R&D Department Roundtable Discussion: The Outlook for Next-Generation Battery Development

GS Yuasa released its R&D roadmap through 2050 in Vision 2035. Three employees involved in next-generation battery development, the head of the R&D Center, and the head of the Corporate Strategic Planning Office, who is the officer responsible for R&D departments conducted a roundtable discussion at the GS Yuasa International Ltd. R&D Center. The five participants discussed the outlook for next-generation batteries, the strengths of R&D departments, human resource development, and other topics.

Front row, from the left

Yoshikazu Nose — Director Responsible for Corporate Strategy, Research and Development, and Procurement, Head of the Corporate Strategic Planning Office

Hiroaki Yoshida — Executive Officer, Head of the R&D Center

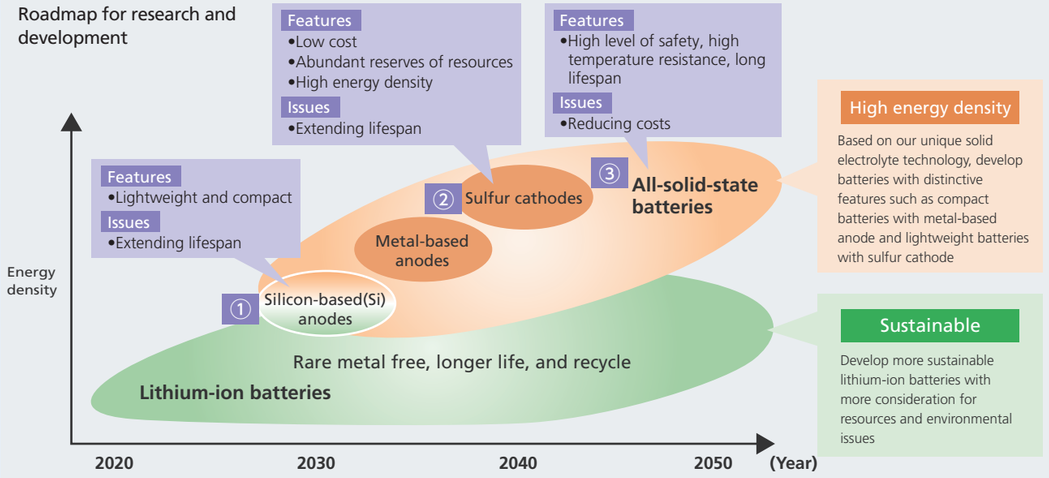
Back row, from the left

Shinnosuke Ichikawa — Group Manager, Next Gen. Battery Department (responsible for silicon-based anodes; ① in the figure below)

Heisuke Nishikawa — Group Manager, Next Gen. Battery Department (responsible for metal-based anodes and sulfur cathodes; ② in the figure below)

Tadashi Kakeya — Group Manager, Solid State Battery Department (responsible for all-solid-state batteries; ③ in the figure below)

Roadmap for research and development



Q: What are the roles of R&D departments?

Nose In Vision 2035, we announced a company policy of focusing on the mobility and public infrastructure fields. As expectations for storage batteries increase further in the future, R&D departments will become even more important for meeting those expectations and contributing to carbon neutrality.

Yoshida That's right. Technological capability is a source of value creation for the Company, and the R&D Center, which is conducting development with the longest perspective in the Company, can be said to be in a position of bearing the future of the Company. The three groups appearing today are responsible for major development projects for achieving the sustainable and high energy density batteries mentioned in the roadmap of research and development.

Ichikawa My group is working to develop silicon-based anodes. Silicon is characterized by abundant resource reserves and extremely high theoretical capacity compared to earlier materials. Among the three groups, we have set the earliest target for commercialization, and although there are significant hurdles that we have to overcome, I believe that it is necessary for us to work with a sense of speed.

Nishikawa My group is working on development of a lithium-sulfur battery that uses sulfur for the cathode and lithium for the anode to create a so-called dream battery. Under the roadmap, we are working toward commercialization around 2035 to 2040. We are currently making use of a New Energy and Industrial Technology Development Organization (NEDO) project with the aim of electrifying aircraft.

Kakeya My group is developing next-generation solid-state batteries through collaboration among industry, government, and academia. Our work was selected for a NEDO Green Innovation Fund project.

Nose Everyone is working on development of next-generation and next-next-generation batteries. The mission is to plant the seeds for the Group's future business. In addition to achieving the targets of Vision 2035, I feel that there is substantial pressure to create new technologies from an even longer-term perspective into the future.

