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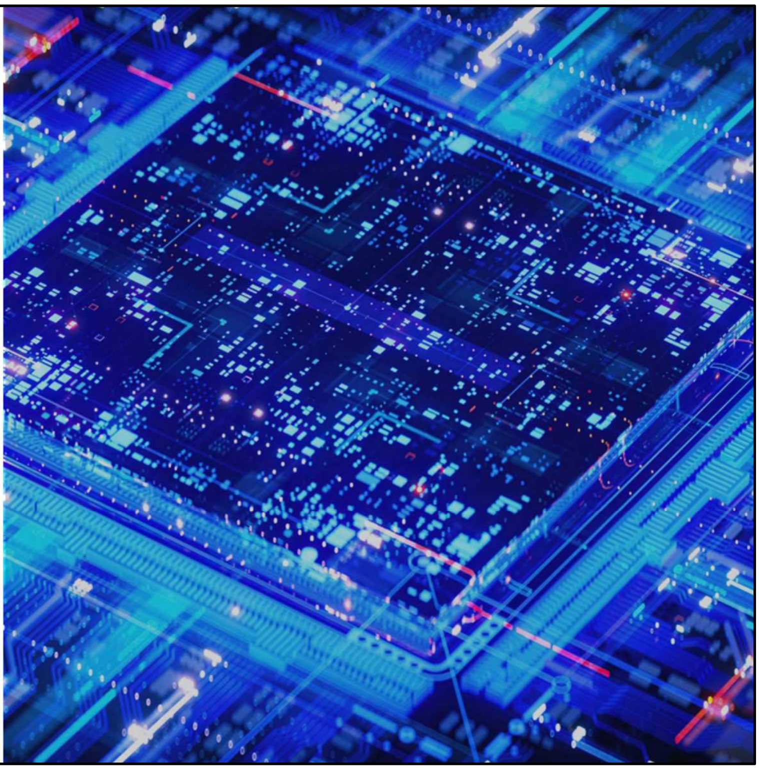
ULVAC, Inc.

IR Seminar 2023

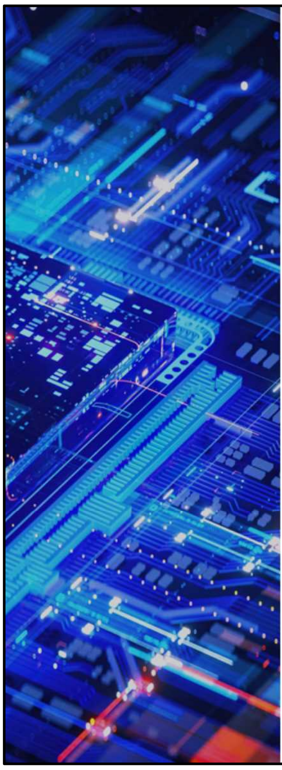
Dec.11, 2023

Please note that the IR seminar materials and explanations have not been prepared for technical purposes, and some parts have been simplified to facilitate investors' understanding.



Thank you for attending ULVAC Inc.’s IR seminar.

I am Umeda, Officer and GM of IR Department.



<Today's Agenda>

I. Double-Sided Evaporation Roll-to-Roll Equipment for EV Batteries Market Trends and Business Development ▶P.6

Yoshiki Iso, General Manager, FPD Division

Joined ULVAC in 2002, worked as an engineer of evaporation and sputtering deposition in FPD Division, and worked in PM and planning department from 2012, General Manager of FPD Division from 2023.

Yoshiaki Yamamoto, Senior Manager, R2R Group, FPD Division

Joined ULVAC in 2006 after working as an engineer of laser, CVD and sputtering in FPD Division, engaged in the development of sputtering and evaporation equipment as the head of development department of FPD division from 2021, the head of R2R Group in the FPD division from 2023.

Masaki Takei, Senior Manager, Applied Vacuum Technology Research Dept. Institute of Advanced Technology

Joined ULVAC in 2005, engaged in research and development of sputtering processes and materials at the Advanced Technology Research Institute until 2015, engaged in the development of vacuum technology for batteries from 2016, Senior manager of Institute of Advanced Technology from 2022.

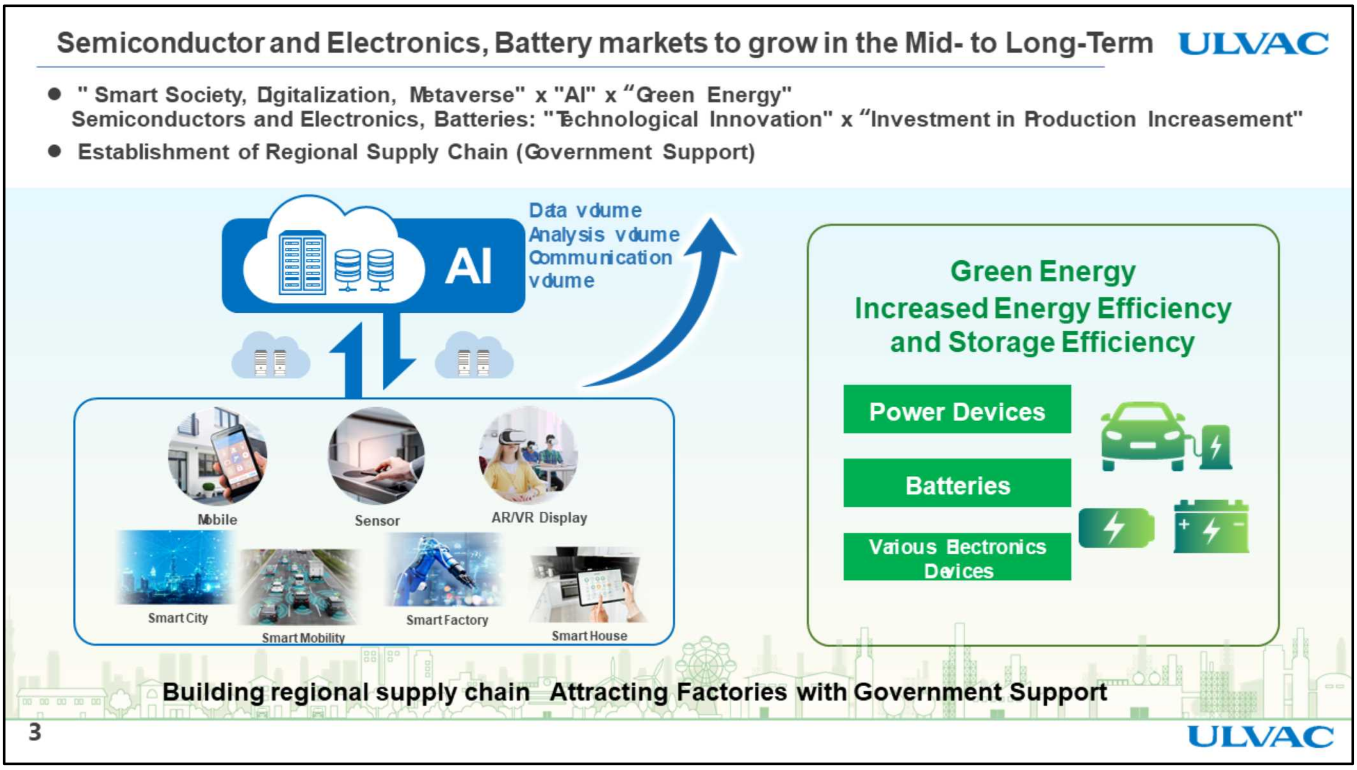
II. Market Trend of Next Generation Power Devices and Our Approach ▶P.25

Harunori Iwai, General Manager, Advanced Electronics Equipment Division

Joined ULVAC in 2000. After working mainly as a sputter engineer in Advanced Electronics Equipment Division, transferred to China in 2020, General Manager of Advanced Electronics Equipment Division from 2022.

As stated in the agenda, Iso, General Manager of FPD Division, Yamamoto, Senior Manager of R2R Group, and Takei, Senior Manager, Applied Vacuum Technology Research Department, Institute of Advanced Technology, will describe the market trend and business development of evaporation Roll-to-Roll equipment for EV batteries.

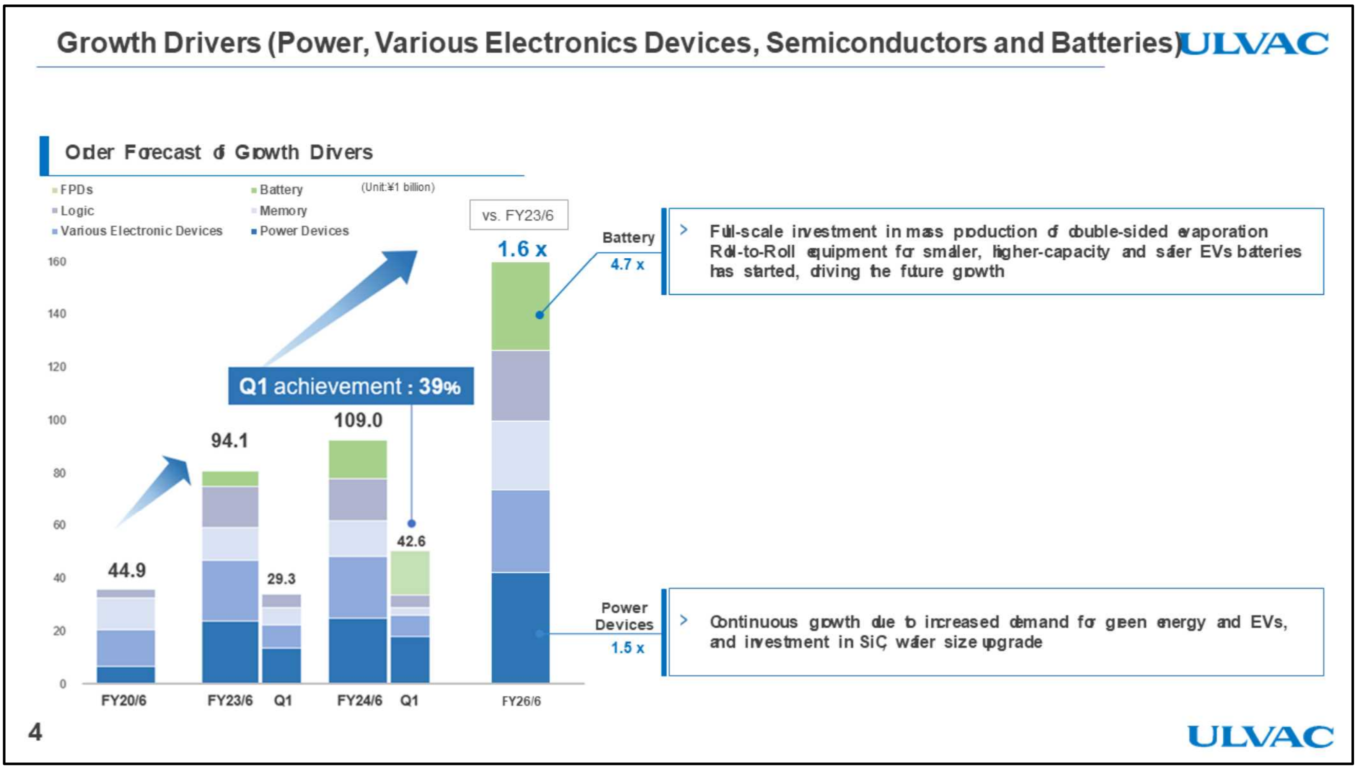
In the second part, Iwai, General Manager of Advanced Electronics Equipment Division, will describe the market trend for next-generation power devices and our efforts in this area.



ULVAC announced its new medium-term management plan this August. The plan is to target net sales of JPY300 billion and operating income of JPY48 billion for the fiscal year ending June 30, 2026.

The demand for servers, sensors, and various electronic devices is expected to increase in the mid- to long-term due to the addition of smart society, digitalization, metaverse, and the use of generative AI, which will dramatically increase the amount of data, analysis, and communication. Electricity will also be consumed more, requiring green energy or improved energy efficiency.

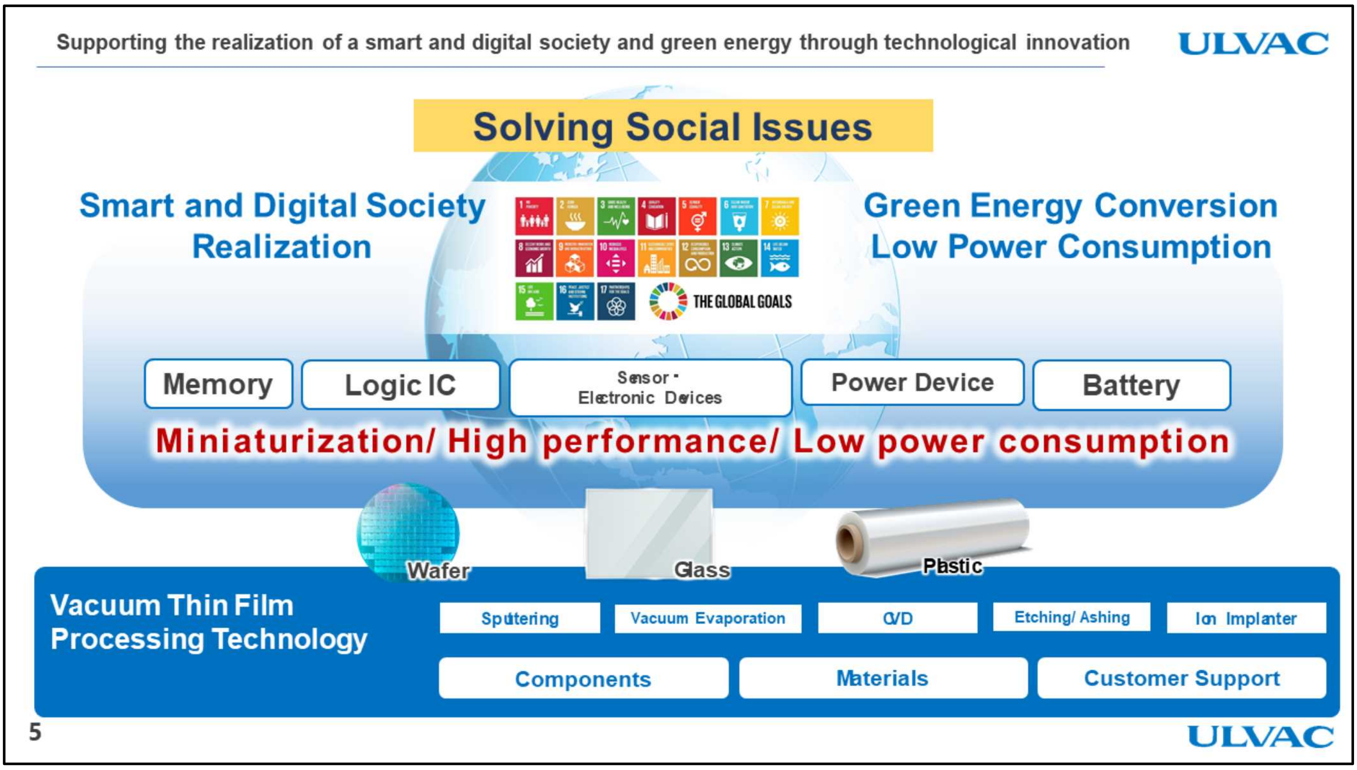
To achieve compatibility with green energy, there is a need to improve the efficiency of power devices, miniaturize semiconductors, and improve the efficiency of batteries.



In this environment, battery-related and power devices will drive future growth, along with the fields of logic devices, memory, and various electronic devices, which we were able to enter for the first time in the fiscal year ended June 30, 2019.

In the battery-related business, investment has been in full swing since Q4 of the previous fiscal year, with orders worth JPY14 billion out of the annual plan of JPY17 billion in Q1. The power device investment was concentrated also in Q1 with orders worth JPY15 billion, about half of our annual plan of JPY30 billion.

This is due to two factors: １）China, the world‘s factory, is finally moving at a full scale to replace its power devices with domestic production and investment is ramping up.2) Investment is also ramping up in Japan to shift from Si IGBT to SiC, mainly for EVs.



ULVAC contributes to the realization of a smart and digital society with its vacuum thin-film technology for various substrates, such as wafers, glass, and plastic films, and also contributes to green energy and low power consumption through miniaturization, high performance, and low power consumption.

The replacement of aluminum foil with double-sided evaporation film in batteries, which we will introduce today, and power devices are also technologies that contribute greatly to green energy and low power consumption.

Market trends and business development of double-sided evaporation Roll-to-Roll equipment for EV batteries will be discussed in Part 1. In Part 2, we will discuss the market trend for next-generation power devices and our efforts in the area.

My name is Iso, General Manager of FPD Division at ULVAC. Today, Yamamoto, Takei, and I will describe the market trend and business development of double-sided evaporation Roll-to-Roll equipmentfor EV batteries.

Summary

Today, we will report on the market trend of double-sided evaporation films and manufacturing equipment for EV batteries, as well as on the business development of R2R evaporation equipment for EV batteries

- **Why is Evaporation Film Technology necessary?**

  With the rapid expansion of EVs and EV batteries, double-sided evaporation film is contributing to the solution of the technological issues of battery safety improvement, downsizing and weight reduction, cost reduction, and environmental load reduction.

  - The replacement of the current collector (one of the battery components) from conventional metal foil to double-sided evaporation film is in full swing.
  - Potential for further demand growth in anticipation of all-solid-state batteries

- **What are the future business plans?**

  We have completed the development of AL double-sided evaporation equipment for Cathode Current Collectors and entered the commercialization phase:
  Starting with the double-sided evaporation film for the Cathode side, we will expand the evaporation technology to other battery layers.

  - Replacement of the Anode current collector from conventional Cu foil to Cu double-sided evaporation film.
  - Replacement of the Anode from the conventional environmentally hazardous coating film to a metallic lithium evaporation film.

