PRO+ MATERIAL STORIES –Main Story–

01 Specialty Steel

The breakthrough is our proprietary TiN miniaturization technology that we have discovered through the structural and compositional control technology which we have continuously refined.

Through a continuous cycle of material creation that is ideally suited to the sophisticated demands and challenges of its customers and the perfection of these materials to a level that can be provided for mass production, Proterial has developed a succession of unique materials that boast high functionality and quality which are then deployed to new applications and new market domains. We will introduce special steel with which we are facing the challenge of full-scale entry into aircraft-related materials based on the development of CVT belt materials and the technology that is the result of a spiral of improvement through co-creation with customers, centered on our proprietary metal structure and composition control technology.

What is Specialty Steel?

The term “specialty steel” is a general term for steel that has been adjusted by adding alloying elements to give it properties that are suitable for its intended use and required characteristics. While common steel is made primarily from iron and 2% or less carbon, specialty steel is made by adding special elements such as nickel and chromium or adjusting the composition in order to specialize characteristics such as hardness, wear resistance, heat resistance, and corrosion resistance.

Major Products

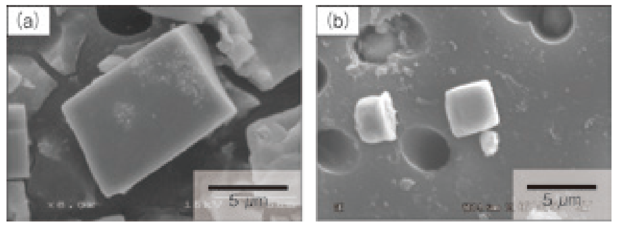
1 Metal structural and compositional control technologies forming the core of value creation

When conceiving of new products and businesses, the metal structural and compositional control technologies that we have built up over the years serve as a source of value creation. Relying on thermal treatment and additive element optimization, these technologies control the microstructures that determine the toughness, wear resistance, heat resistance, workability, and other characteristics of metals. By enhancing these structural and compositional control technologies, we are able to provide metals with a variety of characteristics, even when their chemical composition is the same. As a specialty steel product, continuously variable transmission (CVT) belt materials used in automobile engines also serve as an example of a component material that we developed by leveraging our structural and compositional control technologies. CVT belts are made by layering about ten flat belts of metal just seven to eight millimeters wide, and securely fabricating these belts into continuous strips, thereby functioning as the transmission to convey motive power from the engine to the tires. Power is transmitted via a belt rather than gears, meaning that there is no shock when changing gears, and they are characterized by good combustion efficiency because it is possible to change gears continuously in accordance with engine revolutions. Demand for these products has also been increasing as automobile manufacturers have been working to improve fuel efficiency. We currently boast the world’s top share (Proterial estimate) of the market.

CVT belt materials

2 From high assessment of our material development capabilities to mass production of CVT belt materials

In the automobile domain, we have built collaborative relationships with Japanese automobile manufacturers through the development of highly complex specialty materials used under harsh environments as part of an effort that has primarily focused on forging materials for engine valves. The relationships of trust we have fostered have also served as the motivation for why our customers choose us as their development partner when conceiving new products. Since the 1990s, we have conducted development of technologies designed to constrain the growth of nitrides contained in metals (TiN) using our structural and compositional control technologies for the energy domain. The development of CVT belt materials was similarly triggered when a Japanese automobile manufacturer who recognized our materials development capabilities approached us about whether we could engineer a CVT belt material with a refined TiN grain. In order to obtain a fatigue strength that can withstand the more than 10 million rotations corresponding to the usage environment of automobiles, the material surface must be free from defects. Specifically, the structure must be controlled to ensure that the inside of the metal is devoid of contaminants to the greatest extent possible. In particular, larger TiN grains lower the fatigue strength of the metal. For this reason, we had to address the extremely challenging demand to constrain the size of the grains to less than 10 microns, about half the conventional grain size.



CVT belt material structure

3 Proprietary TiN miniaturization technology leading to the solution of difficult problems

It took three years for our TiN miniaturization technology to reach the level of quality required by our customers. At the outset of mass-production, the acceptance rate for the TiN dimensional standard was only about 10%, yet we continued to develop the technology further in order to improve the yield. As we did so, we came face-to-face with a new challenge, namely that different samples would demonstrate varying TiN grain sizes and unstable quality, even at the same level of nitrogen content. However, we patiently evaluated and verified the production process, and eventually discovered that the TiN grain size correlated to the magnesium content of the material. Having identified the technological background, and having also analyzed the mechanisms, the way opened to stable mass production through quality control that actively utilized magnesium. Our CVT belt materials that help increase the fuel efficiency of automobiles have been adopted by many automobile manufacturers. We also addressed new demands from our customers, including detoxifying the impurities in the metals, based on the test results and knowledge we had acquired through our past technological developments, resulting in our product being installed in a growing number of vehicle models and becoming a mainstay product that has driven our sales upward since 2010.

