Advanced Materials Business Division

Business Briefings

September 26, 2025

Tokuyama Corporation

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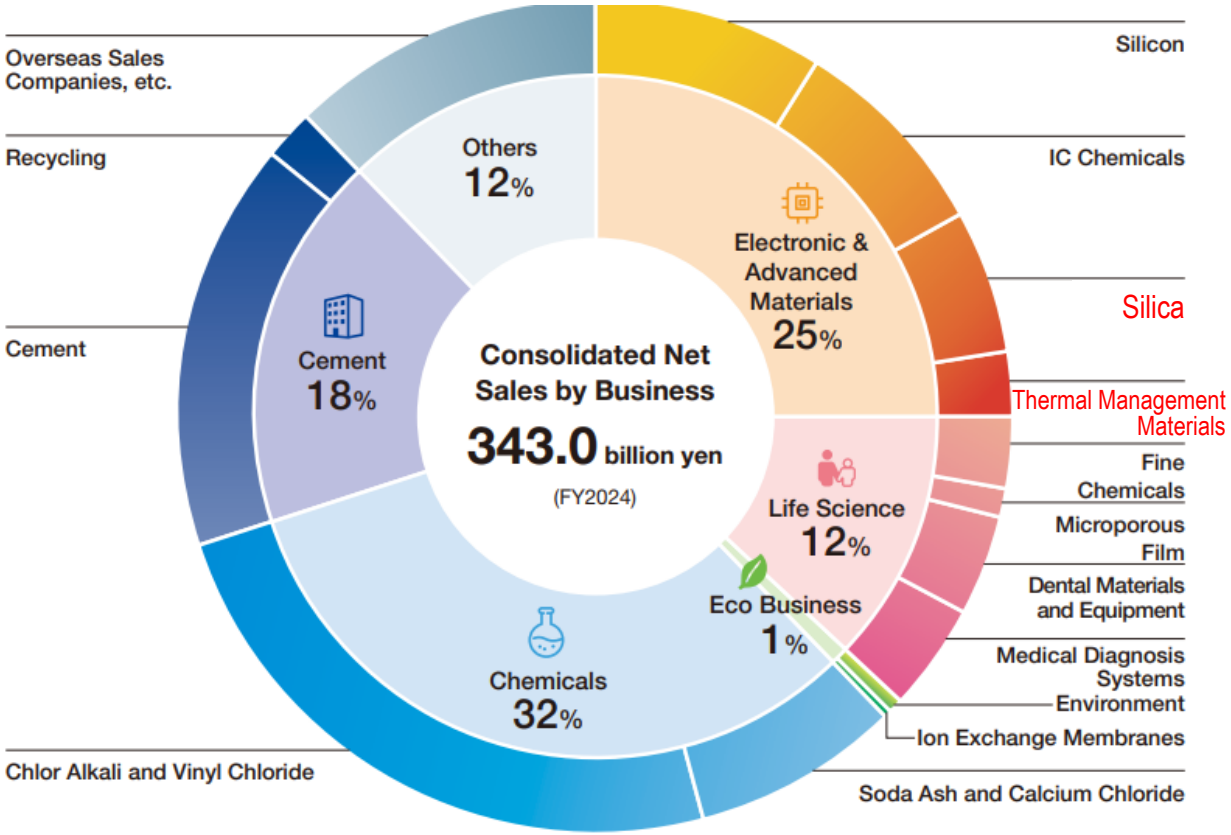
1. About the Advanced Materials Business Division

Advanced Materials Business Division

Electronic & Advanced Materials Business Goal

Push forward with globalization, and capture top share in the high-purity and thermal management materials fields supporting the miniaturization and stacking of semiconductors