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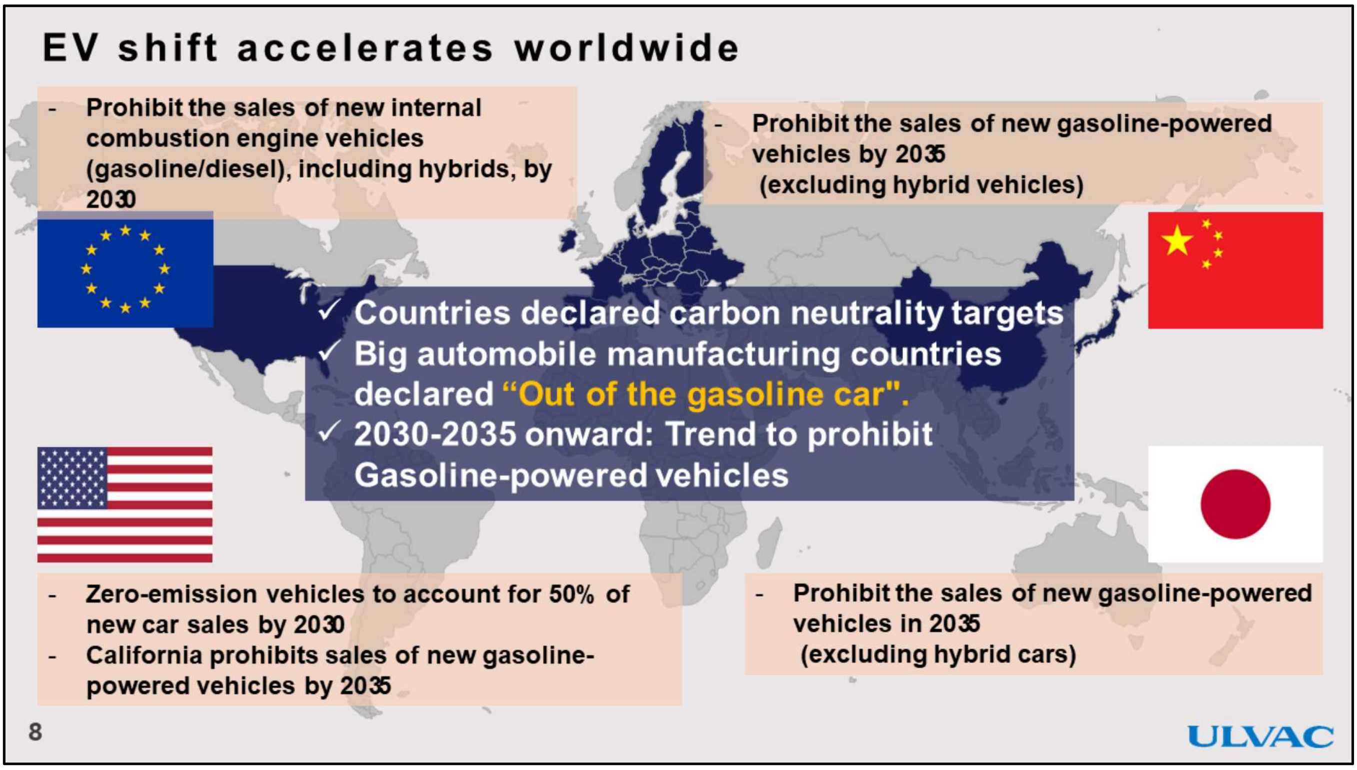
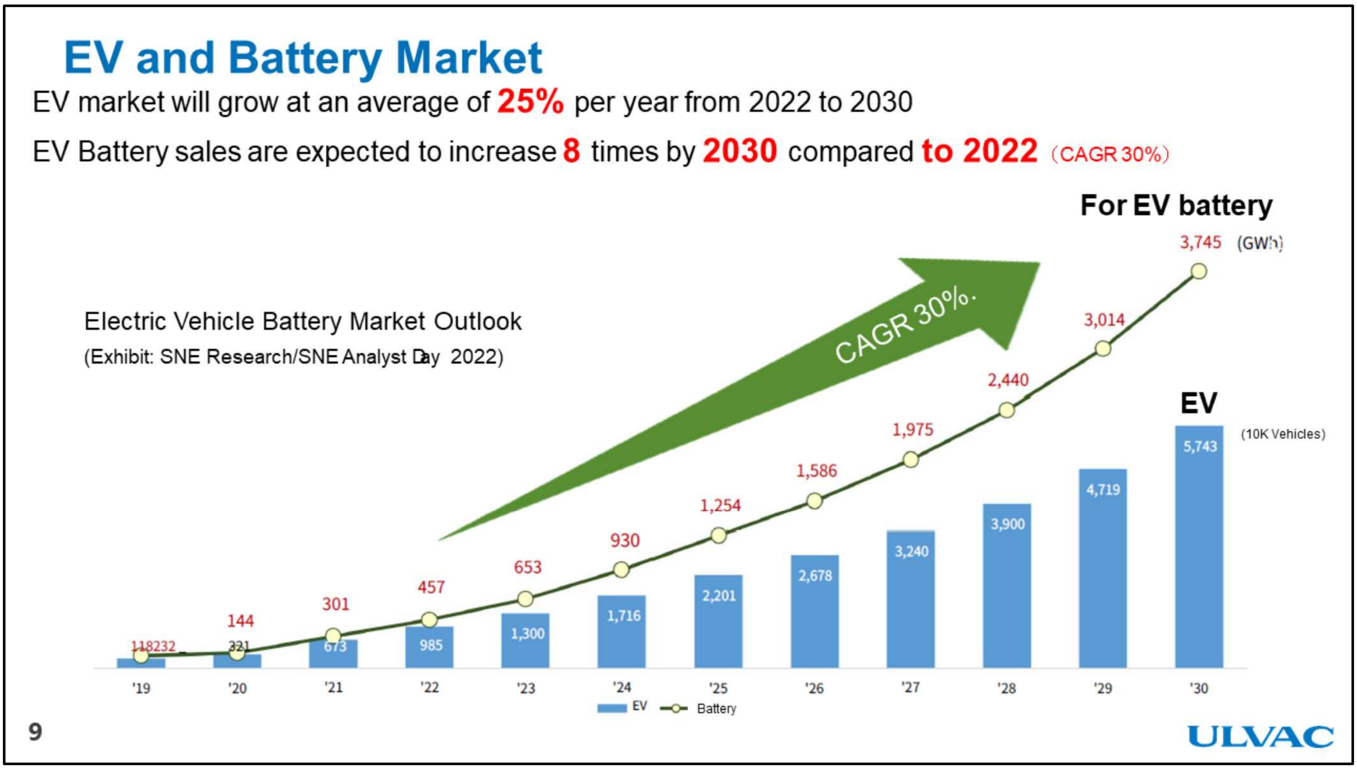
This is a summary of today's seminar. First, to answer the question of why evaporation film is necessary, we will explain how evaporation film can contribute to solving the technological challenges surrounding batteries, such as improving safety, reducing size and weight, lowering costs, and reducing environmental impact in the rapidly expanding EV and EV battery market.

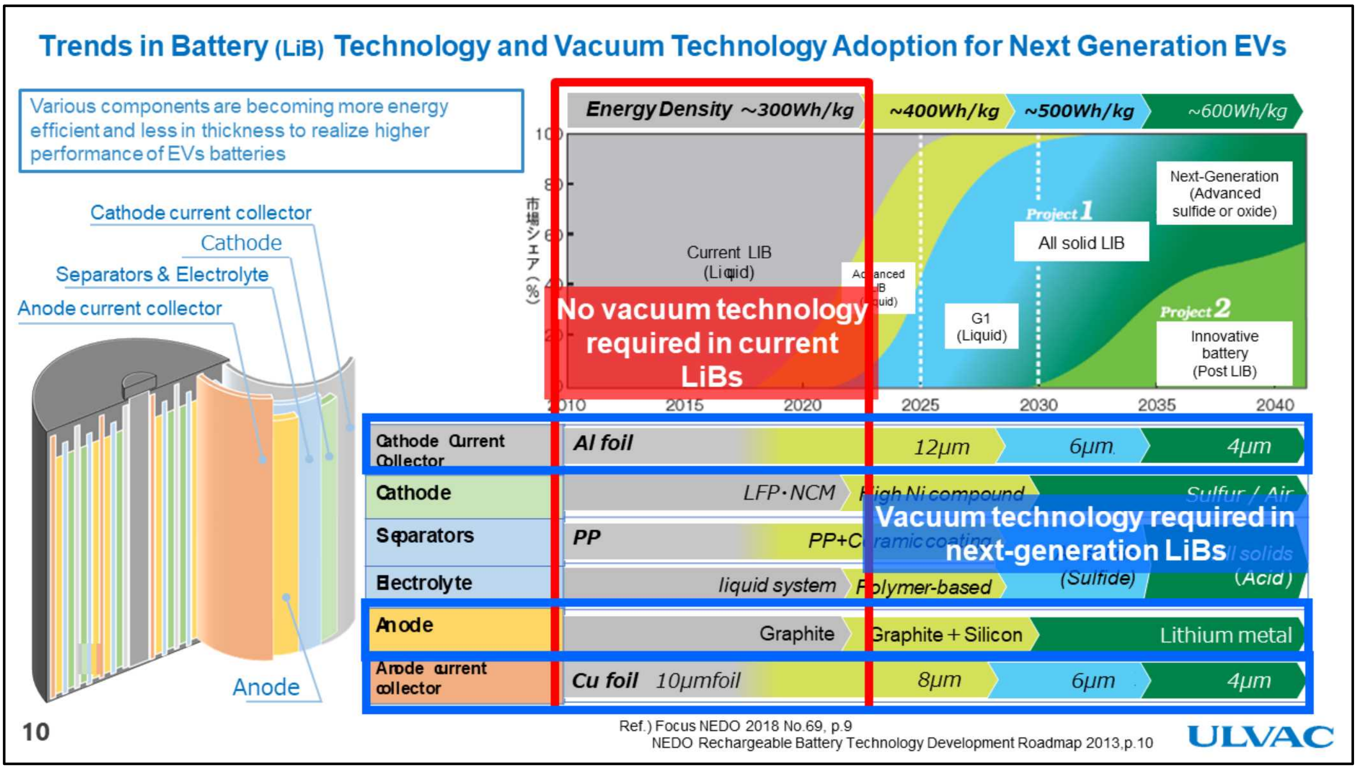
Regarding business developments in this market, we will discuss the full-scale investment to replace conventional aluminum foil with double-sided aluminum evaporation film for Cathode current collectors and introduce the expanding evaporation technology for other battery layers, such as Anode current collectors and Anode materials, starting with double-sided evaporation film for cathode materials.



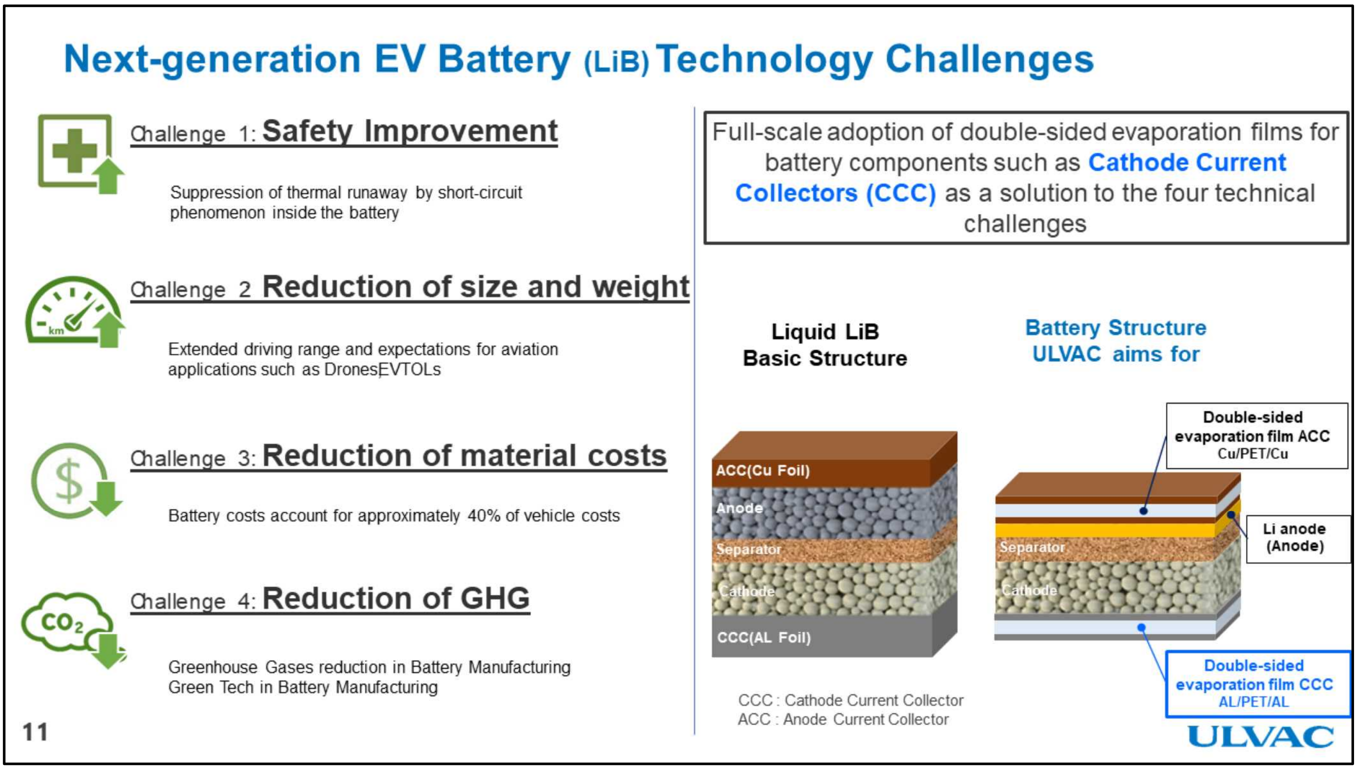
The background of this session is that each country has set carbon neutrality targets as a countermeasure to global warming, and the trend away from gasoline-powered vehicles has become undeniable.



Against this backdrop, the EV market is projected to show a CAGR 25% between 2022 and 2030, and demand for EV batteries is expected to increase eightfold.



This is the roadmap for higher battery performance. Vacuum technology previously has not been used in lithium-ion batteries, which are currently the mainstream. In recent years, battery materials have begun to be reexamined in order to improve the performance of current batteries and to develop next-generation batteries, such as solid-state batteries. Vacuum technology has attracted attention as a manufacturing technology for next-generation battery materials, and some materials are beginning to be used.



Here is why vacuum deposition is attracting attention in the battery market.

EV batteries are expanding rapidly in line with the growing EV market, but they are facing 4 major technical challenges.

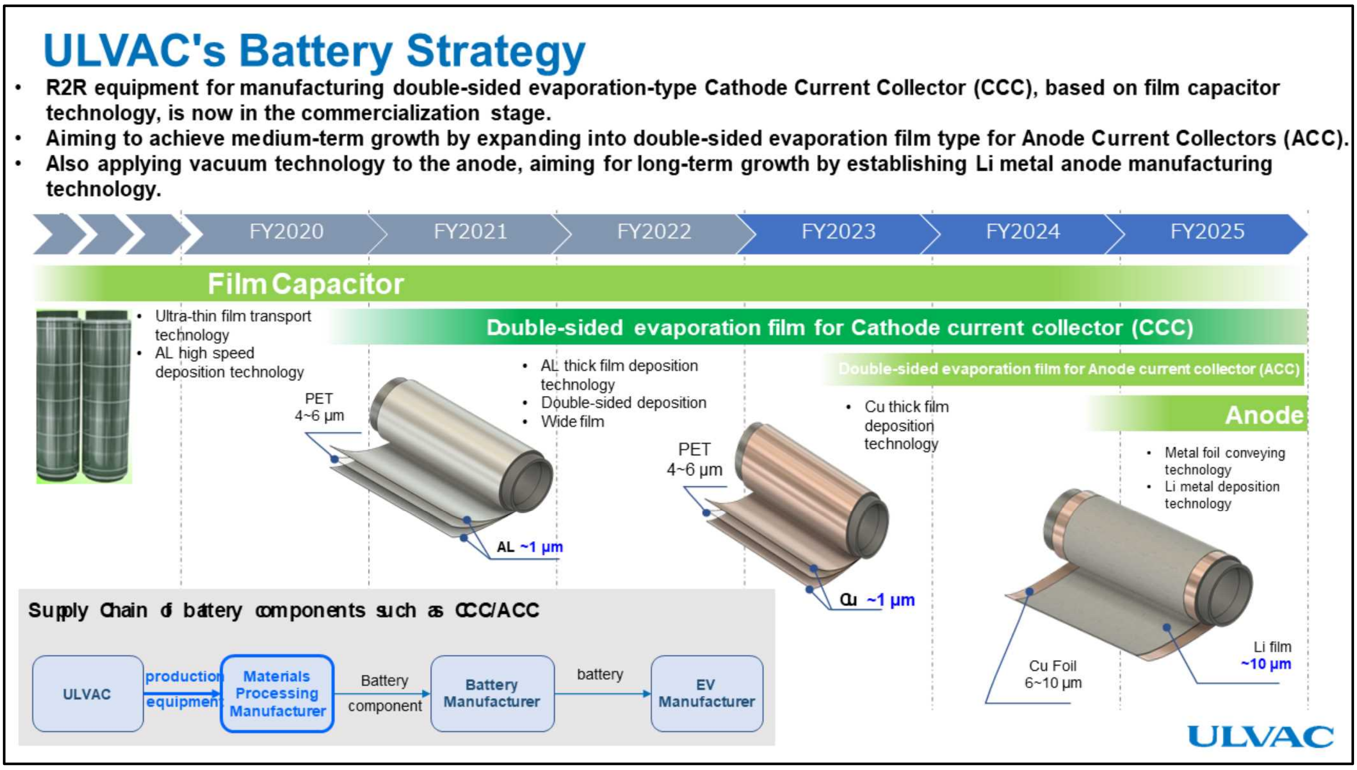
One is to improve safety. In the past, EV batteries caught fire that led to massive recalls, making this a serious issue for both users and manufacturers.

Second, lighter and smaller next-generation batteries with greater energy storage capacity per unit weight are needed to extend the driving range of EVs and to expand the usage to aeronautical applications, such as Drones and EVTOLs.

In order to lower the price of EVs, it is also necessary to reduce the cost of batteries, which account for 40% of the vehicle cost. Reducing greenhouse gas emissions in battery production is also an essential social issue in order to achieve net zero emissions.

As a solution to these four problems, the full-scale application of vacuum technology to battery components, such as Current collectors and Anode materials, is expected to be realized.

In particular, the Cathode current collector made of PET film, with aluminum deposited on both sides, is already being used in some EV batteries.



We will explain our battery strategy for the adoption of vacuum deposition technology for these battery components.

We have already completed the development of the deposition technology and equipment for the battery's Cathode current collector, known as CCC, by applying our existing Roll-to-Roll evaporation technology for the Film capacitor market. It is commercially available now, and several material manufacturers have already purchased our equipment.

As a future direction, starting from the Cathode current collector technology, we will expand the double-sided evaporation technology from Cathode electrode Aluminum to Anode electrode Copper in the current collector market. We also aim to achieve medium- to long-term growth by replacing Anode materials.

Regarding Cathode current collectors (CCC), Yamamoto, Senior Manager of R2R Group, will present the details, and Takei from the Institute of Advanced Technology will present details on Anode current collectors (ACC)and Lithium Anodes from a mid- to long-term viewpoint.

Why Focus on Double-sided Evaporation Film CCC?

