Research and Development

In the course of promoting The TOP 2021, the medium-term business plan, the Showa Denko Group aims to become a world-leading manufacturer of functional chemicals. Based on the key concepts of *deepening*, *fusion*, and *introduction*, the R&D strategy focuses on creating "pipelines" for products that will contribute to the next generation, while continuing to strengthen existing operations with the aim of creating *Koseiha* businesses. Our intent is to maximize customer experience (CX) by providing our customers with first-class engineering, products, and services.

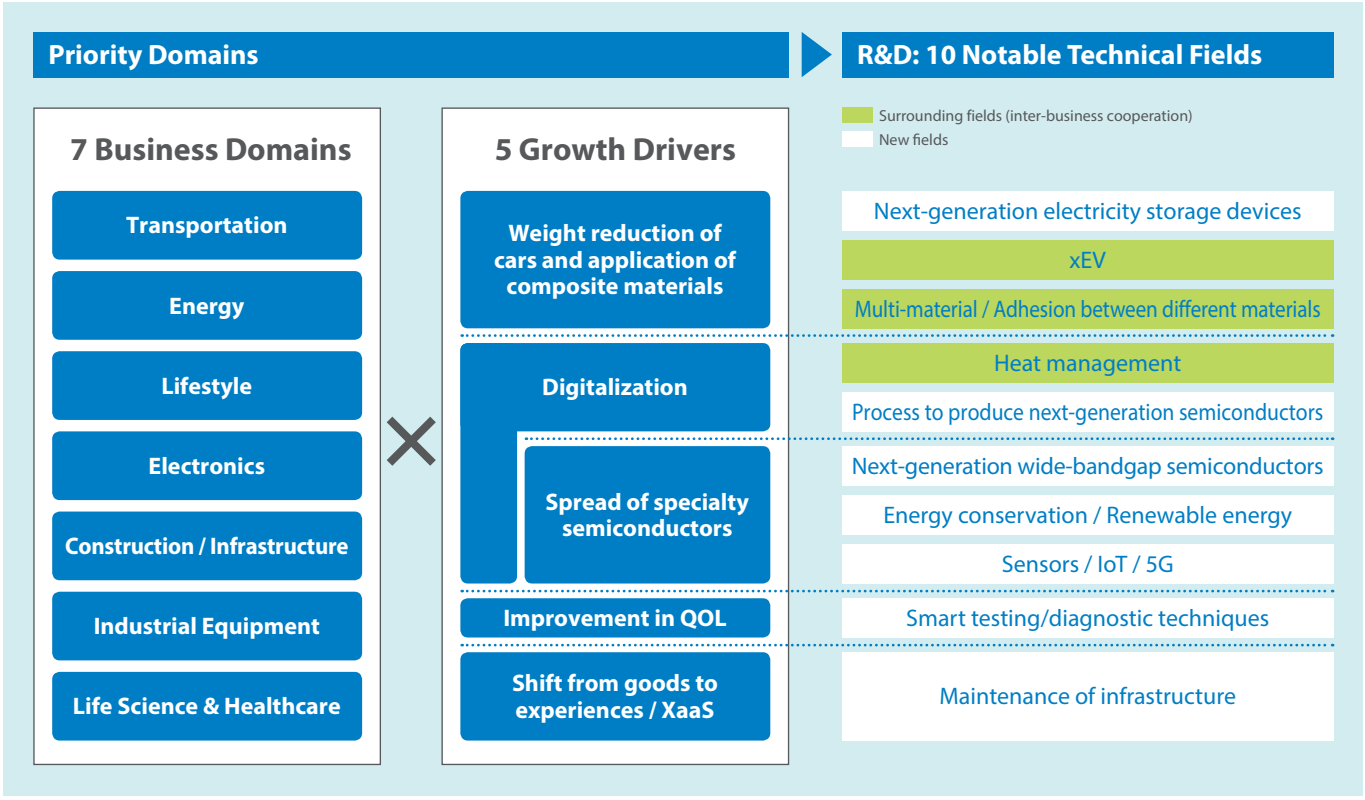
To strengthen the creation of these "pipelines," we will fundamentally reinforce our marketing programs to achieve a firmer grasp on market and technology trends when identifying targets for R&D, and to invest our R&D resources intensively in 10 technical fields, including those that are multi-material or that promote adhesion between different materials and for processes to produce next-generation semiconductors. These 10 targets correspond to our seven business domains: Transportation, Energy, Lifestyle, Electronics, Construction/Infrastructure, Industrial Equipment, and Life Science & Healthcare.

The Advanced Technology Lab, established in 2019, is exploring and drafting proposals for next-generation research themes, based on unrestricted thinking and perspectives that are not constrained by the trends and "tides" of the industries served by the Group and current business fields.

Our initiatives to strengthen existing operations—with the aim of creating *Koseiha* businesses—will be centered on the Institute for Integrated Product Development, which was reorganized in 2019. At the same time, measures to "deepen" and "fuse" a variety of human resources and technologies are being further accelerated and expanded, then rolled out to the Company as a whole. In addition, computational science, analytical technology, and evaluation technology will be positioned as basic research themes that facilitate the fusion of the various technologies of the Group, and these technologies will be further strengthened going forward. Moreover, we will actively introduce any necessary technologies from outside entities, through M&As and by adopting approaches such as open innovation.