Priority Measures

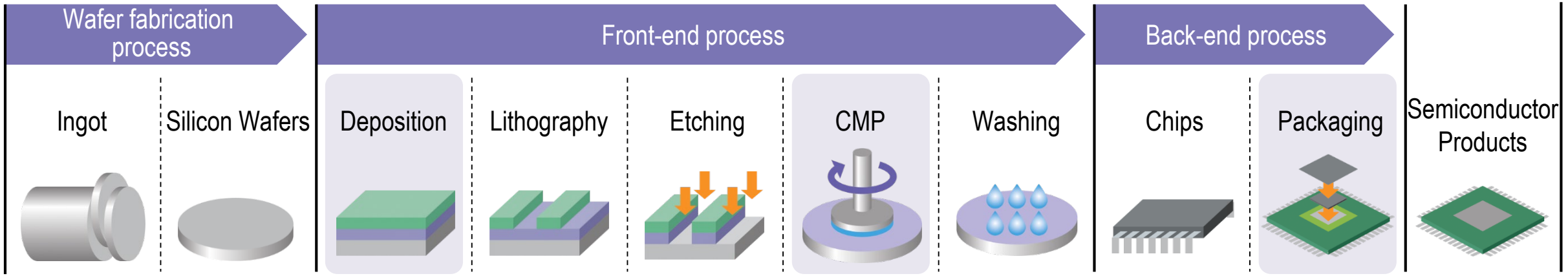
- **Pursue aggressive expansion in overseas markets**
- **Develop new applications, expand product portfolio**
- **Produce high-quality products, pursue analysis technology**

Features of the Advanced Materials Business Division

- **A wide variety of product lines**
- **Differentiation through Powder control technology (particle size control / surface treatment) and ceramic sintering technology**
- **Customer proposal capabilities that leverage a broad technical base**

Tokuyama Products Used in Semiconductor Manufacturing Processes

Provision of high-purity materials with high-level functionality that support the miniaturization and stacking of semiconductors