Reason 1: **Safety Improvement**

Reason 2: **Reduction of size and weight**

Reason 3: **Reduction of material costs**

Reason 4: **Reduction of GHG**

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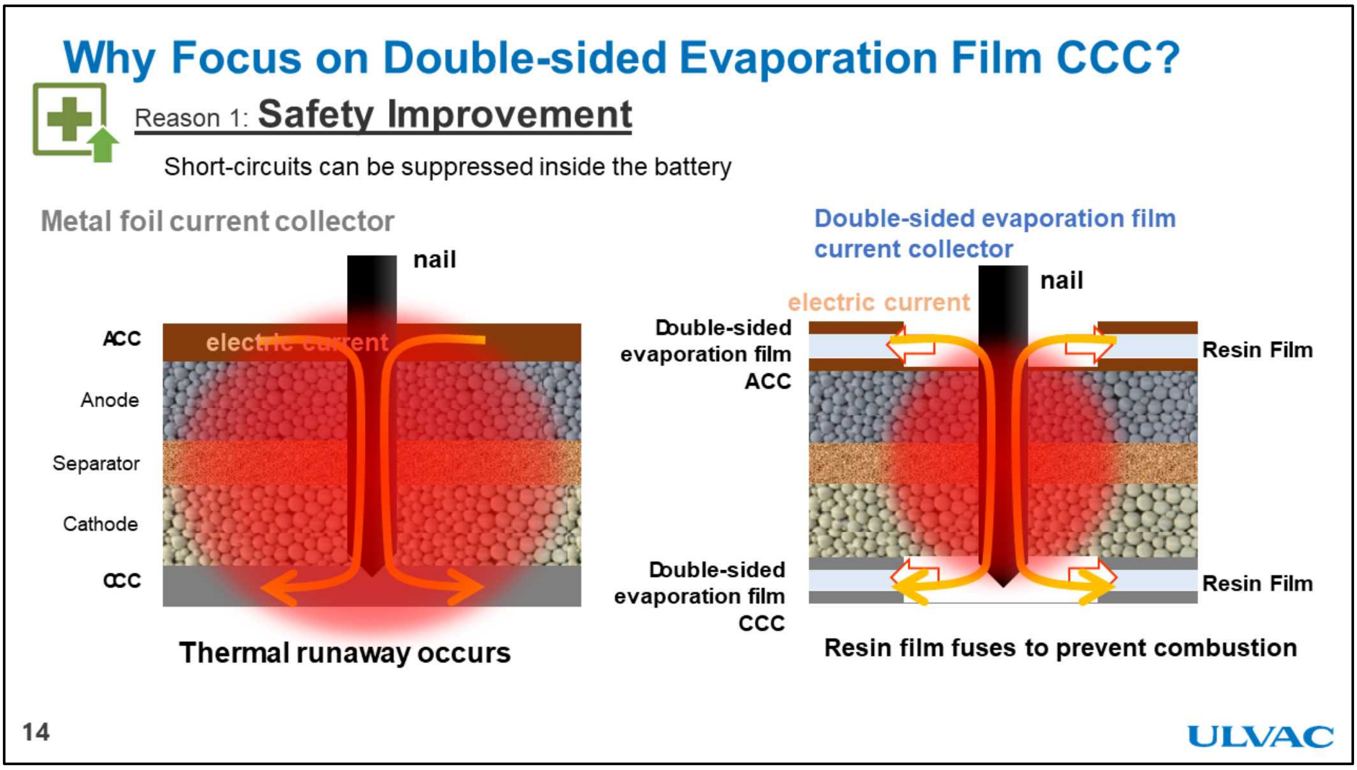
I am Yamamoto of the R2R Group, and I will explain why we are focusing on double-sided evaporation film CCC.



The first reason why double-sided evaporation CCCs are attracting attention is that they improve the safety of Lithium batteries. Double-sided evaporation film current collectors act as a fuse and prevent the occurrence of short circuits inside the battery.

At present, metal foil current collectors are unable to block the transmission of current and generate heat, resulting in thermal runaway if a short circuit occurs between an ACC and CCC because of a nail or other object piercing the current collector.

On the other hand, if a double-sided evaporation current collector with a resin film such as PET is used, even if a nail sticks into the collector and causes a short circuit between an ACC and CCC, resulting in an overcurrent and heat generation, the resin film will melt before the battery burns because the metal layer is thin, and the PET film is weak against heat in a double-sided evaporation collector.

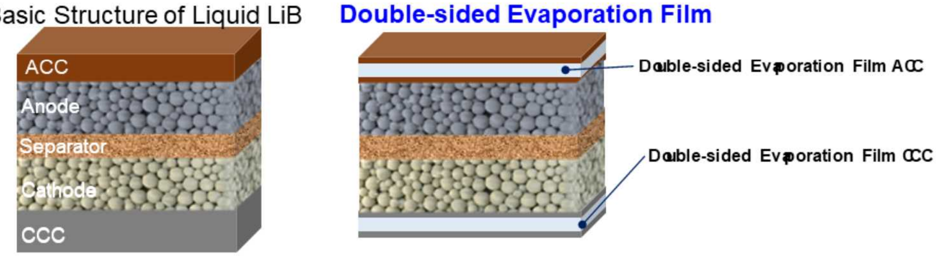
This prevents electricity from conducting between the resins by eliminating contact points with nails and other objects, thus acting as a fuse. Double-sided deposited current collectors ensure that short-circuit currents are only temporary and enhances battery safety.

Why Focus on Double-sided Evaporation Film CCC?

Reason 2: **Reduction of size and weight**

Replacing conventional copper and aluminum foil with double-sided evaporation film enables lighter weight and higher energy density

Basic Structure of Liquid LiB | **Double-sided Evaporation Film**



per MWh	unit	Liquid LiB Structure	Double-sided Evaporation Film Adopted	Difference
ACC Weight	kg	645	289	-55%
CCC Weight	kg	389	139	-64%
Other battery weight	kg	2,966	2,966	0%
Battery weight	kg	4,000	**3,394**	**-15%**
energy density	wh/kg	250	**294**	**18%**

(Source)Funder Securities Research Institute

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The second reason why double-sided evaporation film CCCs are attracting attention is they help reduce the size and weight of lithium batteries.

Here are examples of an ACC and CCC in terms of weight and energy density of batteries per megawatt-hour.

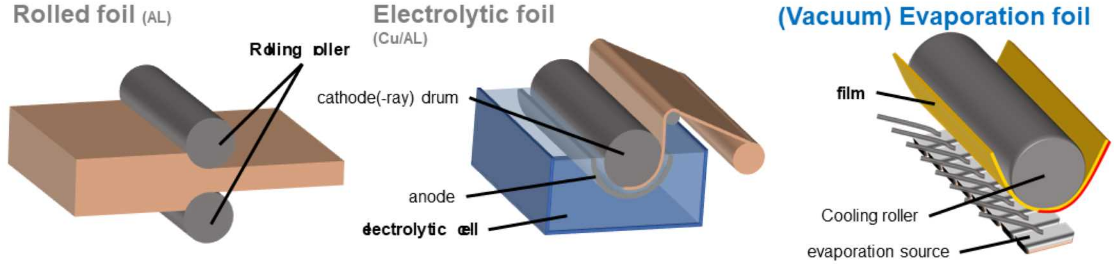
The copper and aluminum foil current collectors used in conventional lithium batteries weigh about a quarter of the battery weight. By replacing them with the double-sided evaporation film current collector, the weight of ACCs and CCCs can be reduced by 50% to 60%.

As a result, the overall weight of the battery is reduced by approximately 15%, and the energy density, which is the storage capacity per unit weight, is increased by approximately 18%. This can improve the driving range of electric vehicles.

Why Focus on Double-sided Evaporation Film CCC?

Reason 3: **Reduction of material costs**

Fewer manufacturing processes and wider widths compared to metal foil enable higher productivity and lower manufacturing costs



	Rolling Foil	Electrolytic Foil	Evaporation Foil
Manufacturing Process	rolling method	plating method	**Vacuum Evaporation**
Thickness Range	6μm to 100μm	4.5μm to 140μm	**50nm to 3μm**
Maximum Width	650mm	1380mm	**1650mm → Expandable**
Production Difficulty	Long production cycle Relatively complex process	Short production cycle Relatively simple process	**Vacuum equipment Adhesion to resin**

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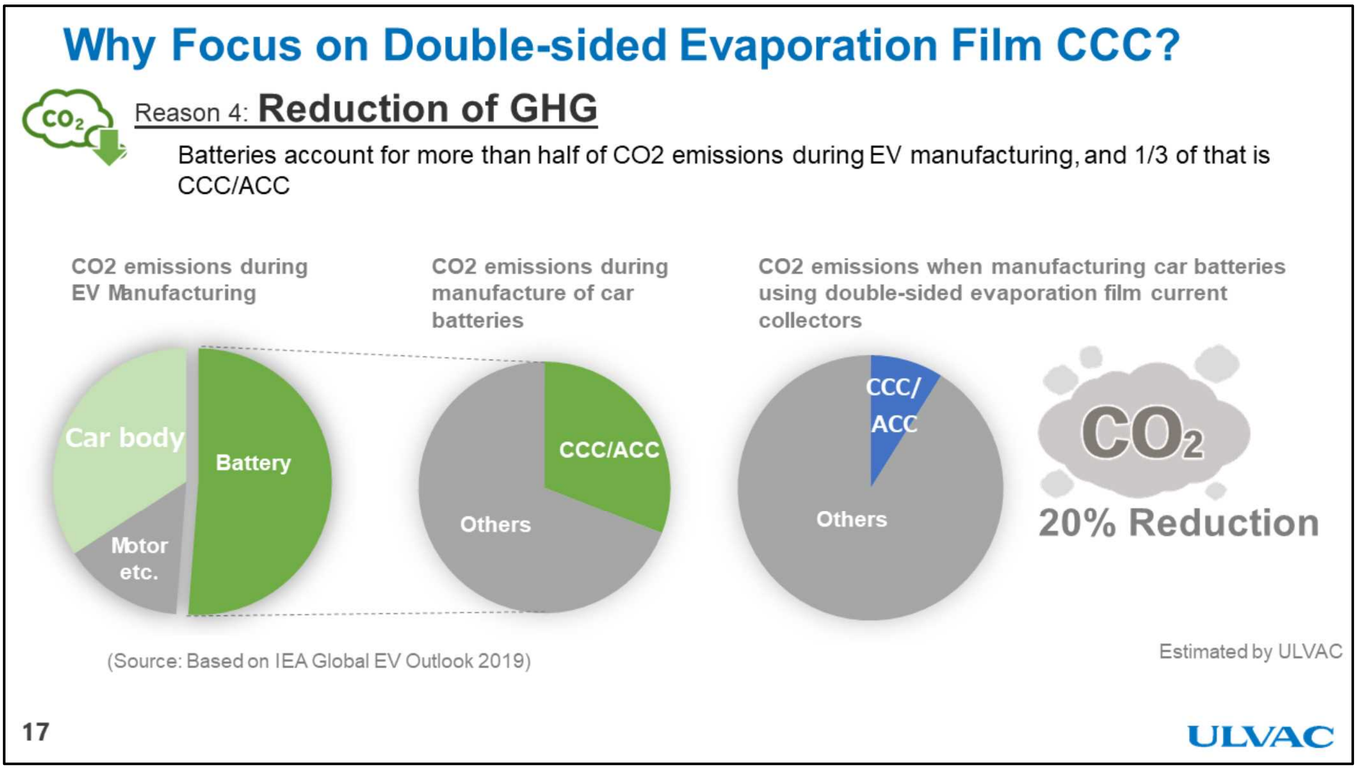
The third reason for double-sided evaporation film CCCs is that they can reduce component costs. Currently, rolled aluminum foil made by the rolling method and electrolytic copper foil made by the plating method are mainly used as metal foil current collectors. Metal foil with a thickness of 4.5 microns to 10 microns is generally used, and thinner foil is difficult to handle, resulting in poor productivity.

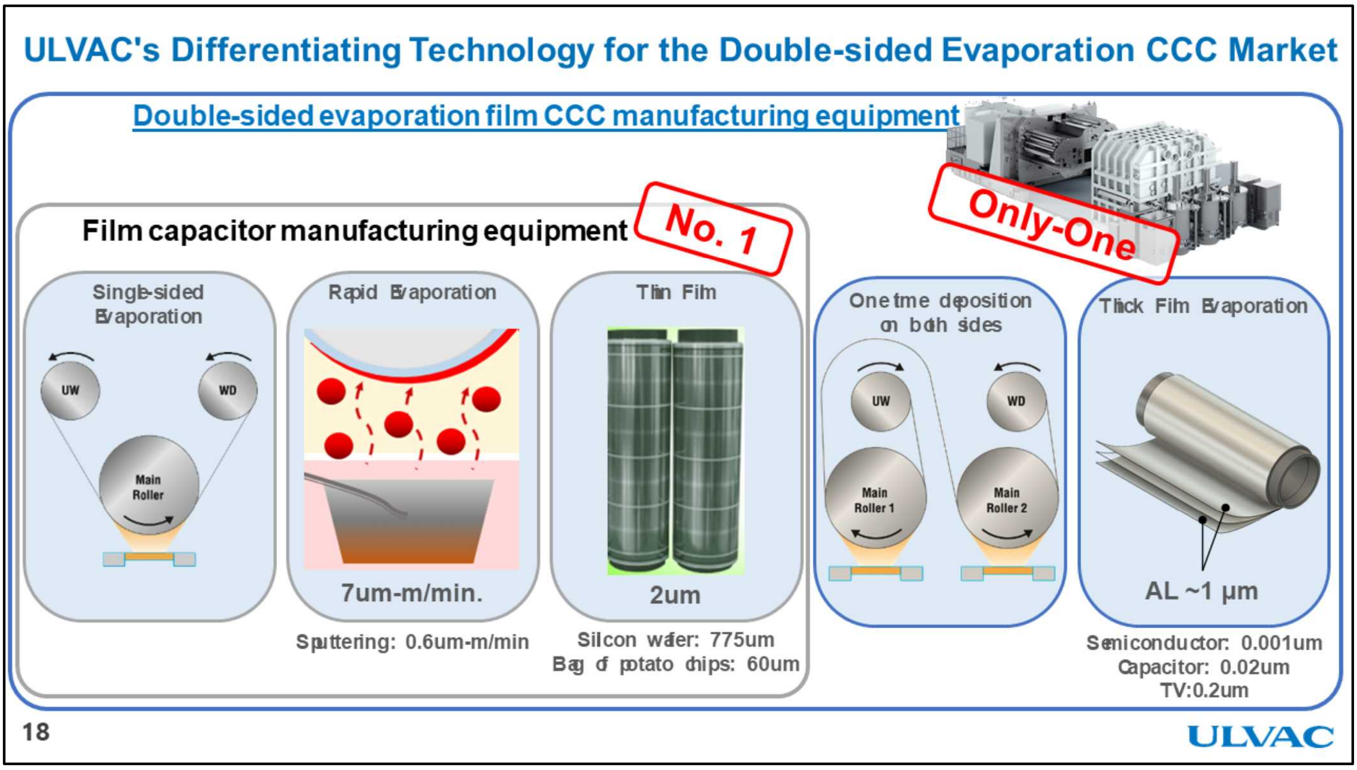
Compared to these manufacturing methods, double-sided evaporation current collectors form thin films of metal on both sides of the resin film by vacuum evaporation, allowing for thinner metal layers to be formed, and reducing the number of materials used.

In addition, vacuum evaporation makes it easier to increase the width of the film than other manufacturing methods, thus increasing productivity and reducing manufacturing costs.



The fourth reason why double-sided evaporation film CCCs are attracting attention is their ability to reduce greenhouse gas emissions and contribute to solving environmental issues. Batteries account for more than half of the CO2 emissions during EV manufacturing. Breaking it down further, one-third of it is copper and aluminum foils for the current collector.

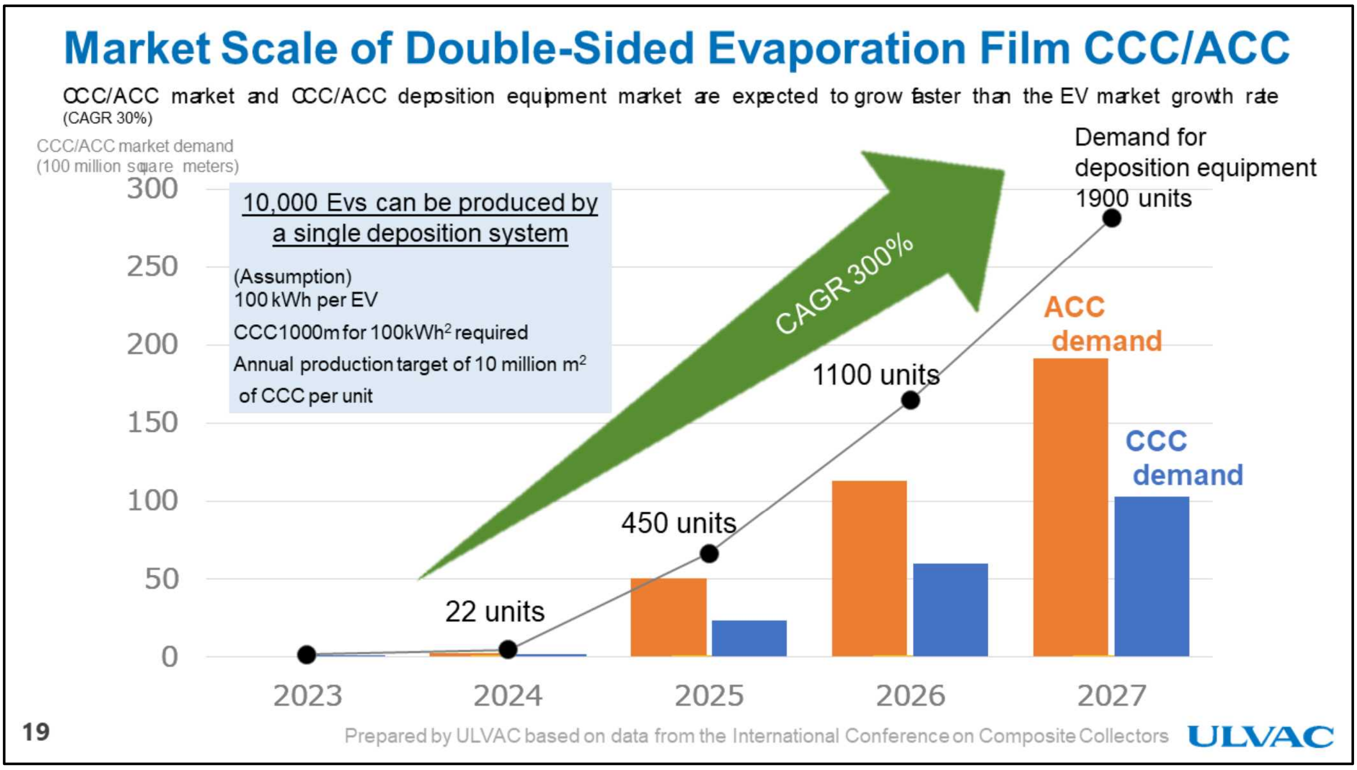
The rolling method used in the aluminum foil manufacturing process consumes a lot of electricity. By replacing this method with double-sided evaporation current collectors, we believe it can reduce the amount of metal material used and contribute to CO2 emissions reduction.