Aircraft engine

4 Opening up a new future with organization and composition control technology

The TiN grain refinement technology we acquired through the development of CVT belt materials expanded in new ways. This included application as an aircraft-related material. As our next pillar of business, the Company has focused on developing aircraft-related materials indicating an outlook for market expansion over the medium- to long-term. We have steadily implemented measures to achieve growth, including the establishment of the joint venture Japan Aeroforge, Ltd., the introduction of a 50,000-ton hydraulic forging press, which is one of the largest in the world, as well as major investments (including investments certified by the Ministry of Economy, Trade and Industry’s Supply Security Plan) at our Yasugi Works (Yasugi City, Shimane Prefecture) and Okegawa Works. As we made progress in these efforts, we received a request to develop a material for aircraft jet engine shafts in a way that applied the technologies for automobile CVT belt materials. Although the performance required of aircraft-related materials is vastly different from that of automobiles, control technologies established through our technological developments enabled stable control of fatigue strength, and we have also successfully deployed products at a relatively early stage in the aircraft market area.

In this way, structural and compositional control technologies have the great feature of being able to create different characteristics even with the same materials, and continuing to refine this technology has led to business development in new fields. We will continue to evolve our structural and compositional control technologies that maximize the potential of metals, thereby providing ideal materials that contribute to solutions for our customers’ challenges.

Yasugi Works

PRO+ MATERIAL STORIES –Main Story–

02 Soft Magnetic Materials

The world’s first nanocrystalline soft magnetic material, created by combining materials and applied technologies cultivated through research and development, as well as through the passion of our researchers.

Nanocrystalline Soft Magnetic Material FINEMET® was commercialized for the first time in the world by Proterial in 1988. It has excellent characteristics and is making significant contributions to miniaturization and energy saving of various electronic devices such as smartphones. However, the path has not been smooth; it has been built through structural and compositional control technologies centered on metals, and strong relationships with a wide range of customers.

Initiatives at the Next Generation Tatara Co-Creation Centre

The Next Generation Tatara Co-Creation Centre (NEXTA) was established at Shimane University as a facility that plays a central role in research and development and human resource development in the “Creation of a Global Base for Advanced Metals - Next Generation TATARA Project -”, a project involving industry, government and academia in Shimane Prefecture. The ultimate goal of the Centre is to create a “Next Generation Tatara Culture”, and it focuses on innovation and the improvement of metal materials. In addition to Proterial’s employees supervising the operations of the project and serving as vice director of the center, the Company is also participating in the “Mass Production of Amorphous Motor Cores” project in the field of soft magnetic materials.

Photo provided by: Shimane University

1 About Nanocrystalline Soft Magnetic Material FINEMET®

FINEMET® is a nanocrystalline soft magnetic material developed for the first time in the world by Proterial. It is thin and ribboned with a unique nanocrystalline structure comprised mainly of iron, with additives of silicon, boron, and trace amounts of copper and niobium. By heat treating thin ribbons of amorphous (lacking crystalline structure) alloy, produced by the rapid quenching and solidifying of high-temperature molten material at a rate of approximately 1 million degrees Celsius per second, nano-sized (about 10 nm) crystal grains are created within the structure. It was generally believed that amorphous alloys had better magnetic properties than ordinary metals (those with a crystalline structure). However, Proterial discovered the surprising fact that the magnetic properties of a material could be dramatically improved through the use of nano-sized crystal grains, and in 1988 we became the first company in the world to commercialize a nanocrystalline soft magnetic material.

Until FINEMET® was commercialized, permalloy and cobalt-based amorphous alloys were used in power supplies and electronic circuits because of their superior soft magnetic properties compared to metals with common crystalline structures. Conventional soft magnetic materials had both advantages and disadvantages; for example, some had excellent permeability[*1] but insufficient saturation flux density[*2], while others had high saturation flux density but insufficient permeability. The introduction of FINEMET®, with its high saturation flux density, excellent magnetic permeability and low core loss[*3], has greatly contributed to the miniaturization and energy saving of smartphones and numerous other electronic devices.