Polycrystalline Silicon

Thermal Management Materials

Aluminum nitride

Silica

Fumed silica

High purity IPA

Thermal Management Materials

Aluminum nitride

Boron nitride

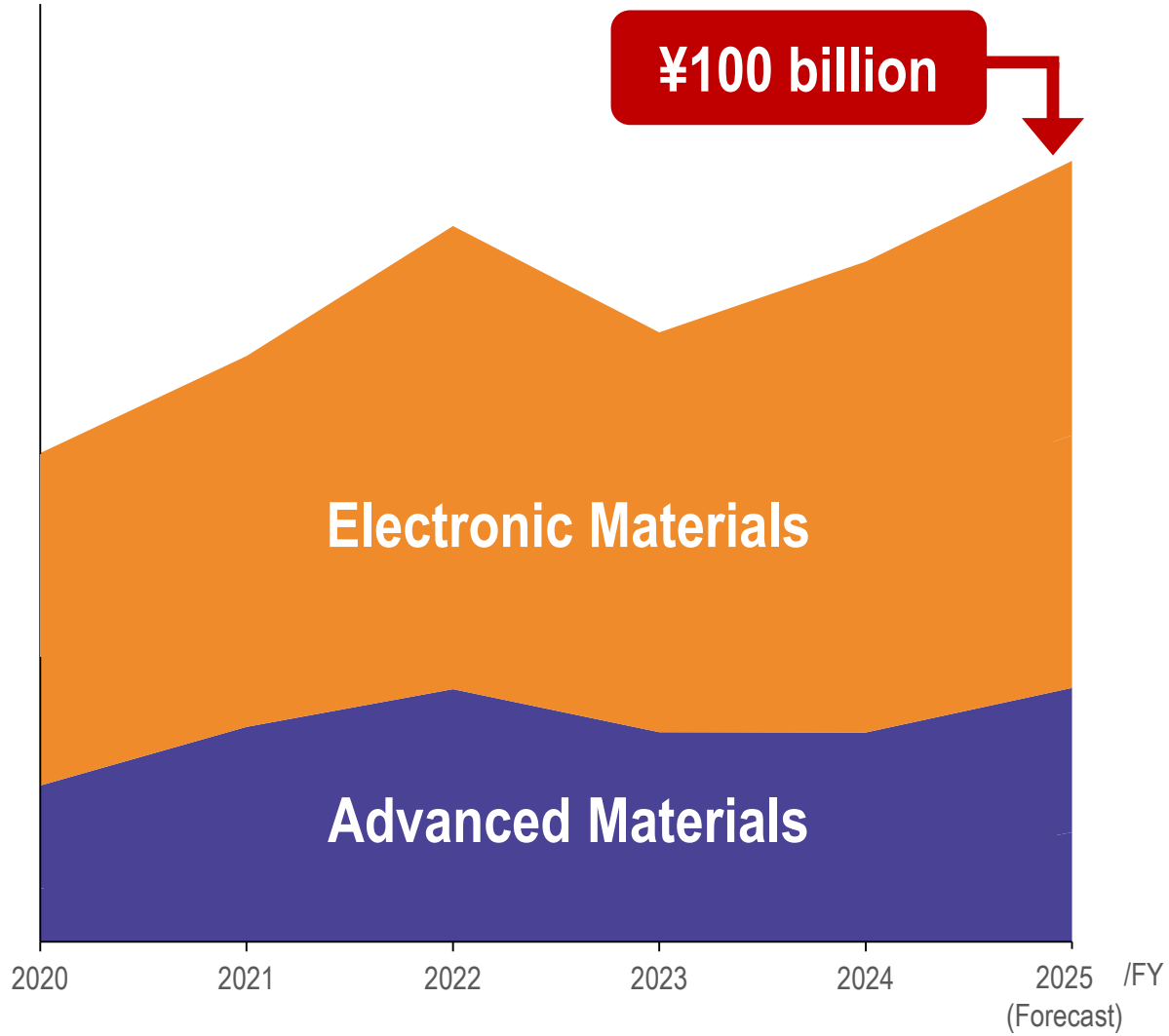
Silicon nitride

Progress of Medium-Term Management Plan 2025

Overcoming the semiconductor recession, aiming for sustainable growth

今後の施策		
Electronic Materials	Silicon	▶Establishment of bases in Malaysia and Vietnam
	IC Chemicals	▶Establishment of bases in Taiwan and Korea ▶Plans for further expansion ▶Establishment of recycling technology
Advanced Materials	Thermal Management Materials	▶Expansion of the product portfolio (fillers, etc.) ▶Establishment of a supply system associated with growing demand
	Silica	▶Additional functionality / Development of new applications

<Sales trends in the Electronic & Advanced Materials segments>



2. Silica Business

What Is Silica?

<Silica> A general term for inorganic compounds, the main component of which is silicon dioxide (SiO_2)

A mineral component that is abundant in nature, with quartz (crystal) and sand being the most common

- Silica produced by chemical synthesis (synthetic silica)
- Synthetic silica offers excellent heat resistance, hardness, insulation, adsorption, and stability, and assists in **adding functionality to many kinds of products**
- Strengths lie in **high purity, particle size control and surface treatment**, utilized in a wide range of fields, including as a functional powder material for **semiconductors, electronic materials, paints, building materials, cosmetics**, etc.