For these reasons, ULVAC is leveraging its accumulated Roll-to-Roll technology to offer products that incorporate new technology that differentiates itself for the double-sided evaporation film CCC market.

ULVAC's background technologies include high-speed film forming technology, which is 10 times faster than the sputtering method, and thin film transport of approximately 2 microns, 1/30th the thickness of a bag of potato chips, which have made ULVAC the number one supplier of aluminum evaporation Roll-to-Roll equipment for manufacturing high-capacity Film capacitors for EVs.

In the double-sided evaporation film CCC manufacturing equipment for lithium batteries, we have added to these technologies our proprietary double-sided batch evaporation deposition and aluminum evaporation deposition technology with a film 50 times thicker than that of Film capacitors. This has earned us a reputation in the market for good productivity and high-quality CCC manufacturing equipment that outperforms competetors.

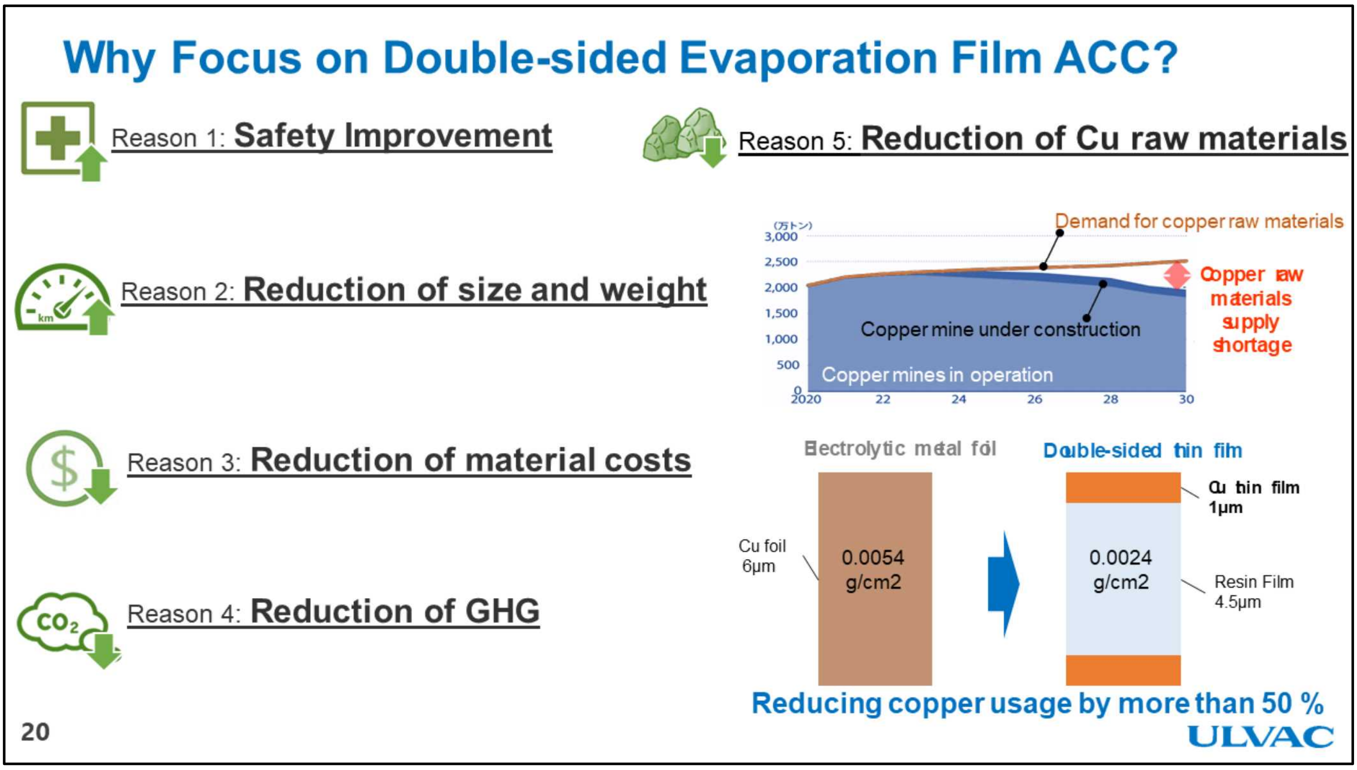


So far, I have explained the expectations for double-sided evaporation films and our differentiating technology. We believe that the double-sided evaporation CCC and ACC markets and their equipment markets will grow more rapidly than the EV market growth rate.

We also calculated that the demand for double-sided evaporation film CCC market will be 10 billion square meters by 2027, and the demand for double-sided evaporation film ACC market will be approximately 20 billion square meters. The total number of evaporation equipment needed worldwide at that time is estimated to be 1,900 units. The market growth rate is 300%.

Since 10,000 EVs can be produced annually with a single deposition system, we estimate that more than 10 million EVs will be produced.

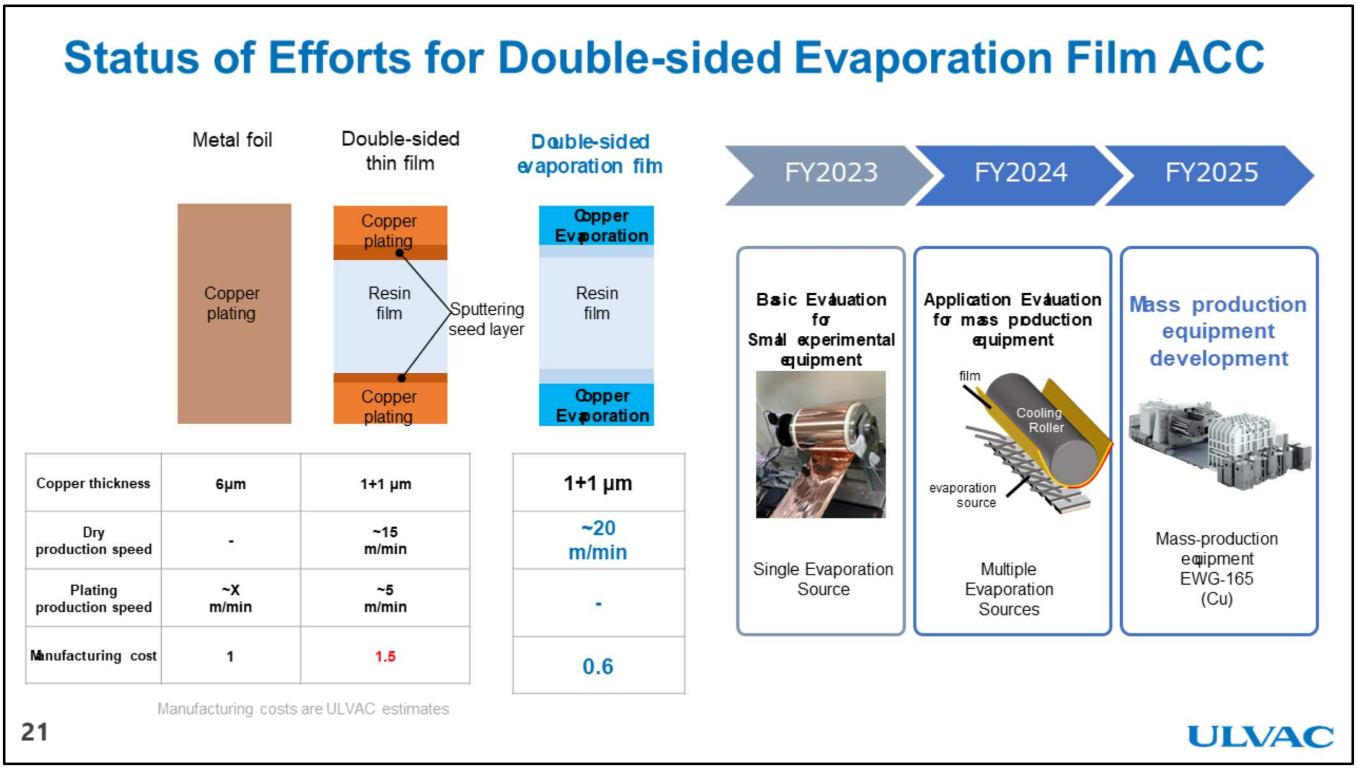
Now, Takei will describe our approach to double-sided evaporation film ACCs.



My name is Takei from the Institute of Advanced Technology.

First, let me explain why double-sided evaporation film ACCs are attracting attention.

In addition to the four reasons shown on the left about the CCCs, a reduction in Cu raw materials can be expected. Copper is one of the valuable resources for which raw material is expected to be in short supply after 2025. Current batteries use electrolytic copper foil of 6 microns or more, but thin films on both sides can reduce this by 50% or more, expected to be a solution to the problem.



	Metal foil	Double-sided thin film	Double-sided evaporation film
Copper thickness	6μm	1+1 μm	1+1 μm
Dry production speed	-	~15 m/min	~20 m/min
Plating production speed	~X m/min	~5 m/min	-
Manufacturing cost	1	1.5	0.6

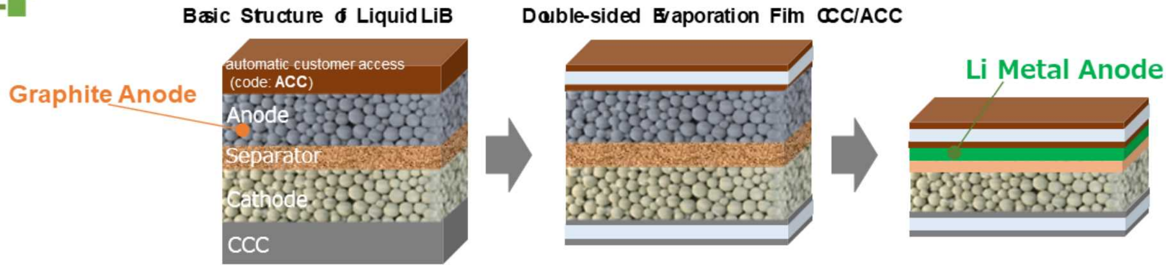
Current double-sided thin-film ACCs are manufactured and prototyped by sputtering a seed layer on both sides of a resin film, followed by copper plating. However, this manufacturing method has the problem of increasing costs.

Therefore, we are applying the double-sided aluminum evaporation technology introduced earlier to develop a production system of double-sided copper evaporation film. We aim to provide value in terms of both reduction of Cu to be used and cost savings.

This development is set to complete basic evaluation using a small experimental device this fiscal year, followed by application evaluation with an actual device in the next fiscal year, and product deployment in fiscal 2025.

Why Focus on Lithium Metal Anode?

Further reduction of size and weight



per MWh	unit	Liquid LiB Structure	Adoption of Double-sided Evaporation Film	Li Anode
ACC Weight	kg	645	289	289
CCC Weight	kg	389	139	139
Anode weight	kg	1,200	1,200	**32**
Other battery weight	kg	1,766	1,766	1,766
Battery weight	kg	4,000	3,394	2,226
energy density	wh/kg	250	294	450

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(Source: Compiled by ULVAC based on data from the Fangzheng Securities Research Institute)

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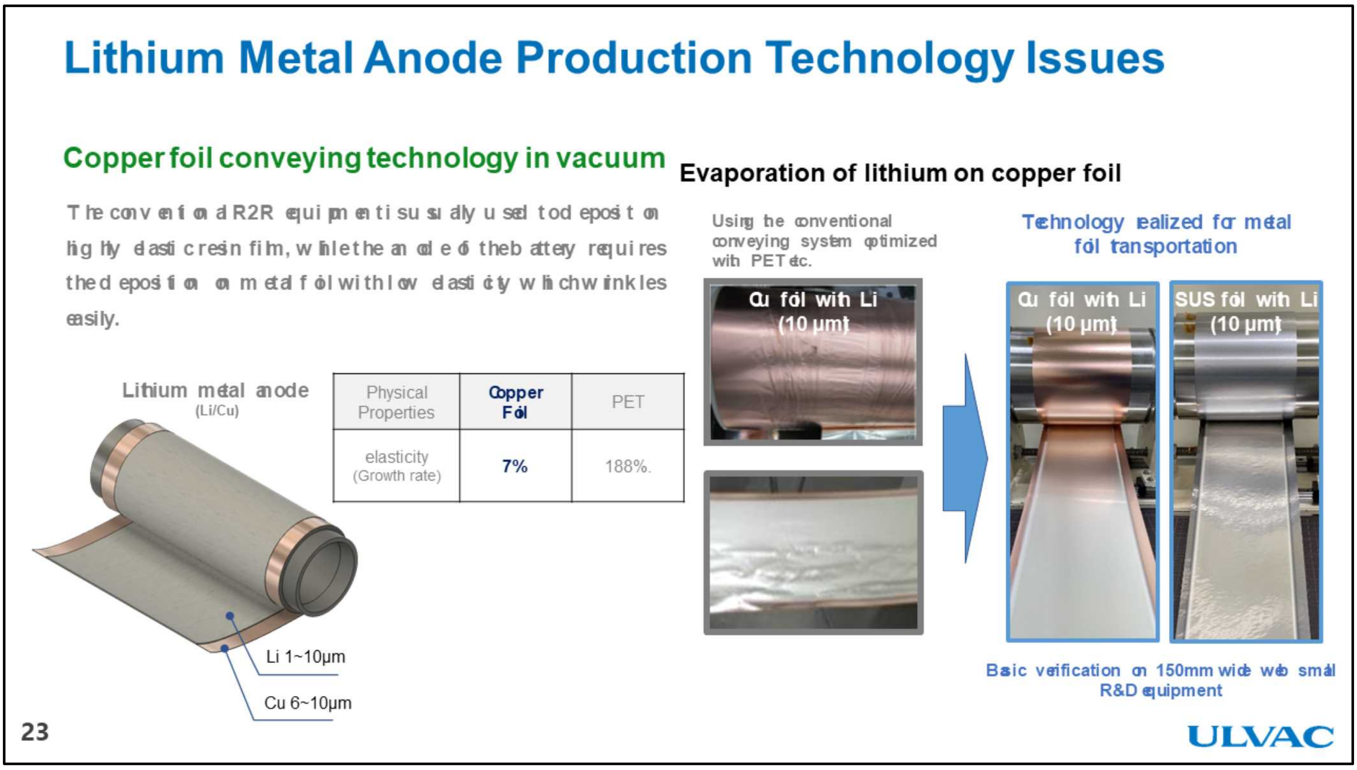
Next, I will discuss the lithium metal Anode, which is attracting attention as a next-generation anode.

The application of lithium metal Anodes can contribute to further downsizing and weight reduction of batteries. Graphite anode is used for the Anode of existing liquid LiBs described earlier, as well as for LiBs applying a double-sided evaporation film CCC and ACC. The Anode weight per megawatt-hour amounts to 1,200 kilograms, accounting for about one-third of the battery's weight.

Converting the graphite anode to a lithium metal Anode can reduce the weight of the anode by about 1/40th, resulting in an increase in battery energy density of about twice the current level.

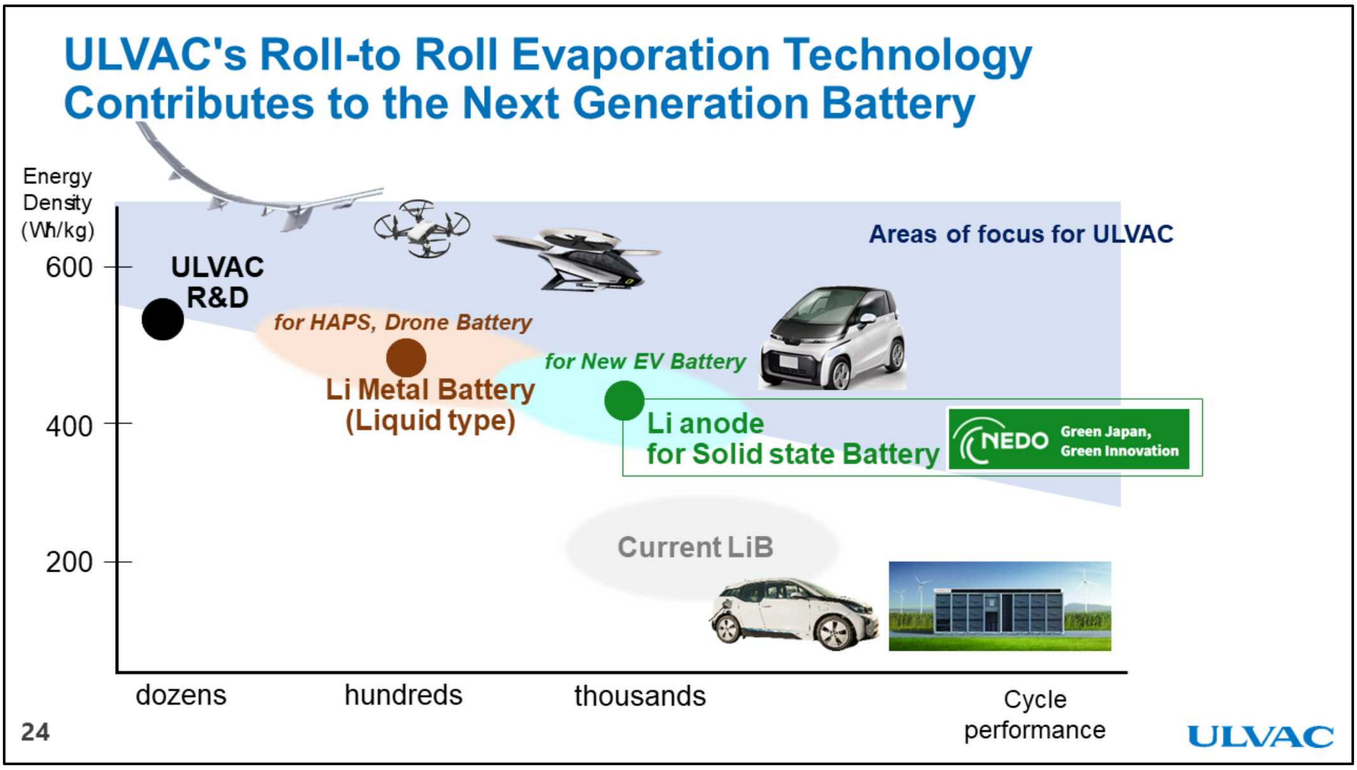


In last year's seminar, we touched on lithium metal Anode manufacturing and production technology issues, and this year's seminar will discuss major progress.

One of the technical challenges in the production of lithium metal Anodes is the transportation of copper and metal foils in a vacuum. If polymer film conveyor technology, as used in CCC production, is applied for conveying metal foil with different physical properties, abnormalities in appearance will occur, as shown in the middle photo.

This fiscal year, we have acquired the technology necessary for metal foil transfer, and as shown on the right, we can form lithium evaporation films in the form of metal foil without any abnormalities in appearance.