Nishikawa I agree. R&D is essential for corporate growth, and everyone in R&D department including even the youngest employees feels a tremendous responsibility for this and is working with a sense of deep commitment.

Kakeya Recently, there has been a lot of reporting about all-solid-state batteries in the news, conveying the extremely high expectations for development. This means that there is also considerable pressure, but we feel that it is very rewarding to be able to play a part in development.

Q: What progress has been made toward practical application of next-generation batteries?

Nose Our competitors are also developing various materials, and we too have achieved steady results.

Yoshida That's right. Even as customers demand ever higher energy densities, Mr. Ichikawa's group demonstrated a high energy density of 400 Wh/kg in a silicon-based anode battery in May 2023. I believe that this represents a major advance forward.

Ichikawa Indeed. The issue with silicon-based anode batteries has been achieving both high energy density and a long lifespan. When using lithium metal, it is relatively easy to achieve high energy density, but achieving an energy density of 400 Wh/kg with a silicon-based anode was nearly unthinkable until just several years ago. We focused on technologies that haven't been used because they were thought to be impossible, and we were finally able to achieve this result by making full use of synthesis and other technologies to steadily overcome the issues we were facing one by one. It's a good thing that we did not allow ourselves to be constrained by the conventional wisdom.

Nose Few of our competitors have achieved comparable levels, and we have an advantage regarding cycle life assuming practical application. We can say that we have achieved world-leading performance with silicon-based anode batteries.

Ichikawa Thank you. Currently, however, it will be difficult to achieve even higher energy densities with silicon-based anode batteries, and Mr. Nishikawa is conducting development of lithium-sulfur batteries to achieve this.

Nishikawa We've been conducting development since 2019 while making use of a NEDO project. We achieved energy density of 400 Wh/kg with a lithium-sulfur battery in fiscal 2021. Fiscal 2023 will be the final year of the NEDO project, but reaching 500 Wh/kg is within sight, and if we can achieve this, I believe that it will be possible to say that lithium-sulfur batteries have the world's highest energy density.

Silicon-based anodes — **Developing technology for achieving both high energy density and lifetime performance and making major progress in practical use of next-generation batteries**

By developing technologies that achieve both high energy density and long service life in silicon-based anode batteries, which face many practical challenges, we demonstrated high energy density of 400 Wh/kg, which exceeds that of conventional lithium-ion batteries. The silicon-based anode is a technology is also applicable to all-solid-state batteries, and this represents substantial progress in terms of the practical application of next-generation lithium-ion batteries.

Silicon-based anode batteries

Nose Speaking of next-generation batteries in general, the Company's unique strength is our ability to adopt various development approaches in terms of materials and partners. Mr. Nishikawa and Mr. Kakeya, your project involves collaboration among industry, government, and academia, doesn't it?

Kakeya Research on topics believed to be important can be conducted at universities over decades. For example, Osaka Metropolitan University, one of our research partners, has been researching solid electrolytes for decades. Unfortunately, companies are unable to conduct this type of research, and a partnership provides the benefit of being able to supplement areas where our knowledge is lacking by making use of the university's knowledge.

Nishikawa I think that's right. Collaboration among industry, government, and academia will be extremely important in Japan's manufacturing in the future. As overseas manufacturers become more prominent, industry, government, and academia are collaborating in a complementary manner to create new energy storage technologies in Japan, and I believe that this will also play a role in Japan's sustainability in the future.

Ichikawa I participated in a cathode material development project with a university, and I learned a great deal.

Yoshida Collaboration among industry, government, and academia is an essential mechanism for the development of industry in Japan. As Mr. Kakeya indicated, I believe that the seeds for future technological innovation can be found in research that is conducted over many years. I hope to continue collaborating with universities in various ways in the future.

Nose My role is communicating with government. Based on a solid understanding of national policy, I hope to convey our requests at the most appropriate times, collaborate with government to contribute to solutions to social problems, and convey information within the Company as well.

Q: What measures are you taking to increase the pace of R&D?

Yoshida DX accelerated even more during the COVID-19 pandemic. We are advancing a variety of initiatives including making it possible to remotely acquire analysis results and increasing the pace of development by introducing materials informatics (MI).