Tokuyama Silica Active in Everyday Life

TOKUYAMA

Thickener for wall, roof, and other paints

Reinforcing filler for window frame sealants

Heat insulating material for EV batteries

For semiconductor encapsulants , such as IC chips

Reinforcement agent for wind turbine blade adhesives

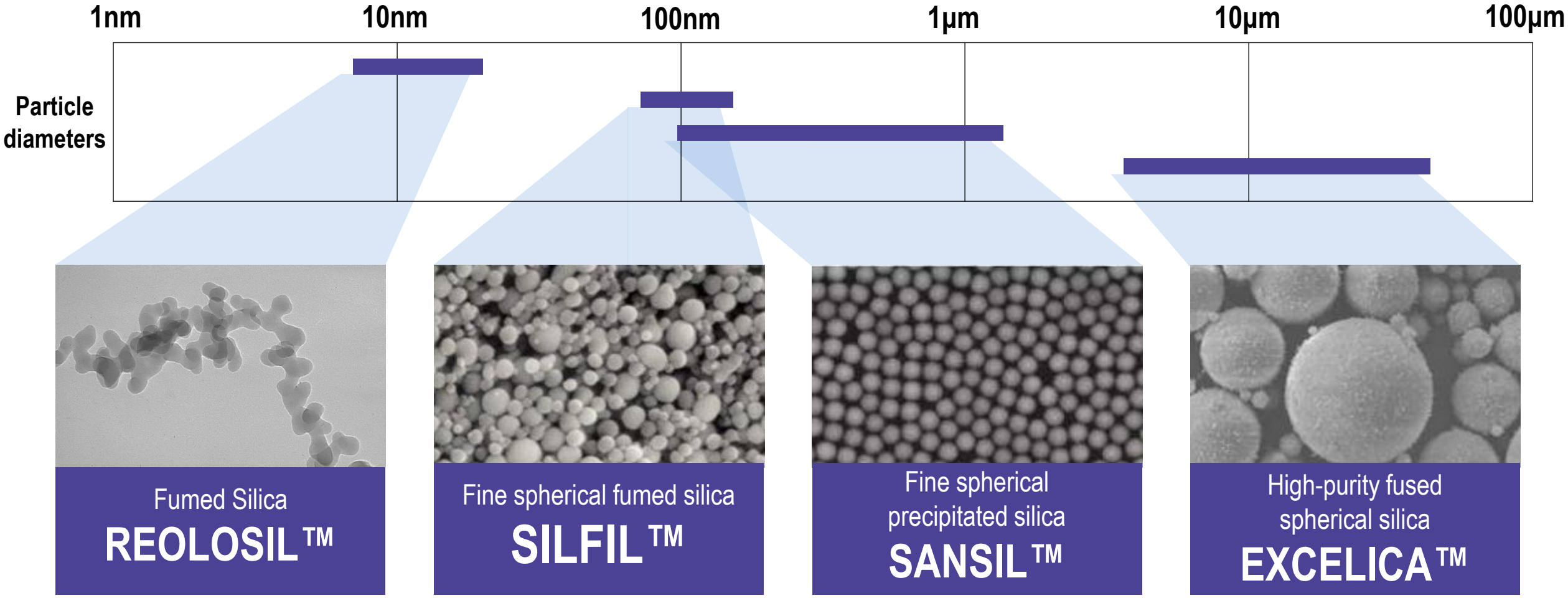
FRP for ships such as yachts

CMP slurry abrasives for smartphone semiconductors

Clear rubber for sneaker soles

Tokuyama's Wide-ranging Silica Product Portfolio

Providing silica products, including those with hydrophilic and hydrophobic properties as well as surface-treatment products, in a wide range of particle diameters and distributions



Fumed Silica Manufacturing Process

TOKUYAMA

▶Fumed silica is manufactured by hydrolyzing high-purity silicon tetrachloride with hydrogen and oxygen
The Tokuyama Factory is an integrated plant equipped with a variety of production facilities and a private power plant to provide the necessary electricity

Coal / Salt

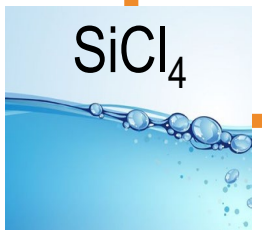
Power plants / Electrolysis plants

Electricity / Chlorine / Hydrogen

Hydrogen

Silicon metal

By-product



Silicon tetrachloride

Reaction

De-acidification

Fumed silica

Silicon manufacturing plant

Recovering HCl

Hydrogen chloride (HCl)