We are also evaluating next-generation batteries using this lithium deposition film as the lithium metal anode in batteries.



I would like to introduce a few examples of batteries with lithium metal anodes.

This graph shows energy density on the vertical axis, and the number of possible charge/discharge cycles corresponding to the life of the battery on the horizontal axis.

Batteries using our lithium deposition film as the Anode have been able to achieve performance in excess of 500 watt-hours/kilogram at the R&D level. This was announced in the *Nikkei Business Daily* as a result of a joint project with Waseda University.

Through the Green Innovation Fund project, we will continue development through industry-academia collaboration among battery manufacturers, universities, and research institutes so that it can be applied to the batteries used in the next-generation EVs shown here.

Umeda: Regarding batteries, first, investment in aluminum evaporation film Cathode current collectors has begun with the aim of making them safer, smaller and lighter, cost saving, and reducing CO2 emissions, and orders totaling more than JPY20 billion were received in the previous Q4 and the current Q1. ULVAC's equipment has been highly evaluated for its competitive advantage and high productivity that enables thick film deposition on both sides in a single batch, and further business expansion is expected in the future as investment in the Anode current collector for copper evaporation film has begun.

We also explained that we are working on technological development to replace graphite Anode with lithium metal Anode as the next generation technology.

My name is Iwai, and I am the General Manager of Advanced Electronics Equipment Division.

Today, I would like to describe the market trend for next-generation power devices and our efforts in this area.

1. What is a power device?
2. Market size and trends of power devices
3. SiC power device manufacturing process
4. ULVAC's equipment lineup for SiC
5. Initiatives on GaN

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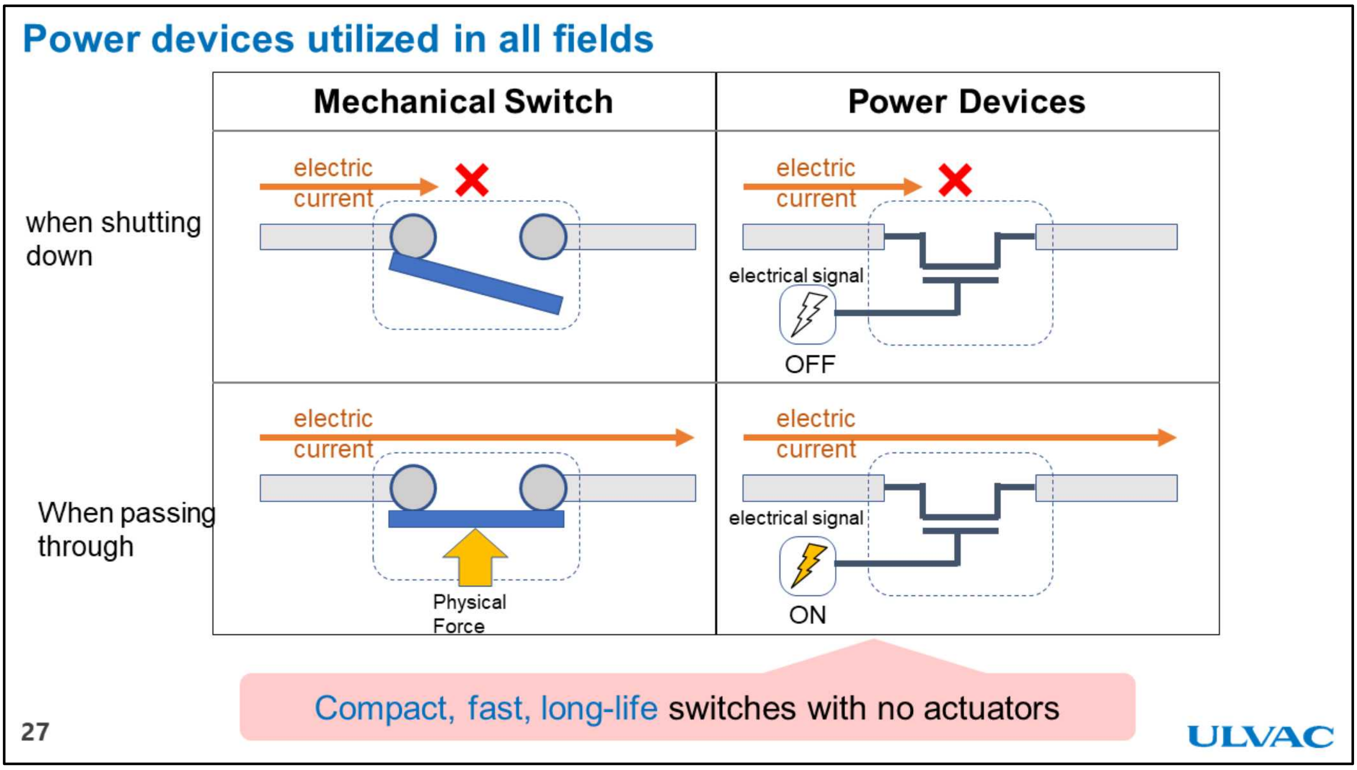
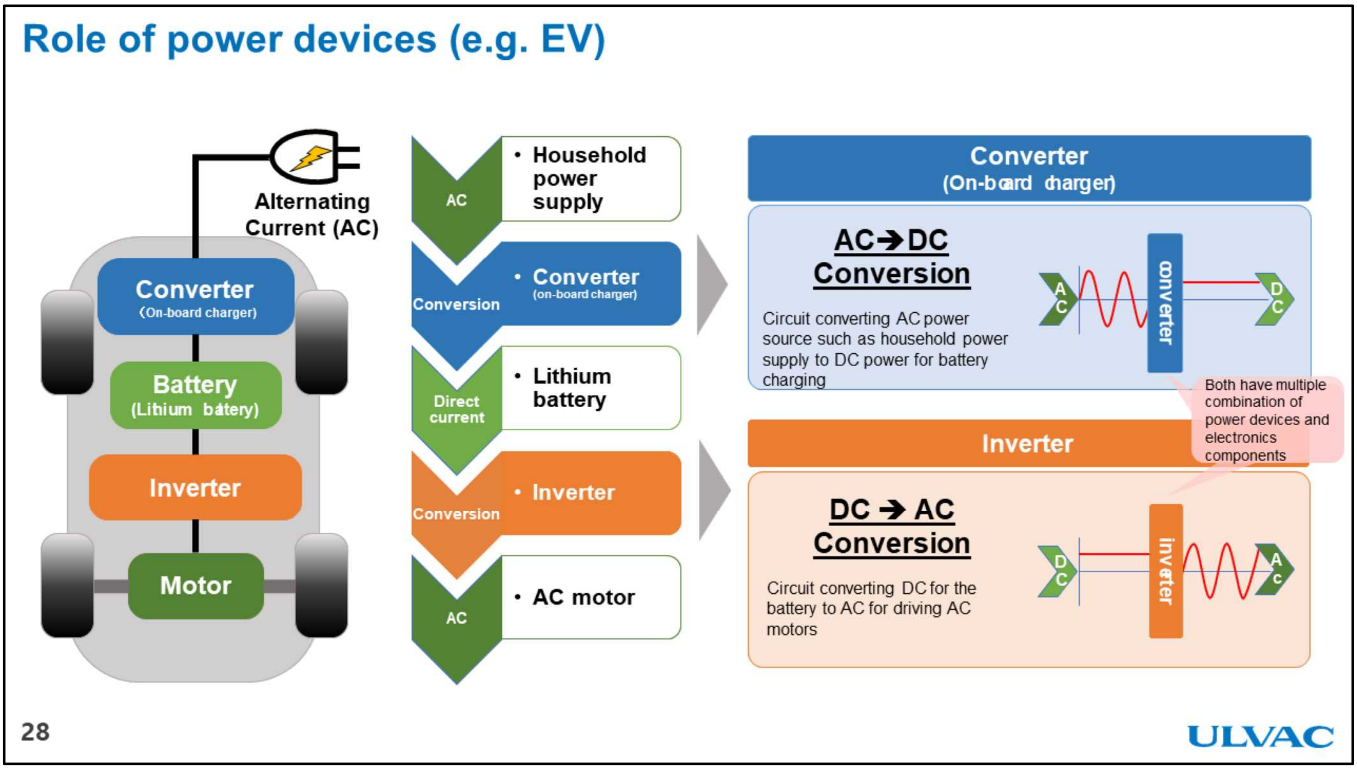
This will be the outline of today's presentation. First of all, I will start with a brief description of power device operation and applications.



The characteristics of power devices is that it can switch electrical signals on and off, whereas the mechanical switch on the left physically moves contacts to switch the current. Since there is no actuators, power devices are compact and can carry large currents at high speed and are used in all fields.

It is said that half of the world's electricity is used to run motors, making power devices extremely important for energy conservation.

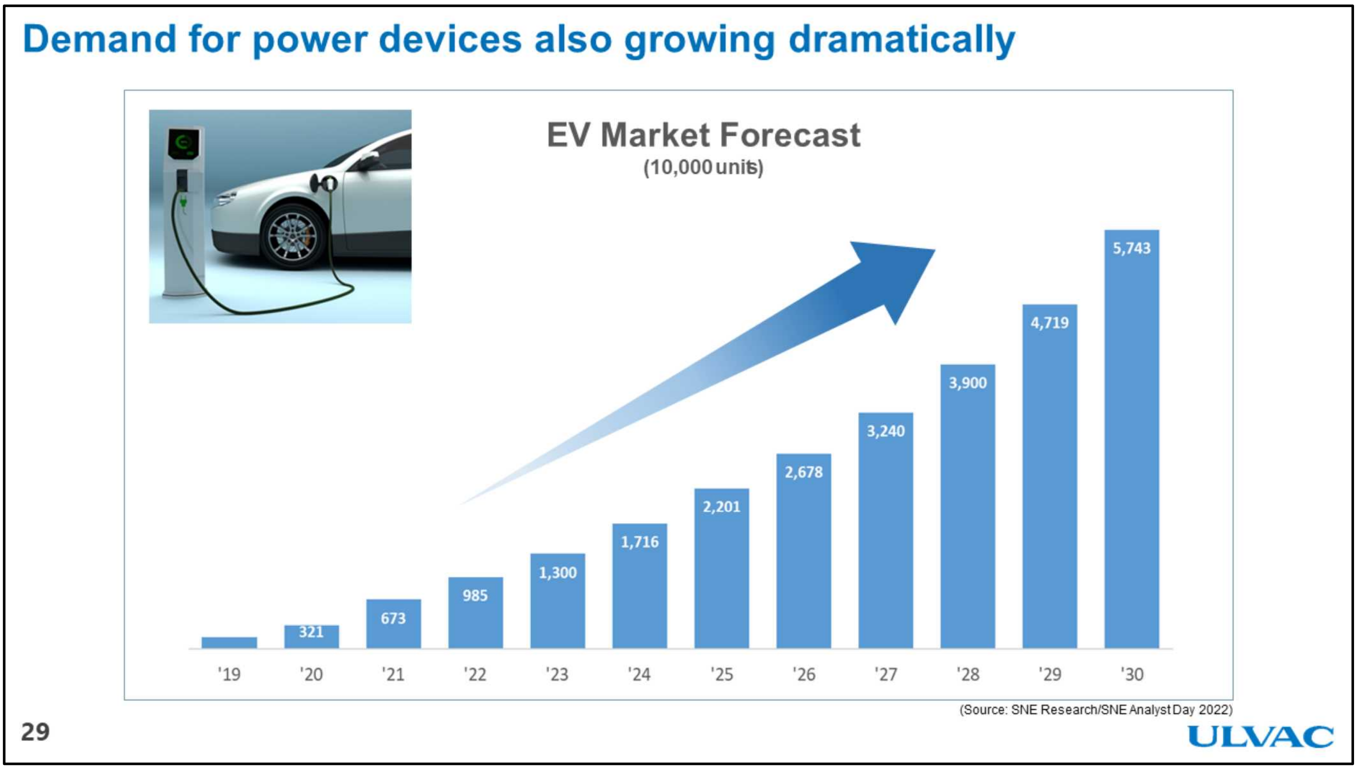


This section explains how power devices are used, using EVs as an example.

When charging a battery from an AC household power source to a DC battery, the AC must be converted to DC. Therefore, an AC-DC conversion circuit, called a converter, is used.

When running, the direct current electricity from the battery is used by the AC motor, so the inverter converts the direct current to alternating current. Both converters and inverters are fabricated by combining multiple power devices and electronic components.

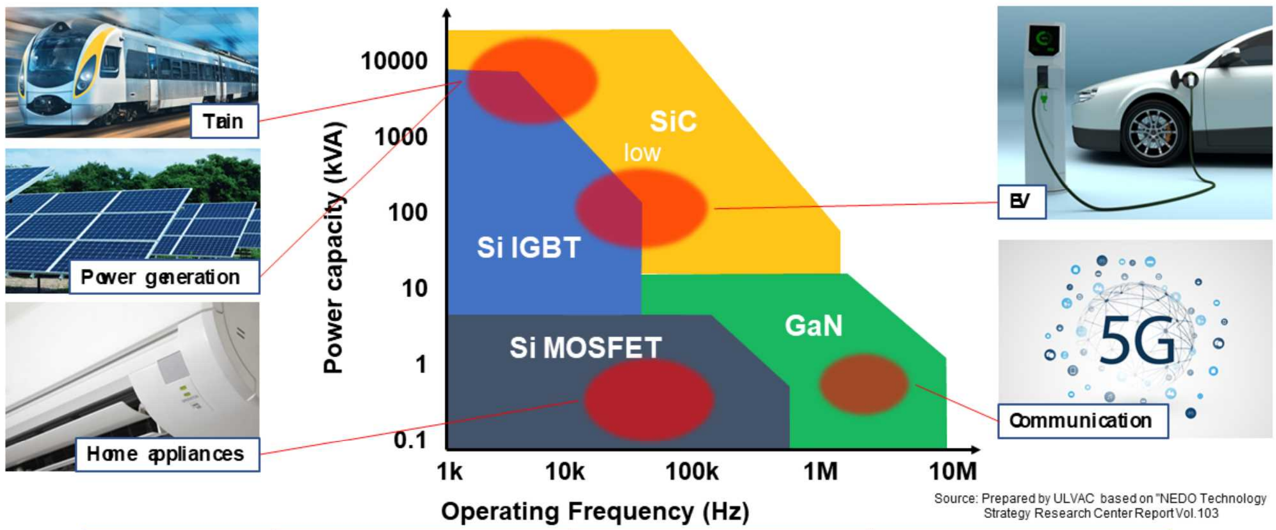
In EV applications, inverters, which perform the conversion from DC to AC, play a major role in power devices, accounting for about 80% of the total.



The EV market is expected to expand significantly due to a combination of environmental measures and regulations in various countries. While the number of vehicles in 2023 is around 13 million units, it is expected to continue to increase to over 20 million units in 2025 and to nearly 60 million units in 2030, and demand for power devices for EVs will also expand dramatically along with this growth.

According to our forecast, 1 million SiC substrates per month will be required in 2025 and 3 million per month in 2030.

Evolving power devices



	Si	SiC	GaN
Advantage	Low cost	Low power loss, compact size	High-frequency operation, compact size
Disadvantage	Upper limits on power and operating frequency	Expensive	Expensive, low current

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Both Silicon and SiC are currently used in EV applications, but SiC is used in higher-priced products due to its smaller size and lower power loss.

GaN is used in some electrical products due to its ability to be miniaturized. It is also capable of high-frequency operation and is used widely for communication applications, such as 5G and the future development of 6G.

In the coming years, demand for SiC and Gallium nitride will further expand due to the growing EV market, market needs for lower power consumption and smaller size, and lower manufacturing costs.

1. What is a power device?
2. Market size and trends of power devices
3. SiC power device manufacturing process
4. ULVAC's equipment lineup for SiC
5. Initiatives on GaN

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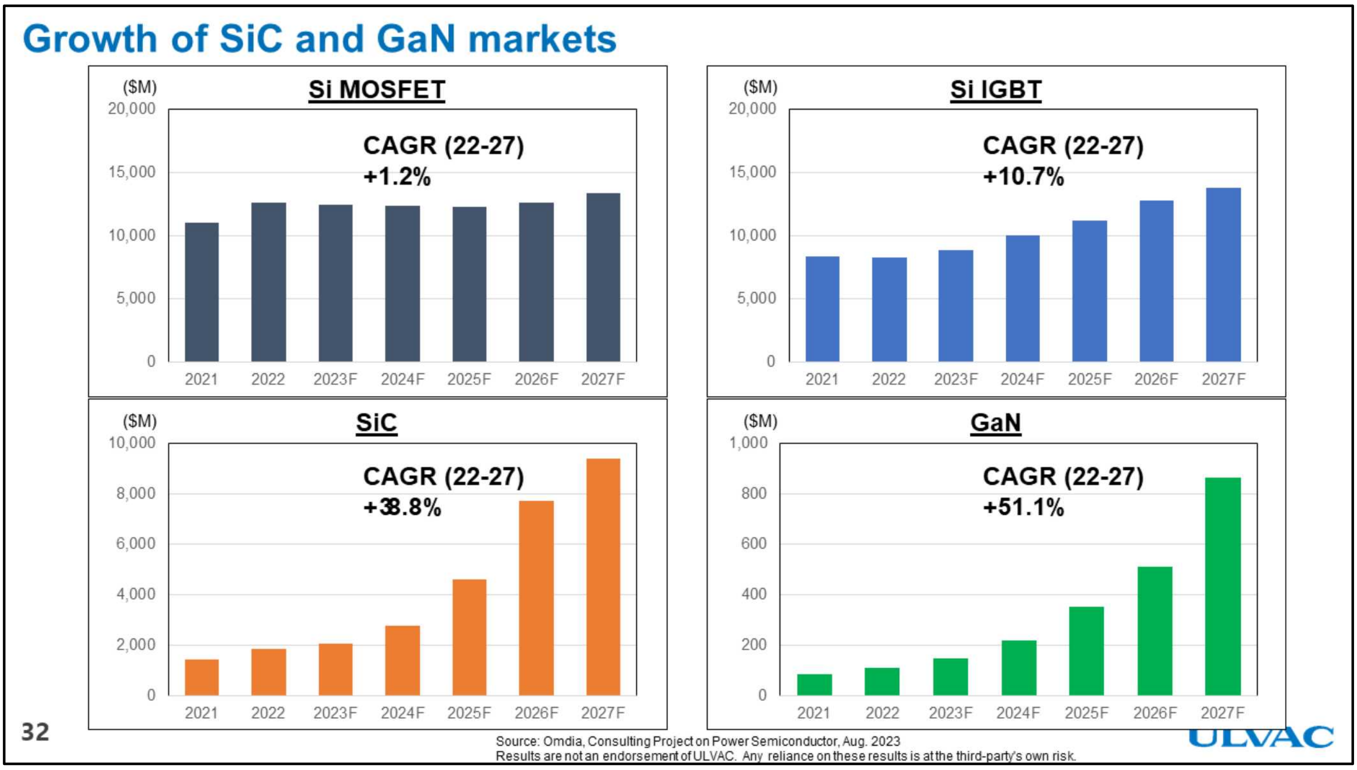
Next, I will discuss the size and trends of the power device market.

