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Introducing the Researcher ❸

Assistant Professor Yoichi Kamihara, who has discovered an iron-based high-temperature superconductive material, proposes new possibilities.

Creating Lossless Power Transmission Cables Using Iron-based High-Temperature Superconductive Material

Toward the ultimate electric lines

Yoichi Kamihara

Superconductivity refers to a phenomenon in which electrical resistivity drops to zero when certain materials are cooled to low temperatures. It had long been believed that superconductivity is a phenomenon peculiar to certain materials and it can hardly occur in materials containing iron. But Dr. Kamihara made a breakthrough in 2008 by discovering superconductivity with a layered iron-based compound.

Superconductivity with materials containing iron

In 1911 Heike Kamerlingh Onnes of the Netherlands discovered that electrical resistivity of mercury cooled to 4.2K (kelvin = the unit of absolute temperature, 0K being -273.15 °C) drops to zero. The temperature at which electrical resistivity becomes zero is known as the superconductivity transition temperature(T_c). Efforts in quest of materials that can become superconductive at higher temperatures have been made in the ensuing years.

"Just a century has passed since the discovery of superconductivity, during which time a number of superconductive materials have been identified. These materials are roughly divided into metal-based compounds and cuprate-based ones. In terms of transition temperature, 39K for MgB_2 discovered in 2001 is the highest of metal-based compounds while high-temperature superconductivity at 135K for a cuprate-based material was confirmed in 1993. After that no significant discoveries had been reported," Dr. Kamihara outlines the development of superconductivity. Amid the stagnancy in the exploration of superconductive materials, Dr. Kamihara and co-workers (his bosses & a student) presented an original paper in 2008. The key point of the paper was the confirmation of superconductivity occurring in a compound containing iron, which overthrew the conventional view that iron, responsible for magnetism, is not suitable for superconductive materials. The paper was soon followed by a Chinese researcher reporting high-temperature superconductivity at 55 K, together leading to the discovery of the third type of high-T_c superconductive material.

"The superconductive material we found this time was an iron-based four-element compound. This combination of elements has great potential for application to other materials in addition to iron. I heard of a positive evaluation that the number of candidate combinations has increased dramatically. It also came to be known that its single crystal is in the shape of a thin plate and that electric current flows in the longitudinal direction through the single crystal thin plate. The establishment of an electric cable processing technology taking advantage of the single crystal's structure is said to be the key to practical application of the superconductor."

The paper surprised and intrigued numerous researchers and became No. 1 in the world in 2008 in the number of citations of theses written in English. In 2009, Dr. Kamihara was honored with the 13th Superconductivity Science and Technology Prize.

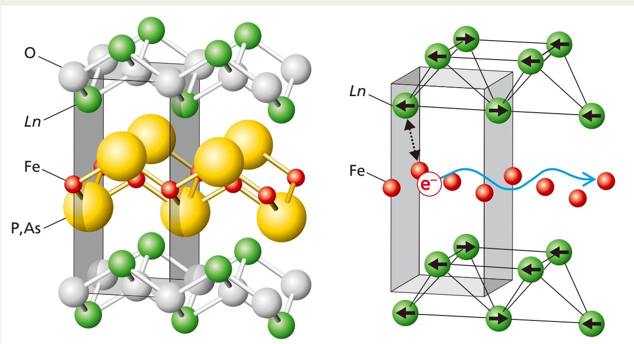
From discovery of superconductivity to practical application

Much is expected of superconductivity for application to many fields such as linear motor, electric power transmission and strong magnetic field generation. Above all, you can safely say the field of application on which the greatest hope is placed is the electric cable made of a superconductive material with zero electrical resistance. Given zero electrical resistance, it is theoretically possible to create electric cables without transmission loss – the ultimate cable that does not waste energy at all during transmission.

"In reality, however, I must admit that there are many problems. Even if we successfully identified an excellent material with a high transition temperature and elucidated its structure, heaps of problems would have to be solved before using the material in electric cables. For example, since an iron-based superconductive material is ceramics made up of small single crystals ranging in size from 1 to 100 micrometers, you cannot process it by stretching or melting like a metal. In order to form a long electric cable, heretofore unknown technologies need to be developed, such as a processing technology capable of orderly arranging the small single crystals, and a technology to prevent the junction between crystals from becoming oxidized, for example. What's more, how should protective coating for the cable be, and how should the cable be connected to the electrode? All such problems must be cleared."

While Dr. Kamihara began to address studies to put superconductivity into practical use, his inquisitive spirit is also directed to exploration into the fourth type of superconductive materials beyond iron-based ones. We'd like to see the fruition of his new challenge.

(Reporter & text writer: Kaoru Watanabe)



Crystal structure of iron-based high-temperature superconductor (left)

The figure on the right is a structural drawing picking out only iron (Fe) and lanthanide (Ln), showing how free iron electrons migrate during power transmission. In the center is a layer of iron, which is sandwiched from above and below by layers of rare earth elements such as lanthanum and samarium. Its single crystal is apt to grow sideways, tending to form a thin plate structure. In the crystal, the element mainly responsible for power transmission is iron; electricity is transmitted as free iron electrons migrate.