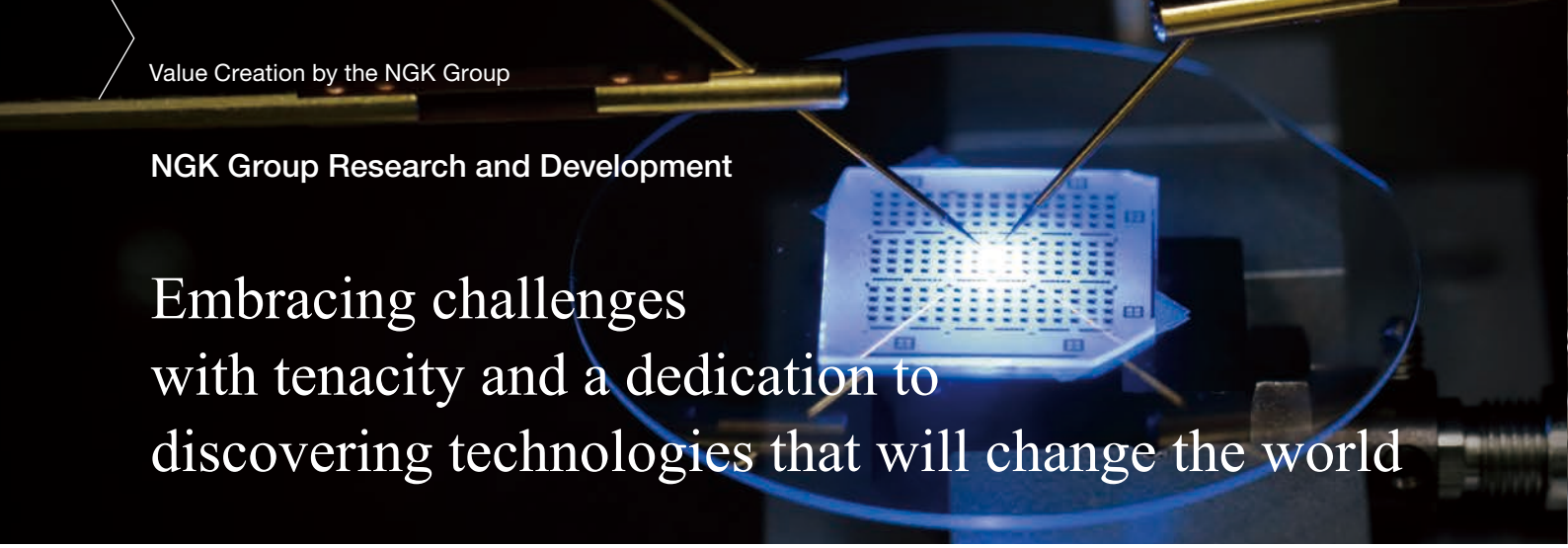


NGK Group Research and Development

Embracing challenges with tenacity and a dedication to discovering technologies that will change the world

R&D Policies

■ Developing ever more advanced technologies and continually creating new products

The basic policy of Corporate R&D is to develop ever more advanced material and process technologies with a focus on fine ceramics while continually creating new and competitive products. We believe that the key is to quickly identify promising seeds and intensively allocate resources to them. We monitor trends and strive to discern market needs. We are stubbornly committed to developing distinctive technologies with the potential to change the world, and we tenaciously embrace the challenges of doing so, a process that sometimes takes more than 10 years. Then we take advantage of our technological strengths in the form of crystalline orientation control*1, multi-ceramics lamination*2, and hydrothermal synthesis*3 to consistently create and supply novel products.

The new product development period lasts anywhere from three to more than 10 years, but we do not give up, even on research that takes a long time to bear fruit. The Development Committee briefs management every year on long-running development projects and seeks a decision on whether to continue them, but in the words of President Oshima, “R&D means embracing the challenge of the impossible.” A culture that makes it easy to embrace such challenges is the strength of the NGK Group’s approach to R&D.