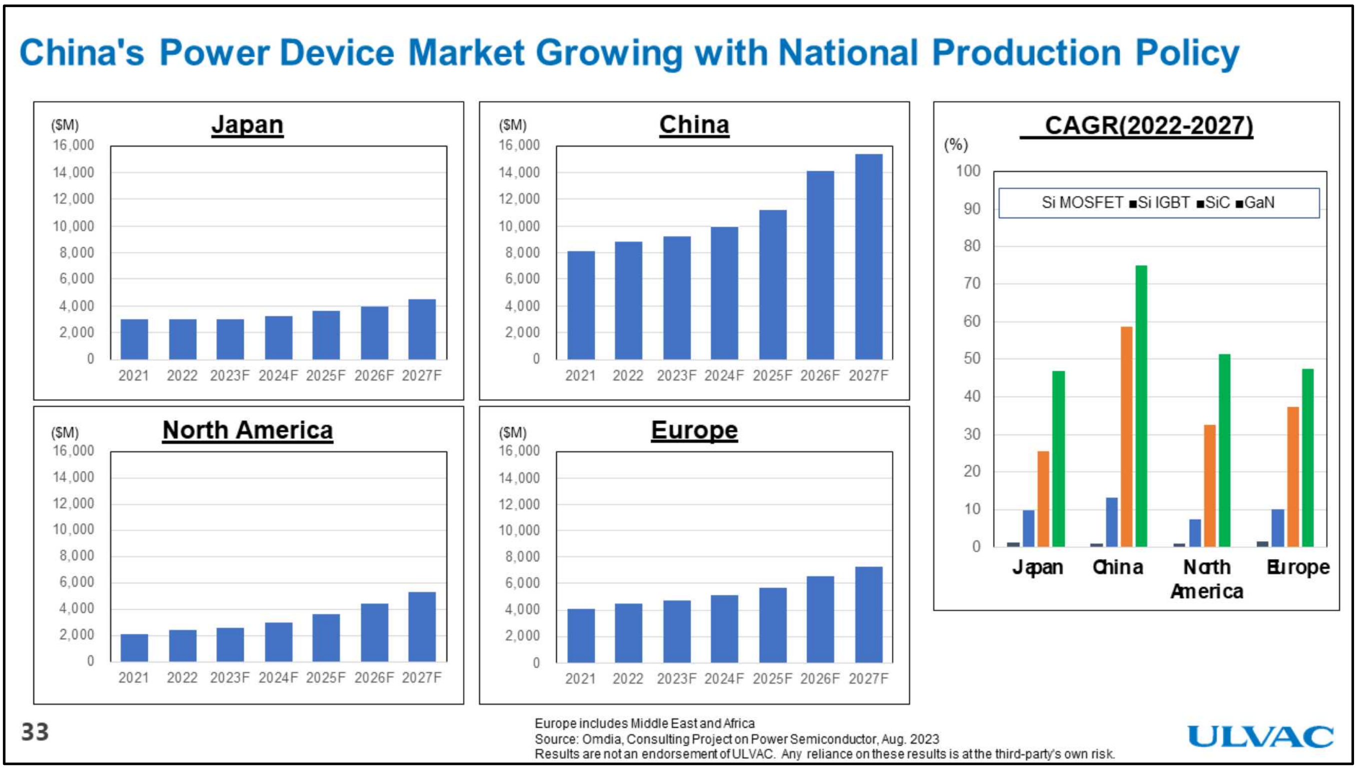


Si-MOSFETs and IGBTs have a wide range of applications and a large market size, but their growth rate is not so large. On the other hand, the appetite for investment in SiC has recently been expanding, partly due to the growing demand for EVs.

Since there will likely be 8-inch SiC products in or around 2023 and cost improvements will also be made, the focus of investment in power devices will shift to SiC in the near term.
The highest growth rate is in GaN. The market size is also expected to grow in the next five years and beyond.

From our point of view as an equipment manufacturer, the increase in devices leads to investment in new equipment, and capital investment is made two to three years prior to the increase in devices. Currently, investment in SiC equipment is growing, and we believe this will be followed by the growth in GaN equipment.

We also believe that the technology shift from Silicon IGBT to SiC for EV applications will be an opportunity for ULVAC to enter in new markets. In Q1, investment in SiC was active in Japan, and we were able to win orders for Ion implantation systems for SiC, for which we have secured a high market share in China.



By region, China has the largest market size and growth, driven by its policy of domestic production and the shift to EVs. The graph on the right shows the growth rate of each region by material. Both SiC and GaN are expected to grow significantly in China.

ULVAC has secured a large share of the growing Chinese Si market with its Ion implanter, and we believe it can grow significantly in the future.

Increased substrate size and structural changes expand business opportunities

China

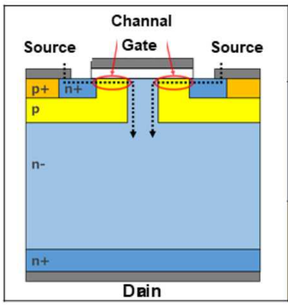
Substrate: 6-inch
Structure: Planar

*It is expected that 8-inch substrates with trench structure will be available in China in a few years.

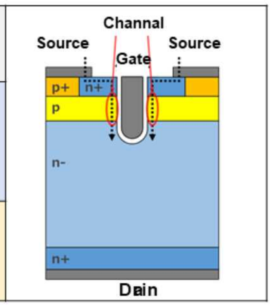
Japan

Shift in
Substrate: 6-inch → 8-inch
Structure: Planar → Trench

Substrate warpage: 6 inches, approx. 200um
8 inches, 300-500um approx.



Planer	Structure	Trench
Simple process	**Advantage**	Low channel resistance (50%↓) Miniaturization is possible (20%↓)
High channel resistance Limits to miniaturization	**Disadvantage**	Complicated process



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In China, where the market size is large, the most common substrate size is 6-inch, and the device structure is planar. In Japan, the current investment is for 6-inch products, but there will be a transition to an 8-inch trench structure. In a few years, China is expected to shift to 8-inch trench structures, and we believe that our track record in Japan will be very important.

ULVAC already has a lineup of sputtering equipment and ion implanter for 8-inch products. The larger the substrate, the greater the warpage of the substrate. It is important to control the warpage of the substrate and to use techniques to transport warped substrates.

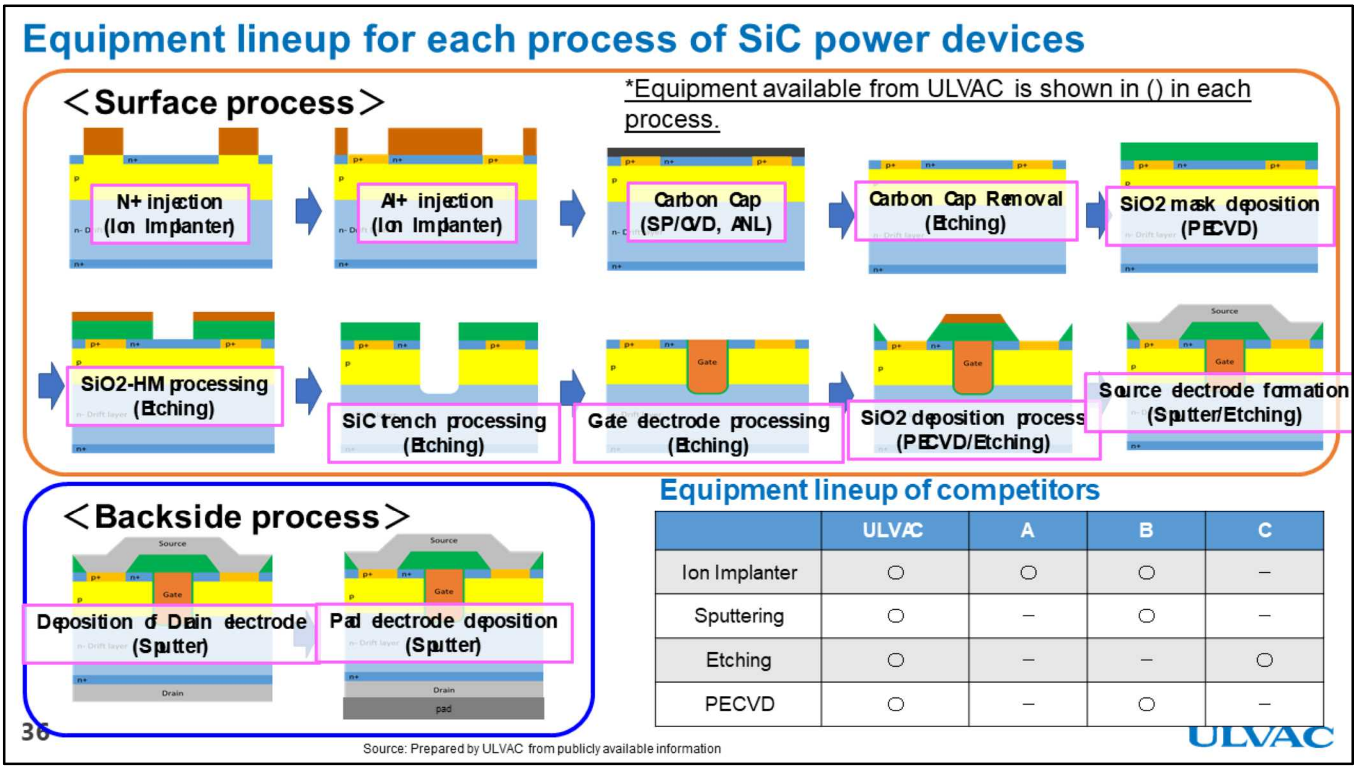
Now, I will describe the differences between planar and trench structures.

While planar has a simple manufacturing process and is easy to produce, it has the disadvantages of high channel resistance, high power loss, and limited miniaturization.

On the other hand, trenches have the advantages of low channel resistance, low power loss, and miniaturization. However, the manufacturing process is complex and requires advanced process technology and know-how.

1. What is a power device?
2. Market size and trends of power devices
3. **SiC power device manufacturing process**
4. ULVAC's equipment lineup for SiC
5. Initiatives on GaN

Next, I will provide an overview of the manufacturing process for SiC power devices, which are currently experiencing rapid growth, as well as the challenges faced in the manufacturing process and ULVAC's strengths.



	ULVAC	A	B	C
Ion Implanter	○	○	○	–
Sputtering	○	–	○	–
Etching	○	–	–	○
PECVD	○	–	○	–

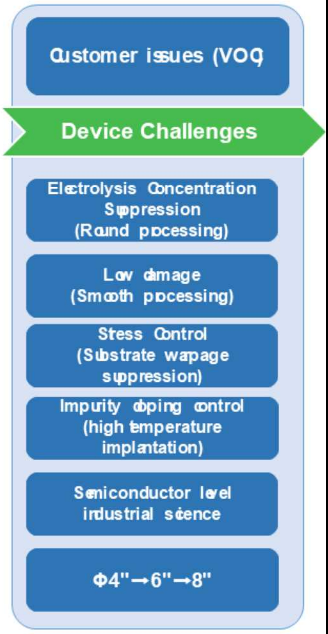
This is an overview of the SiC power device manufacturing process.

This is an example of the trench structure described earlier. Wet processes such as cleaning, and photolithography processes such as exposure are omitted, but vacuum equipment is used in many processes in the manufacture of SiC power devices because the front-end semiconductor processes are adapted.

In this figure, the process indicated by the pink square frame is the vacuum equipment provided by ULVAC. Our advantage over our competitors is that we can provide all vacuum equipment, including ion implanter, sputtering equipment, etching equipment, and PECVD equipment.

ULVAC's Vacuum Technology to Solve SiC Power Device Issues

		Si	SiC	issue
1)	Ion Implanter Number of times processed in one process	One time	**Plural times**	• Throughput
2)	Ion Implanter Processing temperature	Normal	**Low/High temperature**	• Ion Implanter Concentration Control • Throughput
3)	Warp of substrate	Small (none)	**Large**	• Substrate warpage suppression • Warped substrate transport
4)	Substrate Price	Low	**High**	Transport reliability
5)	Response to trench structure	Utlizing accomplishment in Si semiconductors	**New development necessary**	Process geometry control



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In the case of SiC, multiple ion implantations are required due to the hardness of the substrate, and the ion implantation temperature must be varied depending on the process. Thus, the challenge is to increase productivity. Since SiC substrates are expensive and warp significantly, it is important to have technology to control warpage and transport warped substrates without cracking.

Trench structures are also important for device characteristics, especially in the etching process, as they limit the processing geometry. To solve these issues, ULVAC has been developing the required technologies and meeting customers expectations through technological innovation.

1. What is a power device?
2. Market size and trends of power devices
3. SiC power device manufacturing process
4. ULVAC's equipment lineup for SiC
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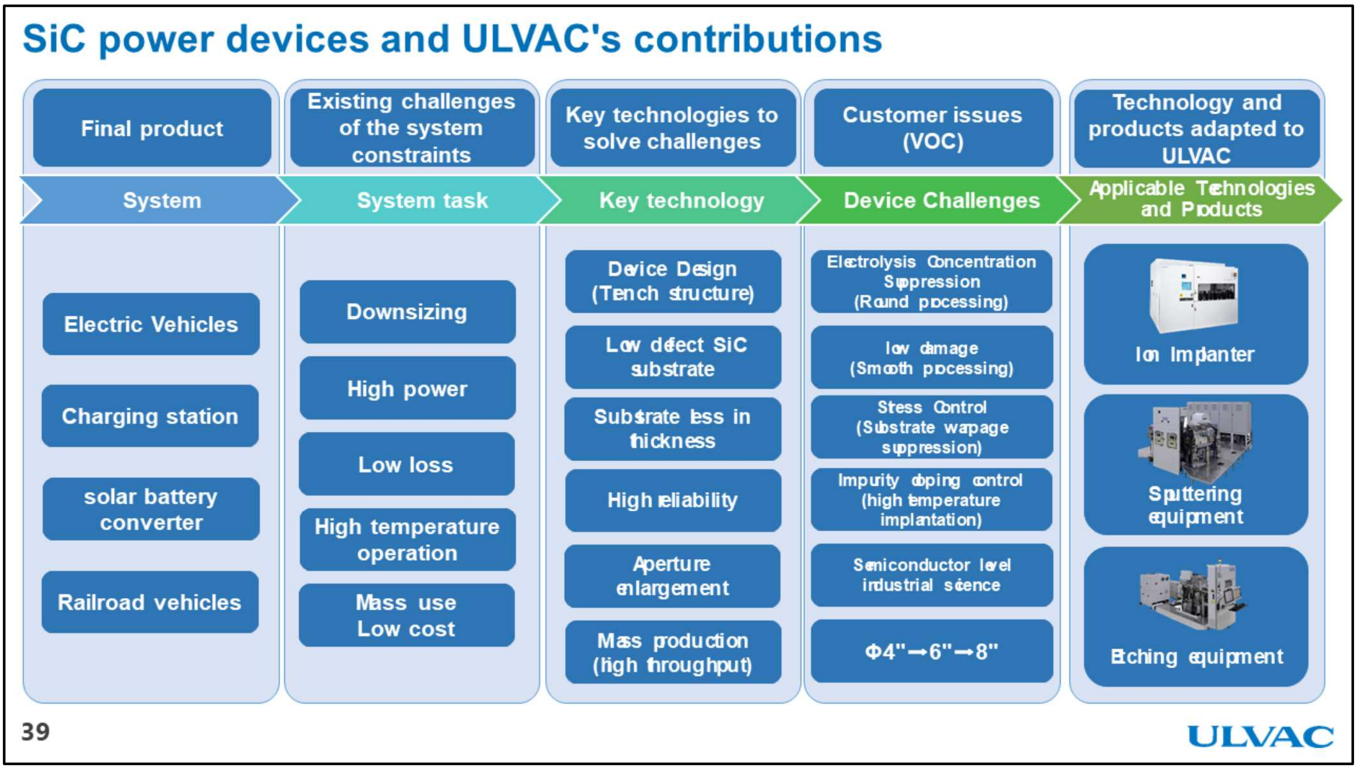
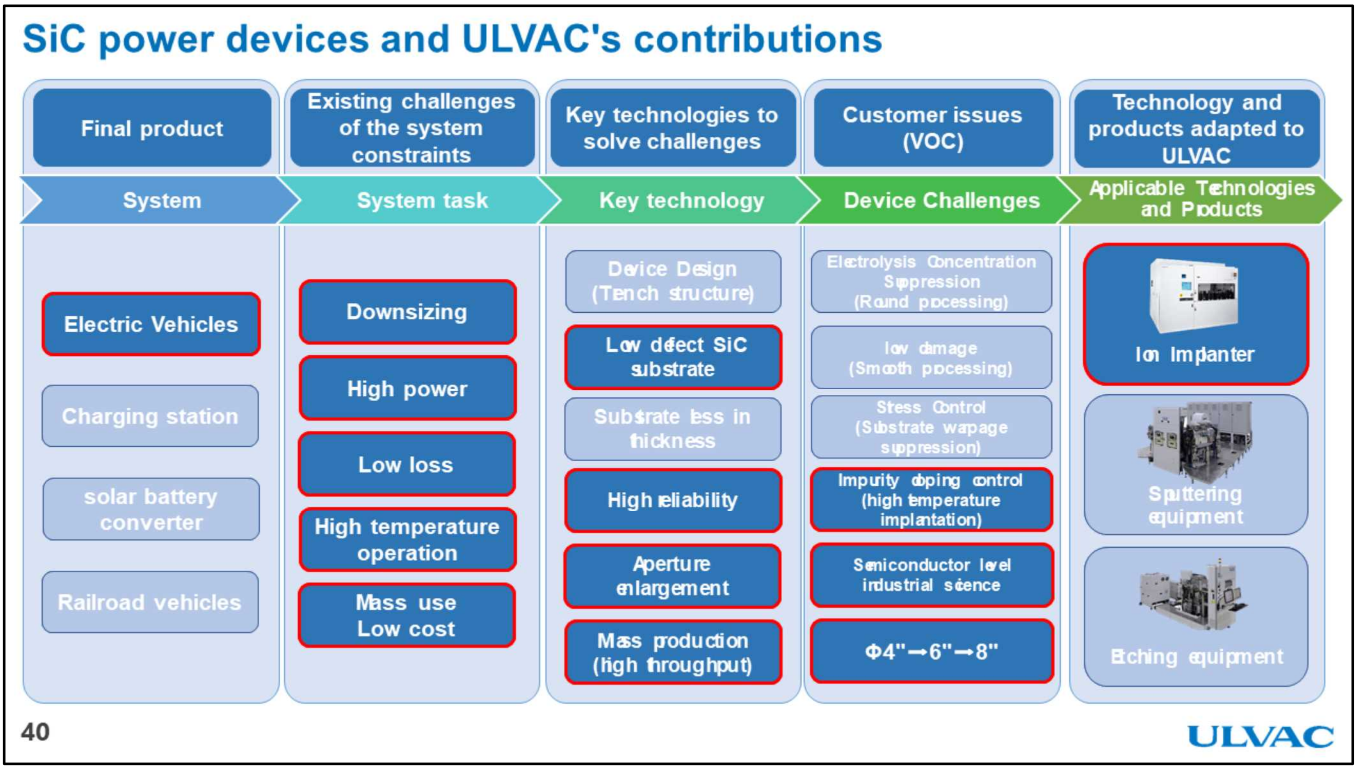
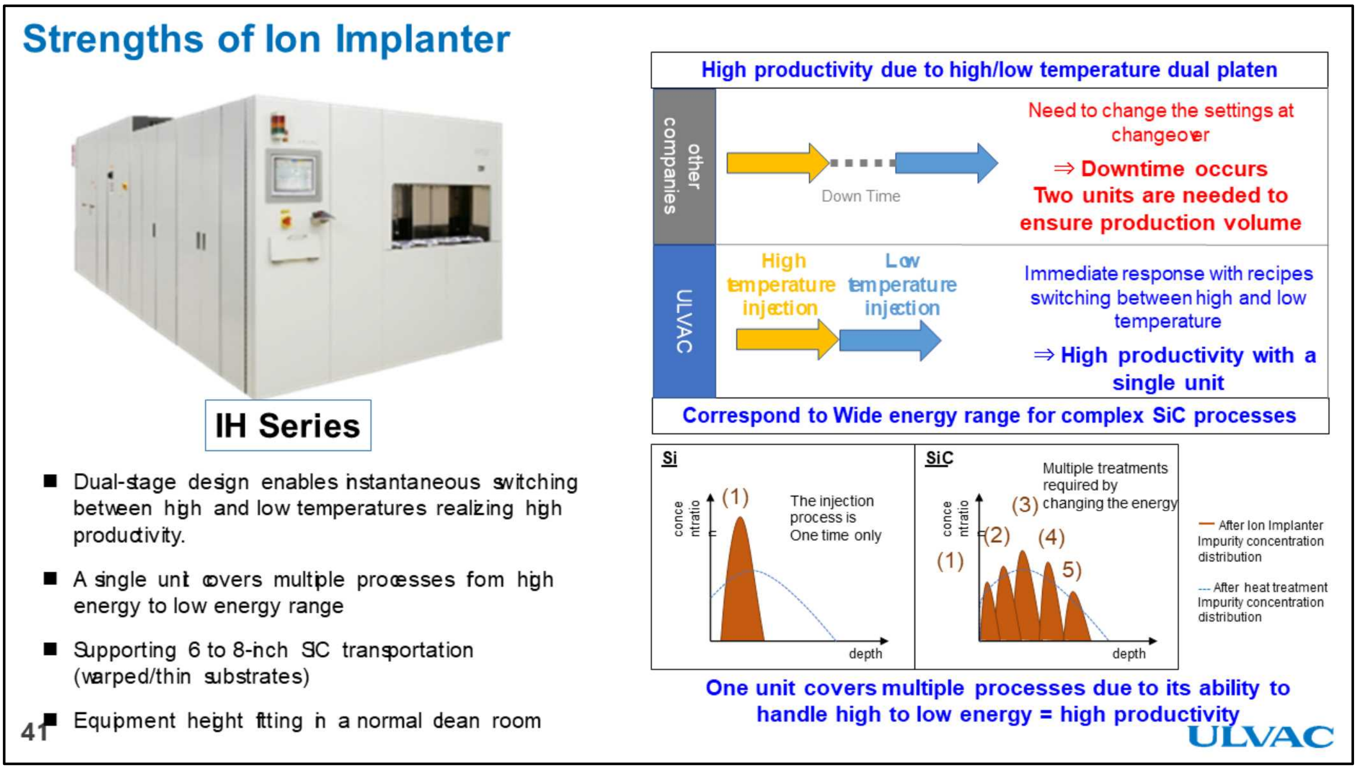
Now, I will present the equipment lineup for SiC and its strengths.



