History of Permanent Magnet Research: Development Commenced in Response to Social Demand

A permanent magnet produces a magnetic field automatically and constantly without any external energy supply. The first permanent magnet was found in naturally occurring mineral in Magnesia, Greece, in about 600 BCE. An artificial permanent magnet was developed by Dr. Kotaro Honda in 1917, which was followed by various other types of artificial magnets. At the same time, research on a magnet that combined cobalt and a rare earth also progressed. In 1969, Dutch scientist K.H.J. Buschow and his colleagues established a compression molding process to manufacture magnets, and this process enabled the commercialization of samarium-cobalt permanent magnets.

However, both samarium and cobalt are rare earth elements, primary produced in Africa which entails associated price rise risks. As it is essential to secure stable mass production for industrial use magnets, what was really sought was a high-performance magnet made from abundant and low-priced materials.

Present and Future of Neodymium Magnets: Overcoming Challenges and Widening Applications

Neodymium magnets suffered from low thermal durability compared to samarium-cobalt magnets when applied in industrial purposes. This issue was addressed by adding dysprosium (Dy), another rare earth element, which improved the magnet's thermal durability to nearly 200°C, thereby enabling applications in motors.

The magnet requires the proportion of dysprosium to be approximately one-third of the neodymium by weight to make it thermally durable; however, the estimated global reserves of dysprosium are less than one-tenth those of neodymium. This forced the research to reduce the use of dysprosium. A solution was eventually found in the technological innovation of grain boundary diffusion, (*) which significantly improved the coercivity at the same time.

Forty years after its invention, uses and applications of the neodymium magnet are widening. Its powerful coercivity contributes to both the downsizing and weight reduction of motors. Sintered magnets are used in a range of areas, including automobiles, air conditioners, hard disk drives, washing machines, vacuum cleaners, elevators, and industrial machinery, contributing to energy saving. The easy-to-shape bonded neodymium magnets are found to be particularly useful in small sites where compact yet high-performance magnets are required, such as spindle motors in hard disk drives, small motors in automobiles, and mobile phone speakers. The hot-deformed neodymium magnet is mainly used in driving motors and electric power steering motors for automobiles.

Demand for neodymium magnets is expected to greatly increase—particularly for motors in the next generation of electric vehicles (xEVs), wind turbines, drones, and electric airplanes. Therefore, it is necessary to improve the magnet's characteristics even further. Neodymium magnets also support the evolution of energy-saving technologies designed to reduce CO_2 emissions. This is another factor that would further increase demand for the magnet towards achieving carbon neutrality. The importance of streamlining manufacturing is also increasing, including improving resource efficiency and recycling technology.

Expectations are further rising for the continued development of magnetic materials to improve their characteristics and to resolve any issues in their manufacture.

Note:

* Grain boundary diffusion: A method to diffuse heavy rare-earth elements—which tend to spread over the surface of the magnet—into the intergranular spaces by applying high temperatures. The heavy rare-earth elements are dispersed through the spaces between crystal grains (grain boundaries) and concentrate on the surface of neighboring crystal grains. This improves thermal durability with a smaller amount of heavy rare-earth elements,

while preventing any reduction in the coercivity due to unwanted local concentrations of the heavy rare-earth elements.