Nano Magnetic Material FINEMET

2 The DNA of an experimentation first approach and the passion of developers led to the development of a world first

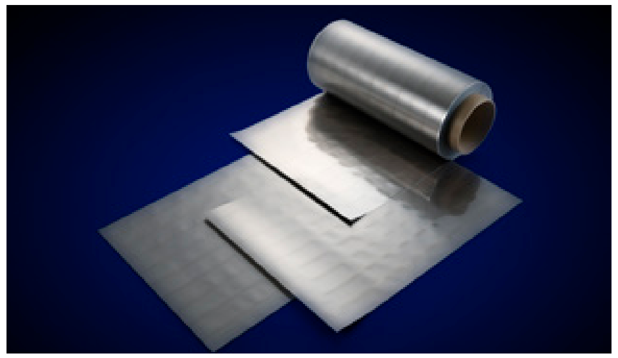
In the late 1970s, the development of new materials such as amorphous metals[*4] caught the world’s attention. At the time, Proterial’s Magnetic Materials Research Laboratory was also working to develop new materials for use in the electronics industry as a mainstay of future growth. The development of new magnetic materials is difficult, however, and practical application can be extremely challenging. This is because the properties of magnetic materials are related to phenomena at the atomic level, and the composition of such materials is subject to tens of thousands of permutations. As a result, repeated experimentation was really the only way to develop a product. And that experimentation uncovered a phenomenon that would later surprise the world. It was common knowledge that amorphous alloys generally crystallize when heat treated, resulting in deterioration of soft magnetic properties. However, in the course of repeated investigation in the early 1980s, our researchers recorded data that demonstrated better magnetic properties than those of amorphous alloys. Not overlooking this phenomenon, which was at first put down to experimental error, the company pursued the acquisition of a patent and establishment of a manufacturing process, and in 1988, succeeded in commercializing FINEMET®. This achievement was made possible by the strength of our experimentation-focused DNA and metal-centric microstructure and composition control technology.

FINEMET Common-mode choke cores/coils

3 Production efficiency improvements and the needs of the times have aligned to take us to a new stage

Following the commercialization of the nanocrystalline soft magnetic material FINEMET®, however, there was not immediate, widespread demand. We knew its characteristics were overwhelmingly superior, but it was a product that was so far ahead of its time, it required some ingenuity in application. And small production volumes forced us to charge very high prices. In the 2000s, regulations on electromagnetic noise being tightened stimulated demand and increased opportunities for dialog with customers about FINEMET®’s applications. Nevertheless, with the price still high, there was no explosive uptake. However, we foresaw the global desire for our product based on conversations with customers, and with repeated improvements to nanostructure control technology and manufacturing equipment, we managed to greatly improve production efficiency. In 2008, smartphones began to be equipped with wireless charging functionality, leading to a sharp increase in demand for FINEMET®. Then the trend toward EVs in Europe producing stricter electromagnetic noise regulations further fueled the material's success.

FINEMET® has come to be used as a soft magnetic material far more widely than any other material. So although it took some ten years for the technology and applications needed for its full utilization to catch up, FINEMET® has at last become indispensable.



Magnetic shield

4 Soft magnetic materials are becoming increasingly important for the realization of a decarbonized society

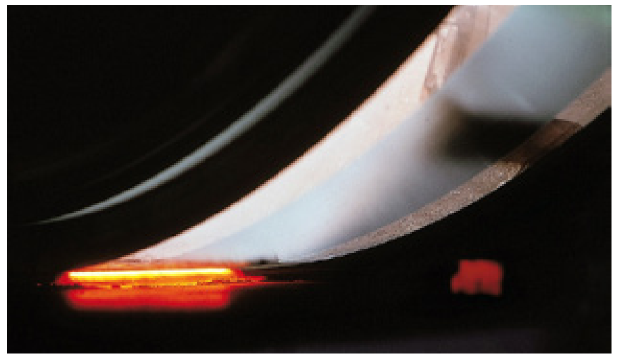
Today, across a variety of fields, there is a trend toward making devices that are more energy efficient, more compact, more lightweight, more functional and less emissive of noise. For such applications, soft magnetic materials are becoming even more important. In particular, with its significant features of both high saturation flux density and permeability as a soft magnetic material coupled with low core loss, we project that the applications of FINEMET® will continue to expand. Proterial will go on helping to solve social issues by providing soft magnetic materials such as FINEMET® that can contribute to the realization of a decarbonized society.

*1 Permeability: This is a measure of the ease with which magnetic flux can pass through a magnetic material. The magnetic permeability of FINEMET® is equivalent to that of Co (cobalt)-based amorphous materials.

*2 Saturation flux density: This is the maximum magnetic flux density that a magnetic body can hold. When magnetic saturation occurs, inductance decreases rapidly and excess current flows, causing abnormalities and malfunctions in devices and circuits. The saturation flux density of FINEMET® is equivalent to that of Fe (iron)-based amorphous materials.

*3 Core loss: The core loss of FINEMET® being less than 1/5 that of Fe-based amorphous materials and equivalent to that of Co-based amorphous materials leads to energy savings.

*4 Amorphous metal: A solid metal that does not have a crystalline structure. While ordinary metals have a crystalline structure with atoms arranged in an orderly fashion, amorphous metals have an irregular atomic arrangement, and have high wear resistance, high hardness, high magnetic permeability that allows magnetic energy to pass through easily, and high magnetostriction that converts electromagnetic energy into mechanical energy.



Manufacturing FINEMET