*1 Crystalline orientation control technology: Technology for eliciting high performance by aligning crystallographic grain orientation in ceramics, which consist of large numbers of grains (i.e. polycrystalline ceramics).
*2 Multi-ceramics lamination technology: Technology that laminates different ceramic materials together and then fires them to harden them into a single structure.
*3 Hydrothermal synthesis technology: Technology for forming ceramics in hot water at high pressure, instead of firing them at high temperature to harden them.

Recent Results

■ Developing a new generation of the EnerCera® battery that can withstand harsh, high-temperature environments

Corporate R&D has succeeded in commercializing four new products over the last five or six years. These products are bonded wafers for SAW filters, a microlens for ultraviolet LEDs, gallium nitride (GaN) wafer for laser light, and the EnerCera lithium-ion rechargeable battery. All of the new products are moving onto a growth trajectory. In particular, Corporate R&D has been working with the EnerCera division established last year to market the EnerCera battery on the back of expectations that it would see a variety of uses in a broad range of fields.

We believe that the marketing approach the NGK Group has used for products in the past, specifically visiting particular customers to seek their input, is no longer adequate. Instead, we are approaching and contacting a wide range of latent customers, for example by placing ads in specialized magazines, creating minisites featuring products, and publishing email newsletters. As expected, we are receiving a large amount of input and suggestions from customers in a variety of industries worldwide, and this response is both motivating and encouraging. It has provided a clear view of what the market requires.

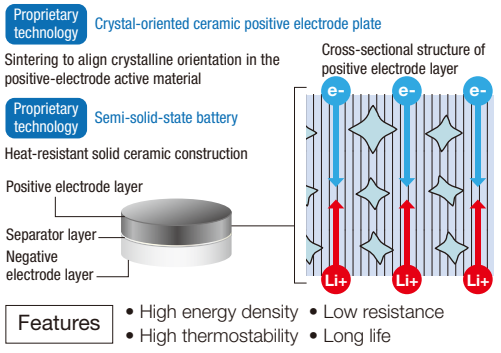
Based on the information we have received, we are currently developing a new generation of the EnerCera battery that can withstand even more demanding, high-temperature environments. Power supplies for sensors installed in automobile tires and backup power supplies used for automated industrial equipment are being called upon to withstand ever-higher temperatures. We have begun shipping samples, and we plan to start mass production in the near future.

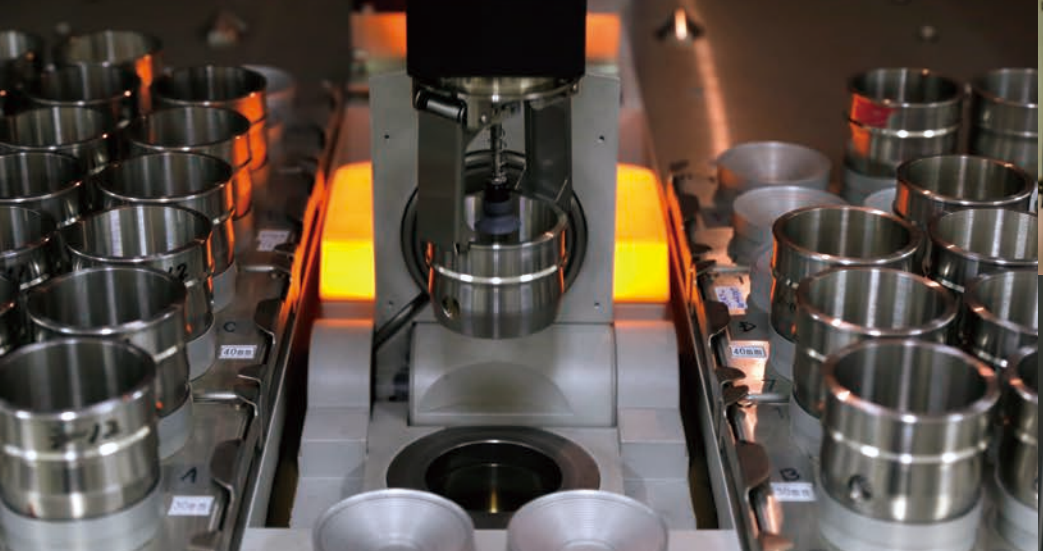
Distinctive Technologies

Delivering small, high-capacity, high-power batteries with high thermal resistance
Crystal-oriented ceramic positive electrode plates and semi-solid-state batteries

