Featured Topic: Direction of Research and Development in Industrial Materials Group

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1. Introduction

At Sumitomo Electric Industries, Ltd., the Industrial Materials Group is only one of five business segments that was organized according to our product category: materials, rather than market. Therefore, it is difficult to find consistency in customers, market, application, and research and development (R&D) direction in each business area.

On the other hand, there is a commonness in that each industrial materials division tries to make the materials and their quality unique and thus to differentiate these materials from the products of our competitors. In the development of new materials, the responsible divisions are also common in approaching the R&D projects scientifically and efficiently by employing computational science, machine learning, and other tools, which will be discussed later.

At the occasion of the publication of this special issue on industrial materials, I briefly describe the history and future direction of development in each of our businesses with a focus on materials.

2. Hard Metals - Cutting Tool Materials

Our hard metal (powder alloy) business has developed over many years with cutting tools as the principal use of this material, and the development of hard metals in this division has made the history of the development of cutting tool materials.

Our hard metal business began in the 1920s when cemented carbide developed in Europe was used for our wire drawing dies. Cemented carbide is a composite material composed of tungsten carbide (WC) as the hard phase and Cobalt (Co) as the binder phase. Due to its excellent balance between wear resistance and chipping resistance, cemented carbide has been used widely as a material for cutting tools, having a large market size. Figure 1 simply shows the evolution and development direction of hard materials for cutting tool use, with the dates in which they were unveiled on the horizontal axis and wear resistance, which directly affects their service life, on the vertical axis. The application of cemented carbide to cutting tools dramatically changed the long-lasting trend in the era of high-speed steel.

Figure 2 shows the technological transition in the development of cemented carbide and coating. The ACE layer, which was developed in the 1970s, and the titanium carbide (TiC) coating by chemical vapor deposition (CVD), were epoch-making technological breakthroughs that dramatically improved the toughness of the surface of

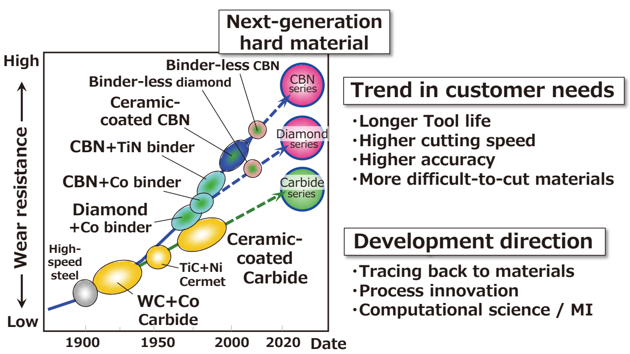

Fig. 1. Evolution of hard materials for cutting tool application and their development direction

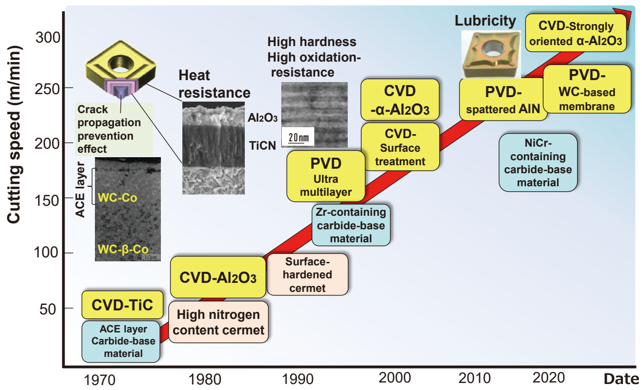

Fig. 2. History of carbide tool development

carbide-based materials. After that, carbide-based materials were upgraded to Zr-containing base materials in the 1990s to meet the needs of customers for cutting steel at higher speeds. In 2020, the base material was further refined by adopting the Nickel-chromium alloy (NiCr) binder phase, having outstanding high-temperature strength. This material has made it possible to cut Inconel and other heat-resistant alloys at higher speeds.

On the other hand, our coating technology has progressed in the form of the CVD and physical vapor deposition (PVD) methods. The latest topics are that the CVD method has evolved until it enables high-speed cutting of ferrous metals through the use of fine and strong orientation technology for α-Al_2O_3 membranes, while the PVD method allows high-speed cutting of titanium alloys through the industry's first use of WC-based membranes.

In addition, the development of artificial diamond in the 1950s through the use of ultra-high-pressure technology and the invention of cubic boron nitride (CBN) in the 1960s were excellent development results in the field of cutting tool materials. In particular, we developed the world's first low-content CBN sintered material in the 1970s, which is sintered with a ceramic binder composed mainly of CBN and titanium nitride (TiN). This CBN-sintered material made it possible for the automotive and other industries to replace grinding hardened steel with higher-efficiency cutting. At present, we are continuing to expand a material lineup suitable for various use environments and thus to accelerate and lead the realization of higher-efficiency, higher-precision cutting through the use of various ceramic coatings. Since 2010, binder-less diamond/CBN sintered material have been developed continuously, and their use for cutting titanium alloys, cemented carbides, and other non-ferrous hard-to-cut materials is increasing. However, it is a matter of regret that no substantially hard new material has appeared on the market since CBN did. In the future, we are required to develop new materials by tracing back to their raw materials or to develop next-generation hard materials by anticipating customer needs in advance and utilizing microstructure control technology through the innovation of production process.