This diagram shows, from left to right, SiC final products, challenges, key technologies that solve the challenges, manufacturing challenges as described on the previous page, and ULVAC products that solve these challenges. I will describe each device in detail.



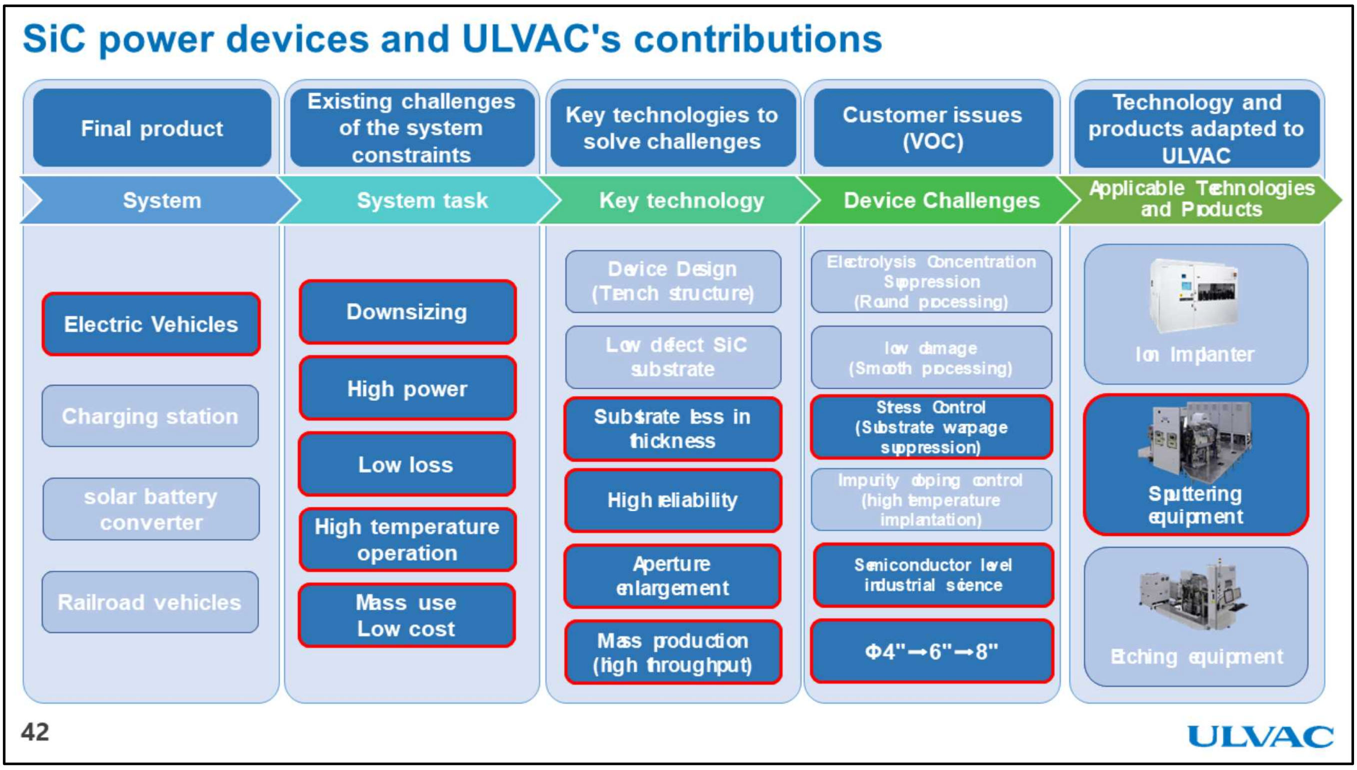
First, ion implanter. For electric vehicles, it is necessary to solve issues such as downsizing, higher output, lower power loss, and lower cost. For SiC power devises, in addition to low-temperature implantation, ion implanters must be able to handle high-temperature implantation, semiconductor-level manufacturing technology, and increased wafer size.



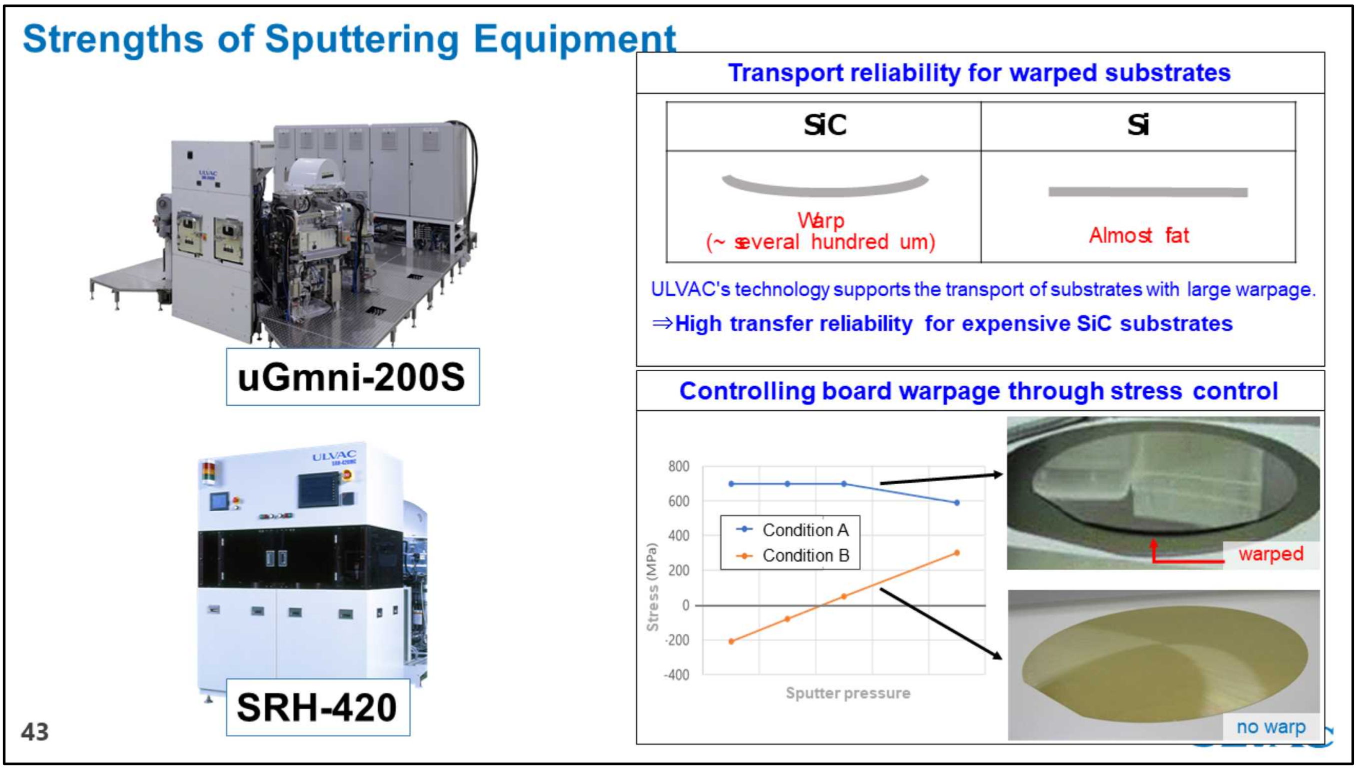
In the case of SiC, multiple ion implants are required at high and low temperatures. Other companies' equipment requires two or more units, because setting changes are necessary when switching between high and low temperatures, resulting in downtime.

ULVAC's ion implanter can easily switch between low and high temperatures by recipe settings, enabling high productivity with a single unit. The ability of a single unit to cover multiple processes, from high-energy to low-energy areas, has been highly evaluated and as a result, we have secured a more than 70% share of the Chinese market, which is the leading market for SiC. Another strength is the high transport reliability for warped and thin substrates.

In addition, the compact ion source specialized for SiC has enabled to reduce the height of the equipment to about 3 meters, compared to the height of other companies' equipment, which is about 5 meters, and the height is compact enough to fit in the clean room of an ordinary semiconductor plant. This is highly evaluated by our customers.

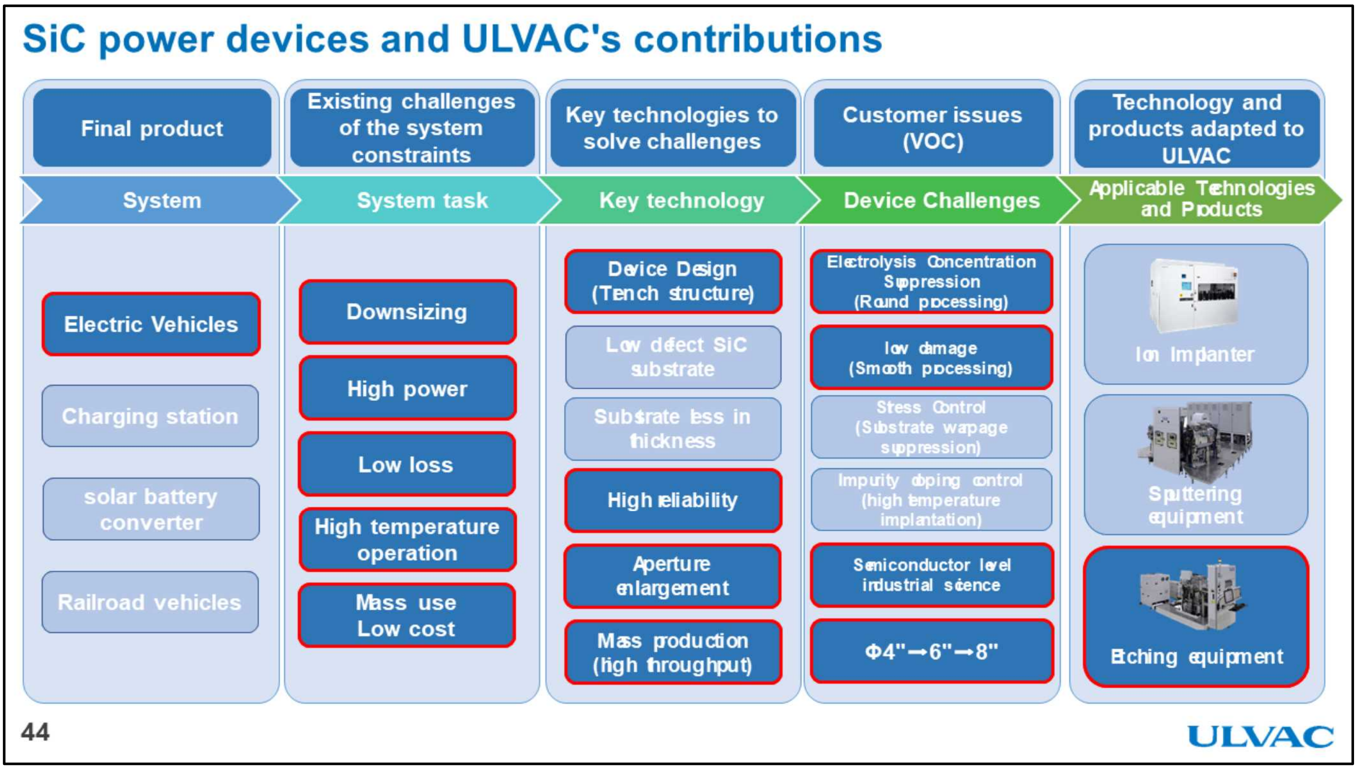


Next, I will describe the sputtering equipment.

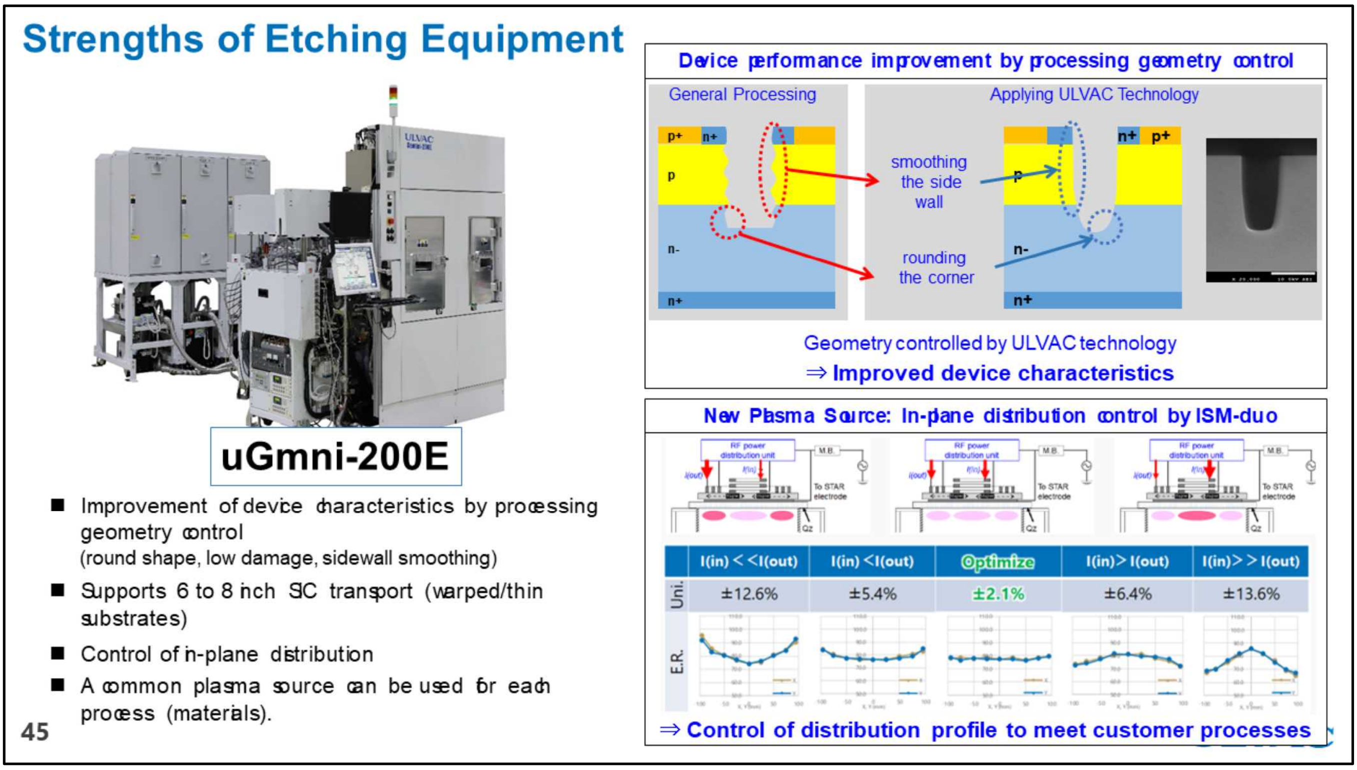


The main features of ULVAC's sputtering equipment are high transport reliability for warped and thin substrates, and the ability to control substrate warpage through stress control.