As a base for embodying the concepts of The TOP 2021, we will build the new Stage for Fusion complex, providing a global center for accelerating *deepening*, *fusion*, and *introduction*, both inside and outside the Company. The Stage for Fusion is scheduled to begin operating in 2022 next to the Yokohama Plant.

Through R&D, the Group will create products and services that touch the hearts of customers, and that offer solutions that make society better.

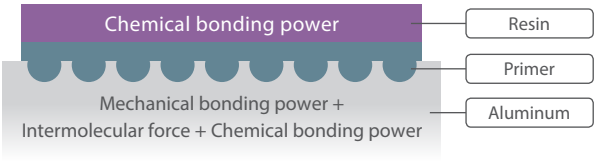


R&D Topics

1 Established technology for directly bonding aluminum alloys and polycarbonate resin

The Group has developed an innovative technology to directly join/bond aluminum alloys and polycarbonate resin (a general-purpose amorphous engineering plastic), *without using an adhesive*. Most current methods for joining or bonding aluminum alloys and polycarbonate resin use fasteners (bolts and screws) or adhesives. In recent years, much attention has been focused on new technologies that directly join/bond resin materials to metallic materials at the time of injection molding. These new technologies are expected to bring advantages, such as the simplification of processes, increased productivity, and enabling processing into complex shapes. In many cases, however, these joints depend on the power of mechanical bonding, such as the anchor effect resulting from applications of resin onto a roughened metal surface. For this reason, it had, up to now, been believed that joining/bonding metallic materials to polycarbonate resin and other amorphous engineering plastics was impractical using conventional methods.

The Group has leveraged our expertise in aluminum alloys and polymer chemistry—accumulated over many years—to directly join/bond aluminum alloys to polycarbonate resin, after the aluminum alloys have undergone both a special surface treatment and the application of a primer. The innovative joining/bonding technology that SDK has developed consists not only of the anchor effect but also of a chemical bond. Our experiments show that this technology can be used under ordinary polycarbonate molding conditions to provide bonding strength in excess of 25 MPa (megapascals), more than enough for practical use. Neither special conditions nor additional equipment are required to achieve a strong bond.



2 Developed repair materials for concrete structures that can be used in cold regions

The Group has developed the *SHO-REPAIR*™ CR-1000 series and the *RIPOXY*™ CR-1500 series of repair materials for repairing various types of concrete infrastructure in low-temperature conditions, such as cold regions.

The infrastructure built up during Japan's "high-speed growth" era continues to deteriorate, resulting in the increasing need for rebuilding or repair. Because rebuilding is expensive, demand for repair is strong. However, there is a problem: existing materials require heaters to cure them after they have been applied to repair concrete structures in low-temperature environments. This makes it impractical to do repair work during the winter months in cold regions. Both of our newly developed repair materials can be used in subzero temperatures without heat curing after application, and they harden to a level suitable for normal use within 24 hours—less than one-third the time required for existing products. Because of these advantages, the new materials are expected to be used on construction during the winter in cold regions, to reduce costs by shortening construction time, and to improve convenience (faster turnaround at construction sites).

3 Built an AI-based patent interpretation support system

In conjunction with IBM Japan, the Showa Denko Group has built a patent interpretation support system for effectively and efficiently screening patent information. Group-wide operation of this system began in July 2019. Using this system is intended to lead to a significant reduction in the time taken by engineers to read and understand patents.

This patent interpretation support system uses cognitive technology from IBM's Watson Explorer, enabling the comprehensive and cross-sectional collection of information, which is then subjected to sophisticated classification and analysis. By providing text analysis and search, as well as functionality for building associations between documents, and concept extraction specialized for patent use, this tool supports more efficient reading of patent information. Moreover, because this system is able to build associations between documents that has been optimized for the characteristics of chemical patents —the technology domain of the Group— it provides an interface specialized for improving the readability of these types of patents.

This system gives structure to claims information in long and difficult patent documents with complex dependencies, and enables this information to be visually displayed, allowing engineers to understand the content of patents more efficiently. In trials conducted within the company in 2019, the time taken to read and understand a single patent was reduced by approximately 45% compared with not using this system. To maximize the utility of intellectual property (IP) as a source of corporate competitiveness, not only should rights be asserted over intellectual property, but it is also important that an accurate understanding of intellectual property is maintained at each stage, from searching for themes to commercialization. Introducing this system throughout the Group will not only open the way to more efficient research and reduce the risk of infringing on the rights of other companies, but it will also promote a more strategic approach to intellectual property activities, allowing us to strengthen corporate competitiveness.

R&D Expenditures

(Millions of yen)

Petrochemicals	Chemicals	Electronics	Inorganics	Aluminum	Others	Total
1,314	3,063	6,334	597	1,971	7,326	**20,605**