3. Special Steel Wires

At Sumitomo Electric, we started the R&D of special steel wires in 1927. For piano wires, one of our current three flagship products, we started their development jointly with then Sumitomo Metal Industries, Ltd. (Nippon Steel Corporation at present) and began to deliver them in 1940, thus marking more than 80 years of the history of piano wire. The production of steel wires for prestressed concrete (PC steel wires) and steel cords (SCs) started in 1952 and 1969, respectively. Special steel wires are basically carbon steel wires, and the history of their R&D can be summed up in the history of strength improvement.

Oil-tempered (OT) wires, which have been evolved from the longest-living piano wires and are mainly used to make automotive springs, are the core products of our precision wire business. In order to reduce fuel consumption and the weight of automobiles, OT wire materials are required to have higher tensile strength and fatigue strength. Currently, OT wires with fatigue strength of up to 1500 MPa have been put to practical use. For SC that are mainly used for automobiles (tires), we have also reduced their diameter (≒ increased strength) and increased their corrosion resistance in response to customers' requirement for improving the fuel efficiency, maneuverability, and durability of automobiles. However, it is hard to expect that both OT wires and SC will expand sales in the future, due to the shift of automobiles to electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs) and the entry of Chinese companies into the markxet. The important challenges we are facing are to find new uses for these products and differentiate them through design development.

Because PC steel wires are used in combination with concrete, they have been developed with attention paid to moderate elongation and toughness, high fatigue strength, corrosion resistance, and durability, in addition to their strength. High-performance steels, such as epoxy coated and filled (ECF) strands which are made by coating the surface of stranded PC steel wires with highly corrosion-resistant epoxy resin, as well as those with optical fibers embedded to enable tension measurement, are unique products that verify our comprehensive strength.

4. Sintered Alloy

The history of our sintered alloy products can be dated back to 1948, when oil-impregnated bearings made of copper powder were launched. Since then, the sintering material has evolved from copper to iron powder, and the use of sintered alloy products has expanded from home appliances to automobiles. With the popularization of automobiles, the use of sintered alloy parts has expanded continuously mainly as engine parts and drivetrain parts. At present, the ratio of dependence of our sintered alloy parts on automobiles exceeds 90%. Sintering is characterized by its ability to mass-produce parts of complex shapes at low cost, rather than by materials. Compared to other businesses, the resources seem to have been poured more into the development of manufacturing engineering technology than into the development of new materials. However, the urgent issue we must address under the current situation in which automobiles are rapidly shifting to EVs is to find new uses of sintered alloy parts for the survival of this business. Some examples of approaches are to promote the replacement of parts that will be continuously used even in the future with sintered alloy parts and to use sintered alloy parts as non-automotive parts, such as soft magnetic composites for axial motors that are used to downsize various drive units. We are also required to trace back to the raw materials, which are now purchased products, with a fresh mind in order to concentrate on the development of new non-ferrous, functional parts through the development of unique metals and their production process.

5. A.L.M.T. Corp.

Finally, the business of A.L.M.T. Corp. is described. This company was founded in 2000 by merger of Tokyo Tungsten Co., Ltd. and Osaka Diamond Industrial Co., Ltd.

The principal products of the former were tungsten (W) powder, molybdenum (Mo) powder, and sheet materials, while the latter had been engaged in the production of diamond-based dies, grinding wheels, and cutting tools. In 2003, we integrated the business of functional components, such as heat dissipation substrates, into that of A.L.M.T. Corp. The products made by this corporation and the market for the products are extremely varied compared to the other three businesses that have already been discussed. Accordingly, the R&D direction of the corporation is also diverse, but one of the businesses that is expected to grow in the future is the heat management business. This business begins with the advancement of our original technology we have cultivated through the manufacture of heat spread substrates to a technology for controlling heat, such as heat generation and heat storage. My suggestion is to combine the above technology with our proprietary material technology and porous metal and other materials design technologies, thus creating a new technology that enables the optimal use of thermal energy.

6. Approach to Digital Transformation (DX)

A typical application of simulation technology is the visualization of stress, deformation, and other phenomena using the finite element method. With recent advances in supercomputers and other devices, it has become possible to analyze and visualize various dynamic phenomena at the atomic level. Most hard materials are composites, and their material characteristics depend on the composition, texture design, and interfacial structure between different component materials. Recently, first-principles calculation is used to calculate the interfacial strength between the hard phase and binder phase with a high degree of accuracy, and the calculation result is checked by observing the actual interfacial structure under an atomic resolution, transmission electron microscope (TEM). In this way, computational science approaches that enable elucidation of phenomena at the atomic level are becoming a major weapon for new materials development. In addition, the application of materials informatics (MI), which uses machine learning and other information sciences, to materials development is expected to enable us to create new substances and to develop materials in new categories without spending a great deal of time.

7. Conclusion

As stated in our 2030 VISION, industrial materials widely support the progress of infrastructures/industries, and the Industrial Materials Group gives us a substantial competitive advantage. On the basis of materials, this special issue covers the shapes of materials, the development of their application, and our GX challenges. I hope that you will become familiar with the breadth and depth of the areas supported by industrial materials, even if only partially.

• Inconel is a Ni-based heat-resistant alloy and is a trademark or registered trademark of Huntington Alloys Corporation.