Silicon is almost flat, but SiC substrates warp significantly, making stable transport difficult. Compared to other companies, it is noteworthy that ULVAC's advanced technological development has made it possible to transport substrates with large warpage and to control the warpage.



Finally, the etching system.



Earlier, I explained that the trench structure lowers channel resistance, power loss, and that the manufacturing process is complex and requires advanced process technology and know-how in order to achieve miniaturization. The key to achieving trench structures is to improve device characteristics by controlling the processing geometry of the etching technology.

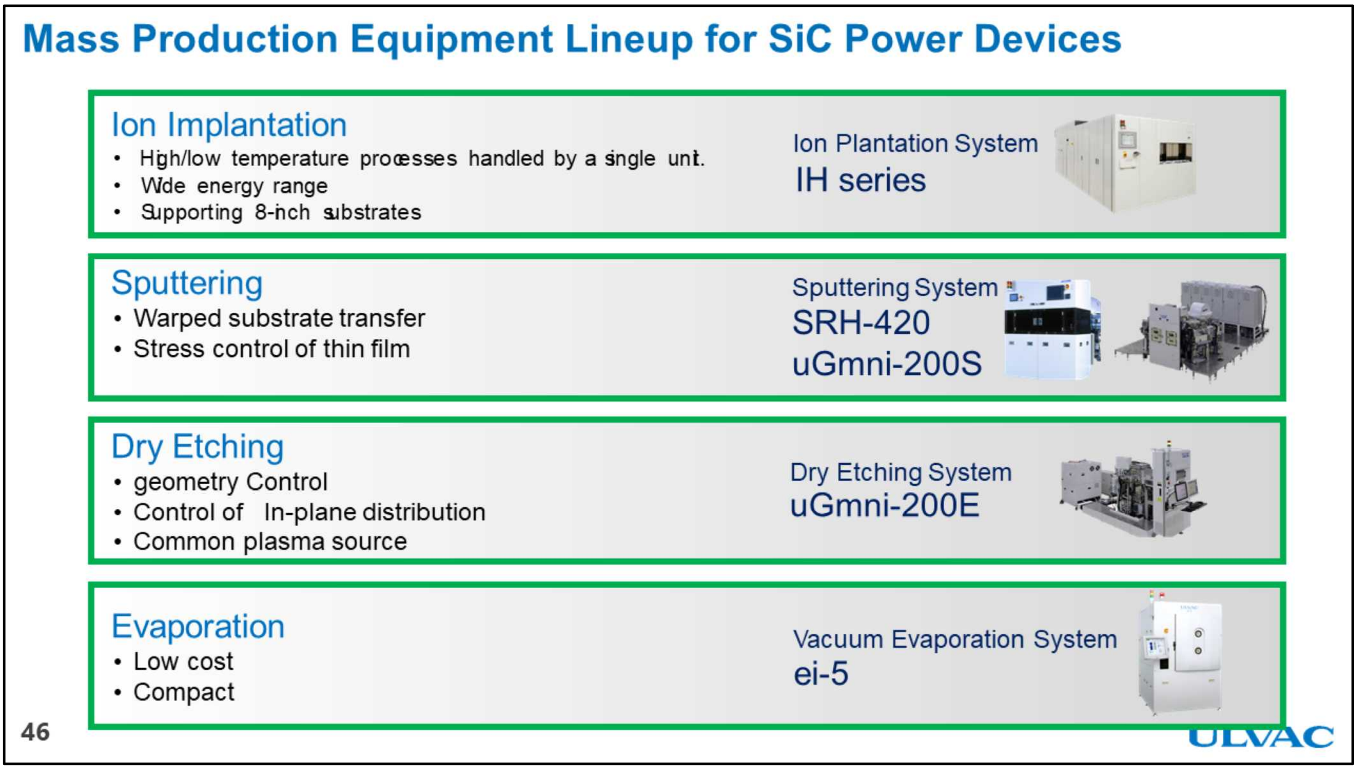
Etching damage to the trench sidewalls will reduce device reliability. Yet, ULVAC's etching technology enables smooth processing of the sidewalls.

In addition, the corners at the bottom of the trench are subject to a concentration of electric fields, resulting in a decrease in the breakdown voltage of the device. With ULVAC's etching technology, it is also possible to process the corners into a round shape. Such etching process geometry control can improve device characteristics.

Another strength of ULVAC equipment is its high transport reliability for warped and thin substrates.

Etching is used in various processes in the power device manufacturing process, and the ability to use a common plasma source for each process has been highly evaluated.

Another feature is that it can be controlled to a distribution profile tailored to the customer's needs through recipe control.



We have organized the strengths of ULVAC equipment introduced so far. In addition to ion implanters and sputtering and etching systems, we also provide evaporation systems for mid to low-end power devices locally produced in China.

1. What is a power device?
2. Market size and trends of power devices
3. SiC power device manufacturing process
4. ULVAC's equipment lineup for SiC
5. Initiatives on GaN

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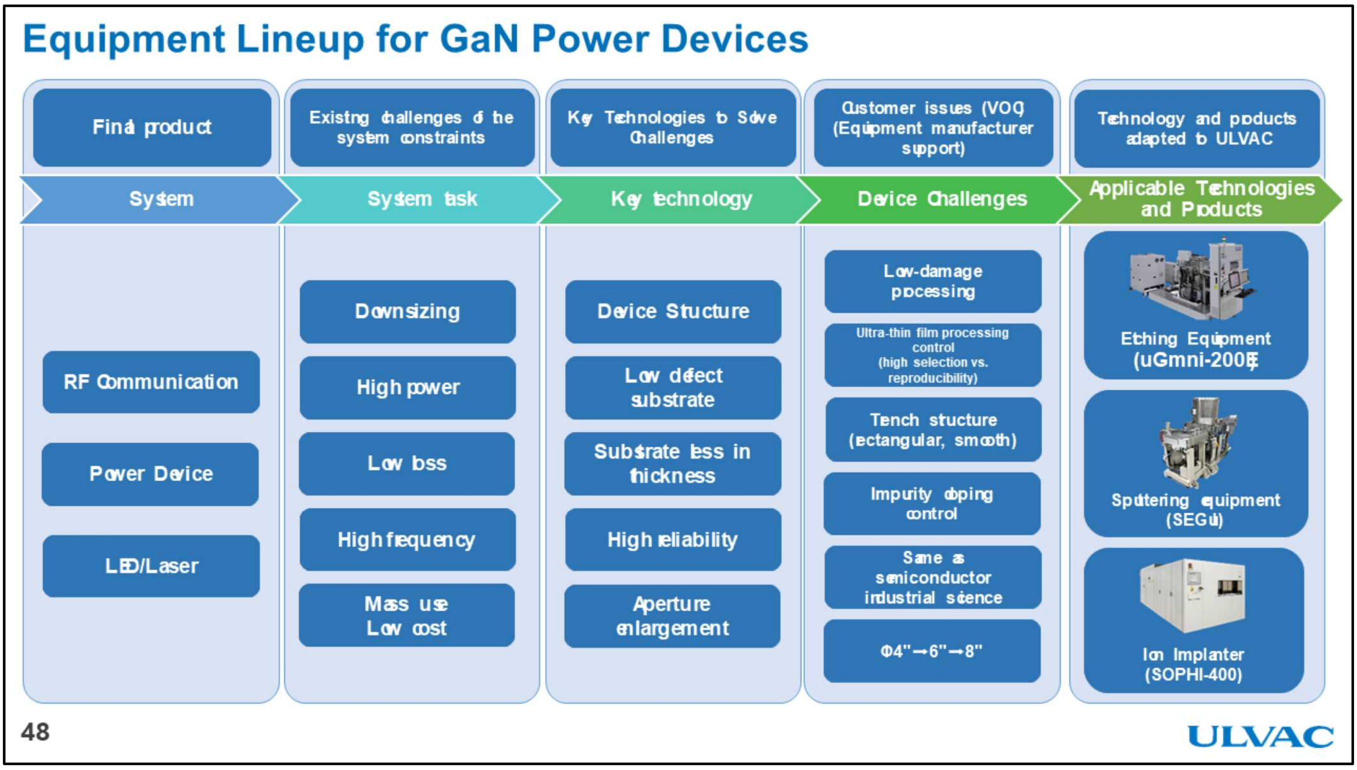
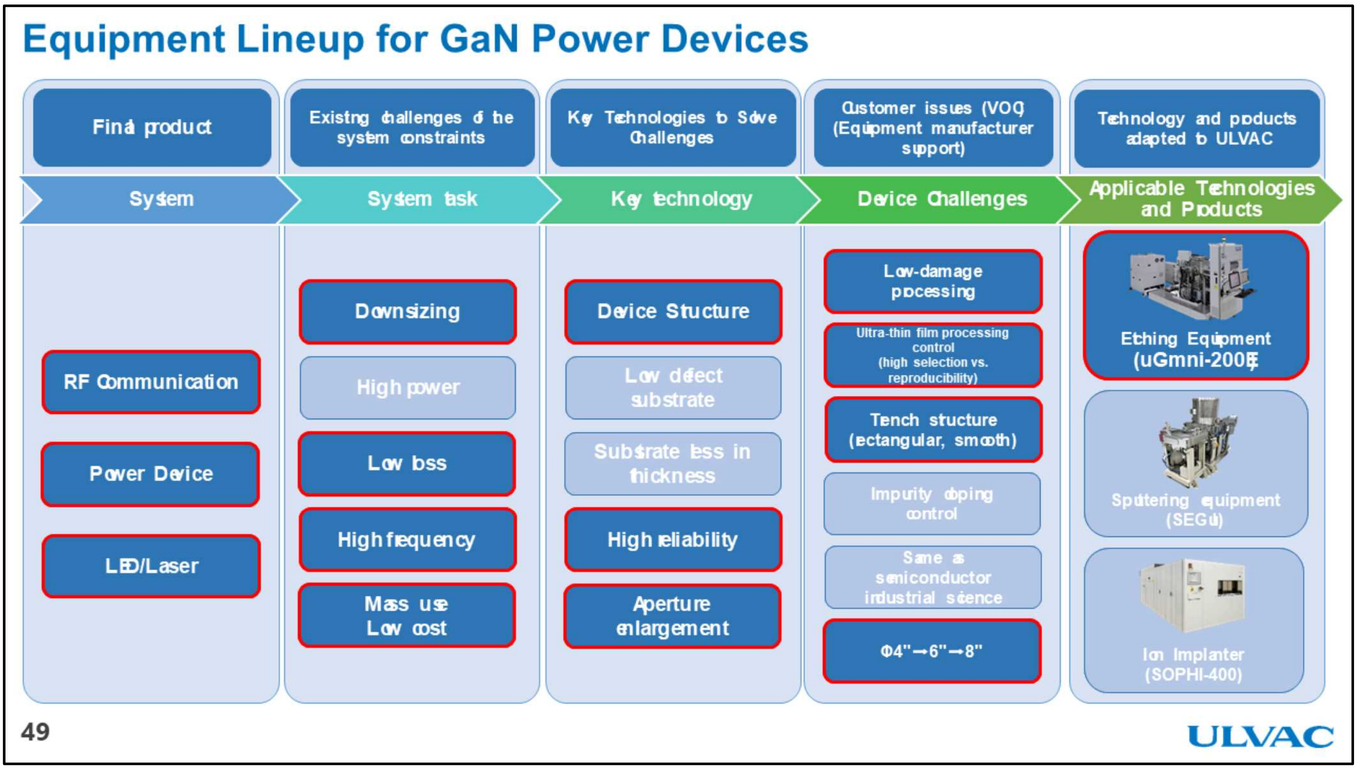
Next, I will explain ULVAC's approach to GaN, which is being actively researched and developed as a next-generation power device.

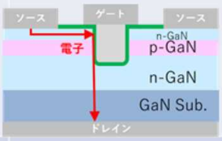


The following is a summary of GaN issues and ULVAC's equipment and technology. Details are provided on the following pages.



First, the etching system.

ULVAC’s Strengths in Etching Equipment for GaN Power Devices

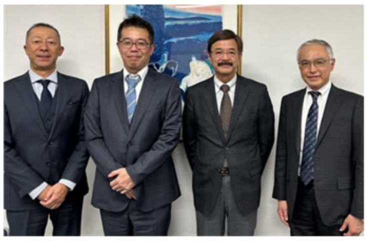
	Horizontal GaN	Vertical GaN
Situation: Equipment Device	Development Completed Mass-production in progress	Development completed Process adjustment in progress
Structure		
Direction of flowing electronics (current)	Horizontality	Vertical
Current output	Small	Large
Process difficulty	Medium	High
Cost (Substrate used)	Low to medium Si, SiC	High GaN

Development of Etching equipment for GaN -Collaboration with Nagoya University

Nagoya University

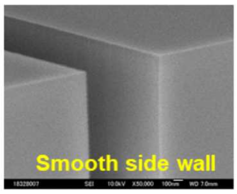
Conference presentation on "GaN Trench Formation

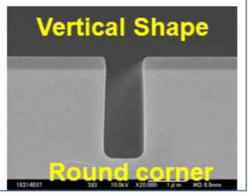
Shinji Yamada et al., Appl. Phys Lett. 118, 102101 (2021);



2023.11.21 At ULVAC Symposium

From left: Mr. Kiyota, Mr. Iwai, Dr. Kaji of Nagoya University, Mr. Umeda





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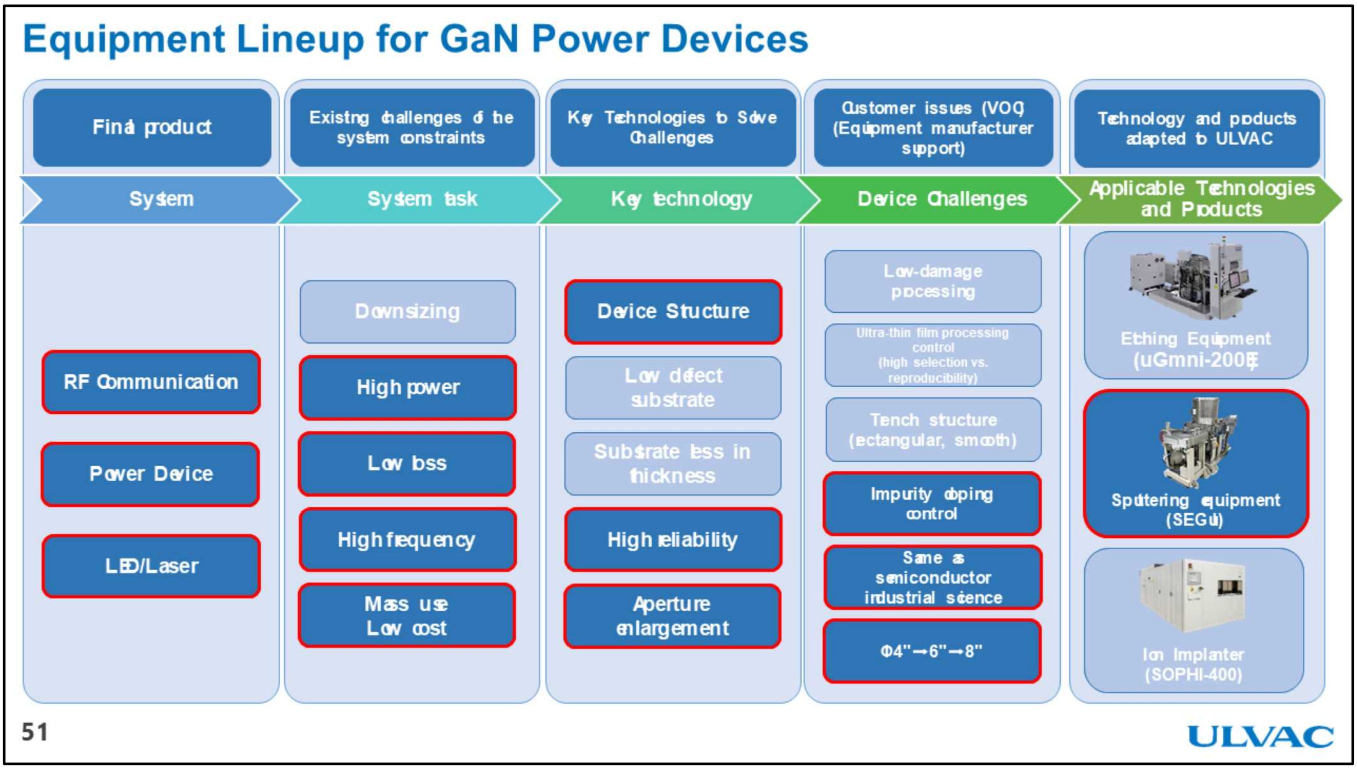
The table on the left describes the horizontal type currently in mass production and on the right describes the vertical type being researched and developed as a next-generation device. Since the vertical type will be able to carry large currents, its applications are expected to grow for high outputs from no on other than relatively small outputs used in electrical products described in Part 1.

ULVAC is also involved in the development of equipment for vertical applications. The results of the development, in collaboration with Nagoya University, have been presented at academic conferences.

ULVAC's etching technology can handle processing geometry control of each part with low damage. Therefore, we have received recognition for improving device characteristics.



Finally, the sputtering equipment for GaN.

Strengths of Sputtering Equipment for GaN Power Devices

■Only Ga, N_2 , Ar and Si or Ge are used as deposition materials.

■Low temperature growth at <700°C

■High carrier density n-GaN [1.0E^{20} (/cm^3)]

■8-inch substrate in-plane uniformity [<±10]

	MOCVD	GaN Sputtering
Deposition temperature	Over 1000°C	Less than 700°C
Detoxification facility Gas detoxification facilities, etc	Necessary ×	Unnecessary ○
Manufacturing cost	High ×	Low ○
Crystalline	Best ◎	Good ○
Carrier concentration	10^{19} (/cm)^3 ○	10^{20} (/cm^3) ◎

SEGul-200

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This is a sputtering system capable of GaN deposition. Conventionally, films have been deposited by the MOCVD process. By switching to sputtering, it is possible to deposit films with a minimum number of raw materials.

MOCVD is a chemical deposition process that utilizes gases and requires the treatment facilities to render the gases harmless. Sputtering equipment does not use special gases, so no such treatment facilities are required.

In addition, compared to MOCVD, high-mobility n-type GaN can be deposited at lower temperatures with a smaller thermal record to the device.

Sputtering equipment has advantages, such as lower equipment costs and environmental friendliness, and business opportunities will expand as GaN gains momentum.

Umeda: Iwai explained that, in the future, SiC investment in power devices will become more active, and the business opportunities for ion implanters, sputtering systems, and etching systems in trench structures will further expand in China and Japan.

We also described how our etching and sputtering systems can contribute to the next-generation GaN technology.

Vacuum technology
for manufacturing
ULVAC