliances generate heat by passing an electric current through a material such as nichrome wire. Let's take a look at how electrical resistance generates heat.

This shows the crystal structure of a metal. You can see that positively-charged atomic nuclei are evenly spaced. These spaces allow negatively-charged electrons to freely pass between the nuclei. This flow of electrons is an electric current.

Now take a look at this. The nuclei in the metal are vibrating intensively. These vibrations make it difficult for electrons to move freely between the nuclei. This is what we call electrical resistance. So when a metal has low electrical resistance, it means that it allows a large number of electrons to move freely between the nuclei. When a material has high electrical resistance, the electrons cannot pass between the nuclei easily, and heat is generated in the material as a result.

Video 2: What is Electrical Resistivity?

In nature, materials range widely from those that conduct electricity well to those that do not conduct it at all.

Homework Question 1
Before the lecture, try to list up some materials that have low electrical resistivity. What about some that have high electrical resistivity? Here are some hints. Metals like copper and lead are materials that have low

resistivity. Materials with high resistivity do not conduct electricity and are called “insulators.” There are also materials with a medium level of resistivity. These are called "semiconductors.” Please have your lists ready to share in the lecture. List materials like aluminum or items around you like a rubber band.

Video 3: What is a Superconductor?

These are not two magnets repelling each other. The top one is a magnet, but the bottom object is made of copper oxide. Why is the magnet floating above the copper oxide? Because, in fact, the copper oxide is in a superconducting state.

Materials in this state do not allow magnetic field lines to enter them. This is one of the characteristics of superconductivity. We can see that the magnetic field lines of a magnet are repelled from the copper oxide. In other words, the magnet is expelled in the air because the magnetic field lines above the superconductor are condensed due to distortion. This creates a repulsive force, causing the magnet to float.

Another important characteristic of a superconductor is the disappearance of electrical resistance. All metals have electrical resistance, but in the superconducting state, electrical resistivity becomes zero. Zero electrical resistivity is the key to solving the world's energy problems.

Think about the electricity that is delivered from power plants. A huge amount of electric power is lost when it travels from a power plant to its destination because of electrical resistivity. This loss equals all of Tokyo’s power use for six months or all of Japan’s for about 18 days. Superconductivity technology, with its zero electrical resistivity, could greatly reduce energy losses. So why is it not used widely yet? The reason lies in its “low transition temperature.”

Let’s go back to the metal model. At room temperature, the nuclei are vibrating intensively, which blocks the electrons’ movement between them. This is the metal’s electrical resistance. Lowering the temperature reduces the vibrations of the nuclei, which allows electrons to move freely between them. When the temperature drops to a certain level, the electrical resistivity becomes zero. This level is called the transition temperature of superconductivity.

The phenomenon of superconductivity was first discovered at a transition temperature of -269 °C. It was observed in mercury in 1911 by Dutch physicist Onnes. This kind of temperature is too low and difficult for practical application. Recent studies show that materials containing hydrogen have some potential. If you discover a superconductor material at room

temperature and under ambient pressure, you might win a Nobel Prize!

Homework Question 2
Here’s something else to think about before the lecture. From these four groups of highlighted elements, choose negatively-charged ions to form hydrogen compounds. Since hydrogen tends to be positive, it bonds with negatively-charged ions. Think of compounds with plus and minus ions whose total charges become zero.

The research of superconductivity has the potential to change the world. Why don’t you take a look into the world of superconductivity with us?