The superb performance of the EnerCera battery is achieved by its unique crystal-oriented ceramic positive electrode plate. Unlike the positive-electrode active material in conventional lithium-ion batteries, in which the crystalline orientation is disorganized, the EnerCera battery’s ceramic positive electrode plate has uniformly oriented crystals thanks to our proprietary sintering technology. By allowing lithium ions and electrons to move linearly at high speed inside the active material, this technology has allowed us to deliver small, high-capacity, and high-power batteries.

Additionally, normal electrodes contain organic binders and conductive agents to improve the flow of electricity. These substances are susceptible to heat, which imposes limits on the battery’s thermal resistance. On the other hand, the EnerCera battery’s positive electrode plate does not contain such substances. Furthermore, use of our proprietary semi-solid-state battery design that laminates the positive electrode plate, ceramic separator, and negative electrode plate together into a single structure that contains a small quantity of electrolyte facilitates high thermal resistance.





Towards the Future

■ Striving to realize a safe, high-performance all-ceramic battery (all-solid-state battery)

The goal of Corporate R&D is to create new value and develop new products on an ongoing basis. First, over the next two or three years, we plan to commercialize zinc rechargeable batteries and large ceramic membranes for CO_2 separation.

The zinc rechargeable battery is a battery with high performance on par with lithium-ion batteries whose most noteworthy feature is an extremely high level of safety, which results from the use of a nonflammable water solution as the electrolyte. This newly developed product from the NGK Group acquired the world's first-ever UL verification mark*4 in the battery energy storage field after UL, a third-party organization, verified a high level of safety due to the lack of thermal runaway and ignition. It can also be used in place of lead-acid batteries, which have been used as backup power supplies in industrial applications. We are currently working with Shimizu Corporation to demonstrate a "peak cut" application that uses electricity stored during off-peak hours to power devices during the day on Seikei Gakuen's campus, where the product's ability to reduce power costs are being checked.

Large ceramic membranes for CO_2 separation are used to separate, recover, and re-inject CO_2 that has been injected under pressure to lower the viscosity of crude oil in oil extraction. A demonstration will begin in Texas in the U.S. during fiscal 2020. We plan to commercialize the product, which has the potential to help realize carbon neutrality, within two to three years. We will also begin working to develop the technology further so that it can be used to separate CO_2 directly from factory exhaust and other emissions. This effort may take some time, but we are excited by the future possibilities.

We are also working to develop GaN wafers further at the same time. Although the current product has a wafer diameter of 2 inches, we believe that we can increase that to 4 to 6 inches ahead of competitors thanks to improvements in crystal growth technologies. We have already begun shipping samples, and we plan to commercialize the product for use in power semiconductors after several years.

We are also working to develop an all-solid-state battery as a project that will hopefully bear fruit in five to six years. Researchers in the field are already approaching commercialization of a battery that uses a sulfide electrolyte, but sulfides react with moisture in the air to produce hydrogen sulfide, which is a deadly poison. We are working to create an all-ceramic battery that uses safer oxide ceramics. Since oxide ceramic electrolytes are characterized by low ion conduction, there are few examples of related development worldwide. However, we are striving to develop the kind of safe, high-performance battery that only the NGK Group could create by advancing the technology used in the EnerCera semi-solid-state battery.

*4 The UL verification mark signifies a high level of safety, backed up by a rigorous safety testing and evaluation process carried out by Underwriters Laboratories (UL), a third-party safety science organization in the U.S. Valid until the end of October 2020.

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Development Committee Chair