"Environment, Energy and Infrastructure" field

Achievement : Developing the world's highest performing Nd-Fe-B type permanent magnet and contributing to energy conservation

Dr. Masato Sagawa
Born : August 3, 1943 (Age 68)
President, Intermetallics Co., Ltd.

Summary

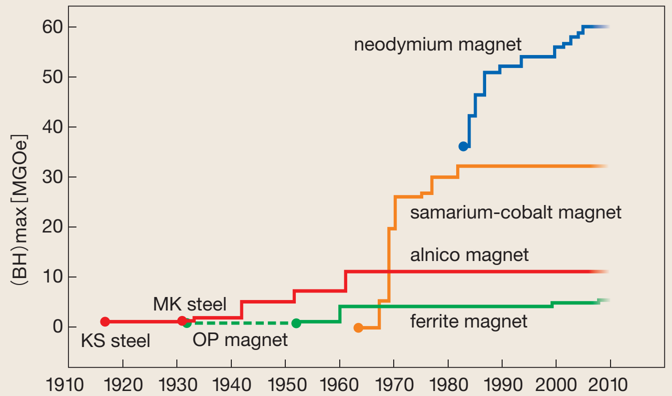
One of the fundamental materials which support our highly industrialized society is a permanent magnet. In order to respond to the expectations for a stronger magnet, the Sm-Co(samarium-cobalt) magnet was developed in the 1960's. However, because cobalt was a rare resource, the scope of its application was limited. Amid such a climate, Dr. Masato Sagawa embarked on the challenge of achieving a permanent magnet using iron, an abundant resource. Dr. Sagawa engaged in research and development of magnetic materials from a completely different perspective to the conventional. In 1982, he discovered the Nd-Fe-B(neodymium-iron-boron) magnet that has the world's largest energy product which breaks the Sm-Co magnet's record in the maximum energy product, and achieved the industrialization of this magnet. Motors which use neodymium magnets are compact, lightweight and highly efficient. Thus, they have greatly contributed to the solution of global environmental issues through power-saving industrial and household electronic products as well as through the high efficiency of new energy sources such as wind power generators.

The progress of permanent magnets using rare earth elements has created modern industry

A permanent magnet refers to an object which continues to supply magnetic flux without the supply of external magnetic fields or electric currents. The ancient Greek philosopher Plato, in his writing "Ion," refers to "magnesia stone" which attracts iron, indicating that the existence of permanent magnets was known from ancient times.

Man created permanent magnets by his own hand in the 18th Century. At that time, only weak magnets could be made which were used for compass indicators. However, in the 20th Century when the use of electric power gained momentum, expectations were raised toward permanent magnets to create a stable magnetic field. Thereafter, many permanent magnets were developed. For example, in 1917 Kotaro Honda of Japan invented the KS steel, and in 1931 Tokushichi Mishima invented the MK steel, and later the Alnico magnet. In 1937 Yogoro Kato and Takeshi Takei invented the OP magnet and later the ferrite magnet. By means of the appearance of highly efficient generators and motors, mankind was able to attain the age of high-tech industry.

Diagram 3 : History of permanent magnet development



Rare earth magnets have significantly higher maximum magnetic energy product in comparison to conventional permanent magnets. Among them, neodymium magnets exceed 50MGOe and have been mass produced.

The development race of permanent magnets reached a turning point in the 1960's with progress in the research of rare earth magnets. Rare earth magnets are magnets which have as their primary components metal compounds consisting of rare earth elements and cobalt. The samarium-cobalt magnet which was developed first was refined in the 1970's, and the value of the "maximum energy product" (MGOe: megagauss-oersted), indicating magnetic performance, was dramatically boosted (Diagram 3).

However, the samarium-cobalt magnet had disadvantages. Both cobalt and samarium were scarce and costly resources, and they were not magnetic materials which could meet large demand. Thus, in the 1970's, there was a growing demand for an inexpensive, strong magnet.

The creation of neodymium magnet was inspired by a symposium lecture

The desire to invent with one's own hands a rare earth magnet without the use of cobalt...such was the big dream of Dr. Masato Sagawa who joined a domestic electronic company after completing a doctorate course at the graduate school of Tohoku University. Dr. Sagawa received an important inspiration when he attended a symposium. At the symposium, Dr. Masaaki Hamano, who was the leading researcher for rare earth permanent magnets who now serves as a fellow of the Society of Non-Traditional Technology, gave a speech about the difficulty of replacing cobalt with iron in the rare earth magnets.