Nishikawa I agree. MI can be used to a certain degree to make predictions about materials that are likely to demonstrate good characteristics even without performing actual experiments, so it is useful in reducing testing processes and raising efficiency. New materials have been discovered in the development of electrolyte materials being performed by Mr. Kakeya.

Kakeya That's right. At the data that the Company has accumulated until now is an important asset. As a result of using this data and performing analysis with AI, materials have been proposed from perspectives that we would never have imagined.

Ichikawa You are all correct, but currently, there are still aspects where it is faster to do the experiments. I feel that it is necessary to properly distinguish between these situations.

Nose The Company is now in the third year of DX implementation, and I believe that the objective is to create an environment where all of you can focus exclusively on research. By using DX to eliminate wasteful work, you will be able to focus on work that enhances added value.

Yoshida To achieve this, it will be necessary for us to review and streamline workflows and determine what can be improved using DX.

Ichikawa Also, there are differences in the ways of organizing data among people, so standardization will be needed.

Nose In addition, the Company has accumulated more than 100 years of technology. I would like to consider digitizing and using this technology in the future. We plan to implement DX along two axes—raising efficiency and enhancing added value.

Q: What are the strengths of the R&D departments?

Yoshida I believe that the mindset of tackling challenges that is been handed down from previous generations is a strength for the Company. Also, the Company has been forged as a battery manufacturer through many years of doing business with good customers.

Nose We have been providing storage batteries to society for more than a century. In the early 20th century, we supported the development of wireless communications and industry, in the post-war period, we accelerated motorization, and later, we conducted business with all automakers in Japan. I think it is exactly right that the Company has been forged by its customers.

Yoshida I believe that we have been able to gain the trust of customers by dealing with them sincerely and producing results, no matter how unreasonable or difficult their requests are.

Kakeya I often think about the Company's strengths. Although the Company is a battery manufacturer, in addition to battery-related patents, it also has many materials-related patents. We have received high evaluations for our solid electrolytes, a key material for all-solid-state batteries. In this way, material development capabilities lead to options, and we are able to develop products that meet customer requests.

Ichikawa The R&D departments also have strong horizontal connections. Even though we are affiliated with different departments, we work in the same room and we create opportunities for information sharing including monthly report meetings.

Nishikawa Sharing information leads to us noticing new things. The atmosphere enables personnel to causally ask questions such as "What is this research like?" and people can discuss things. There is a lot of exchange of technology among personnel.

Yoshida Recently, frontline department members have been focusing on measures to truly understand the corporate philosophy and Vision 2035 and put them into practice. Mr. Nose has also explained these matters to us.

Nose That's right. The Company has an extensive track record and substantial development capabilities in the areas of mobility and public infrastructure, and the roles that we are expected to play are growing more and more. I believe that it is important to link Vision 2035 with on-site work and develop an understanding.

Yoshida It is important to be aware that Vision 2035 is not something created by the Company, but is connected to the work of every employee.

Nose Certainly. I'm looking forward to increased opportunities to talk with development personnel. I hope that we can create new value and contribute to the creation of a sustainable society by transforming your dedication and enthusiasm into the power to create a new future under climate with an abundant spirit of tackling challenges.

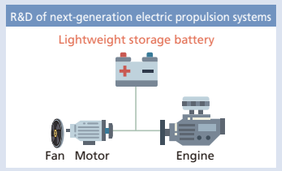
Sulfur cathode

Collaboration among industry, government, and academia

Joint research with Kansai University on a next-generation aircraft project

In a NEDO project for practical application of advanced propulsion systems for aircraft, we are conducting R&D on lithium-sulfur batteries in collaboration with Professor Ishikawa of Kansai University with the aim of maturing the technology to a level where proposals can be made for next-generation aircraft.

Exterior view of a lithium-sulfur battery



Overview of the project for practical application of advanced propulsion systems for aircraft

All-solid-state batteries

Collaboration among industry, government, and academia

Joint research started with Osaka Metropolitan University on technological development of all-solid-state batteries

GS Yuasa is conducting joint research with Osaka Metropolitan University on development of next-generation storage batteries and next-generation motors, a technology proposal selected in April 2022 for the NEDO Green Innovation Fund (the selected research topic is "Next-Generation Storage Battery and Motor Development").

- **Advanced solid-state battery development items**
  - Development of a solid electrolyte that combines high ionic conductivity with superior water resistance
  - Development of high-capacity cathode with low cobalt content
  - Development of anode with high capacity and long-life performance
  - Development of cell design and manufacturing processes that facilitate mass production