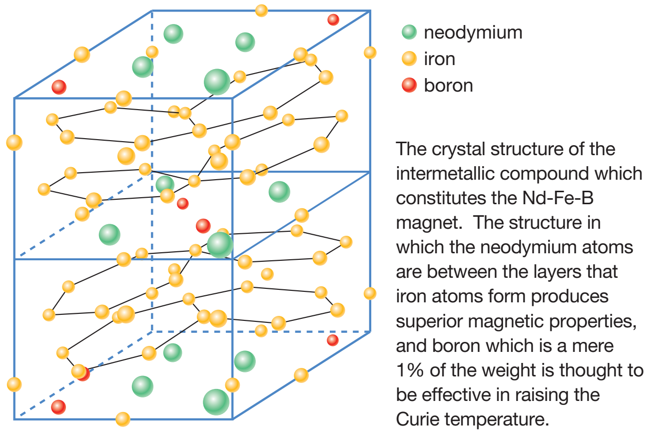
One of the challenges in rare earth magnets using iron was the low Curie temperature which is known as the temperature above which the magnetic ordering disappears. In the crystal structure composed of rare earth and iron, the interatomic distance of the iron was too close, which causes the low Curie temperature. This was the explanation of Dr. Hamano.

While listening to the lecture, an idea came to Dr. Sagawa's head. The idea was, "if elements with small atomic diameter such as carbon or boron were placed between the rare earth and iron atoms, the distance between iron and iron would be extended and the Curie temperature could be raised." Also, "as rare earth elements, neodymium which is a more abundant resource and with greater magnetic moment, should be used in place of samarium."

There are 2 steps in inventing a magnet. The first step is to find an intermetallic compound that has great makings for a high performance magnet. The second step is "making a permanent magnet" in order to develop the optimum alloy microstructure based on the new intermetallic compound. Following the symposium, Dr. Sagawa immediately began working on the experiment of magnetic materials combining these elements, and after a few months discovered the Nd-Fe-B intermetallic compound. He had a succession of new ideas for making a permanent magnet based on the new intermetallic compound, but because the company he was affiliated with was engaged in a different project, he was not able to engage in full-scale development of a new permanent magnet.

Amid such a background, it was Sumitomo Special Metals Company (now Hitachi Metals Limited, NEOMAX Company) that took notice of the potential of Nd-Fe-B magnet and welcomed Dr. Sagawa to join them. Dr. Sagawa, along with the Sumitomo Special Metals development team, embarked on the effort for making a permanent magnet, and within a few months after Dr. Sagawa joined this company and 5 years from his initial inspiration, a new permanent magnet base on the Nd-Fe-B intermetallic compound was borne; it has a Curie temperature as high as 310℃ and the maximum magnetic energy product of 35MGOe. Around the same time, certain companies overseas also took notice of the Nd-Fe-B magnet, but Dr. Sagawa and his associates continued to pioneer new approaches in the research for the commercialization of the new magnet. For example, in producing the magnet, a sintering method which had high volume efficiency and a wide range of application had been selected by Dr. Sagawa. To industrialize this process, it was necessary to develop a sophisticated technology to form a microstructure suited for a high performance permanent magnet by handling ferromagnetic particles broken down into micron order.

Diagram 4 : Revealed structure of Nd-Fe-B magnets



The crystal structure of the intermetallic compound which constitutes the Nd-Fe-B magnet. The structure in which the neodymium atoms are between the layers that iron atoms form produces superior magnetic properties, and boron which is a mere 1% of the weight is thought to be effective in raising the Curie temperature.

In addition, they were still in the process of development and had various issues to overcome before commercialization, such as further improvements in heat resistance and corrosion resistance. However, by replacing a part of the neodymium with dysprosium, heat resistance was improved and with the newly developed coating technique, the heat corrosion problem was also overcome.

The progress of neodymium magnets has achieved energy conservation and is contributing greatly to the preservation of the global environment

Neodymium magnet, the world's strongest magnet was created from the inspiration gained at the symposium in 1978. In the 1980's and 1990's, research and development was carried out, and presently, neodymium magnets which have the dream-like performance of 50MGOe are being mass produced.

Additionally, the impact that neodymium magnets have had on society has also proved extremely great. Not only they have made possible higher performance electronic products including HDDs, which serve as external storage for computers, but they have also contributed towards the development of environmental technology such as energy conservation and new energy sources.

Furthermore, motors using neodymium magnets are more compact and have higher efficiency in comparison to the conventional dielectric motors. Thus, they are used extensively from household electronic appliances such as air conditioners, refrigerators and vacuum machines to elevators, transport machinery, machine tools and heavy construction machinery, thereby contributing greatly to energy conservation. Motors account for a high percentage in the global power demand, and in Japan, for instance, it occupied 57% of the domestic power demand in 2005. By replacing traditional induction motors with high efficiency motors using neodymium magnets, a considerable amount of electricity can be saved. Additionally, not only are they used as effective measures against global warming and application for wind-generated electricity which is rapidly spreading as a new source of energy, but they are also used for all hybrid and electric cars. Thus, their contribution toward energy conservation and the reduction of carbon dioxide emissions is steadily increasing.

In 1988, Dr. Sagawa founded Intermetallics, a research and development company. In cooperation with university researchers, he has pioneered new potential for neodymium magnets. For example, in order to improve the temperature properties, a large quantity of dysprosium is used in neodymium magnets. However, similar to cobalt, dysprosium is a very rare resource. Intermetallics has developed a new manufacturing process where dysprosium use can be reduced to a half or eventually to one-tenth in order to achieve the same conventional magnetic force. It is anticipated that this can lead to increasing popularity of environmentally friendly electric cars and effective use of natural resources.