Reaction of fumed silica

$$SiCl_4 + 2H_2 + O_2 \rightarrow SiO_2 + 4HCl$$

Silicon tetrachloride | Hydrogen | Oxygen | Silica | Hydrogen chloride

Products

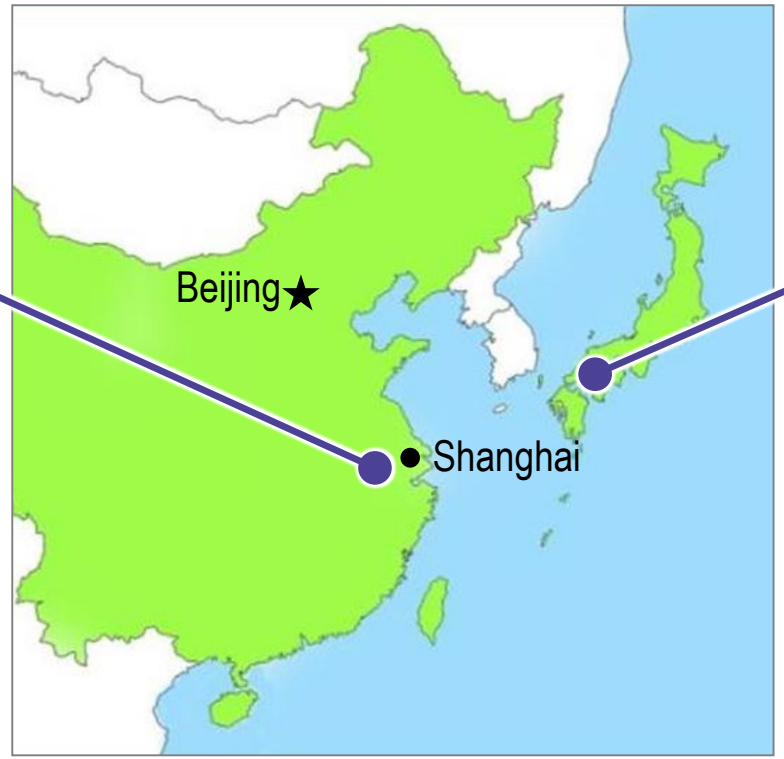
*Silicon tetrachloride : Utilizes a by-product generated during the polycrystalline silicon production process

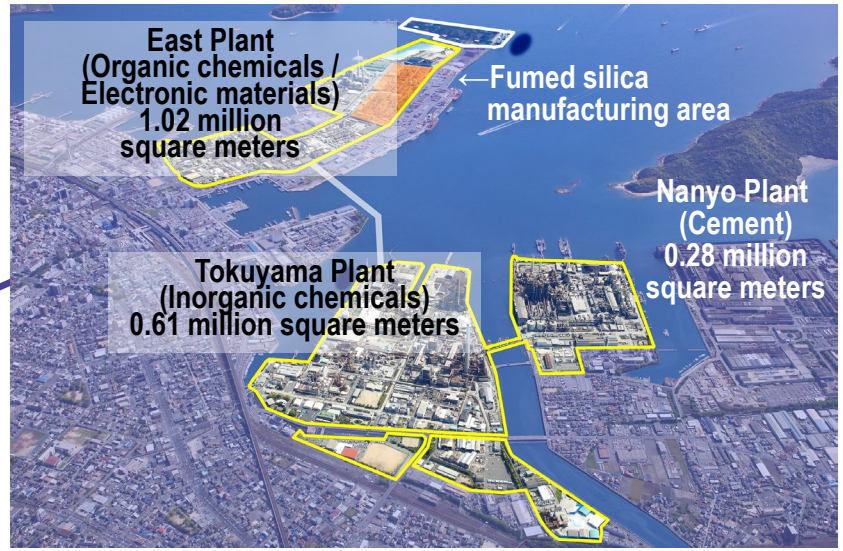
Two-Base System (Japan & China)

Base : Tokuyama Factory / Yamaguchi Prefecture (Japan)
Tokuyama Chemicals (Zhejiang) Co., Ltd. (established in 2005) / Jiaxing City, Zhejiang Province (China)

▶Global sales development centered on Asia with a two-base system

Tokuyama Chemicals (Zhejiang) Co., Ltd
(Jiaxing City, Zhejiang Province, China)





Tokuyama Factory
(Yamaguchi Prefecture, Japan)

Market Growth and Tokuyama's Silica Business

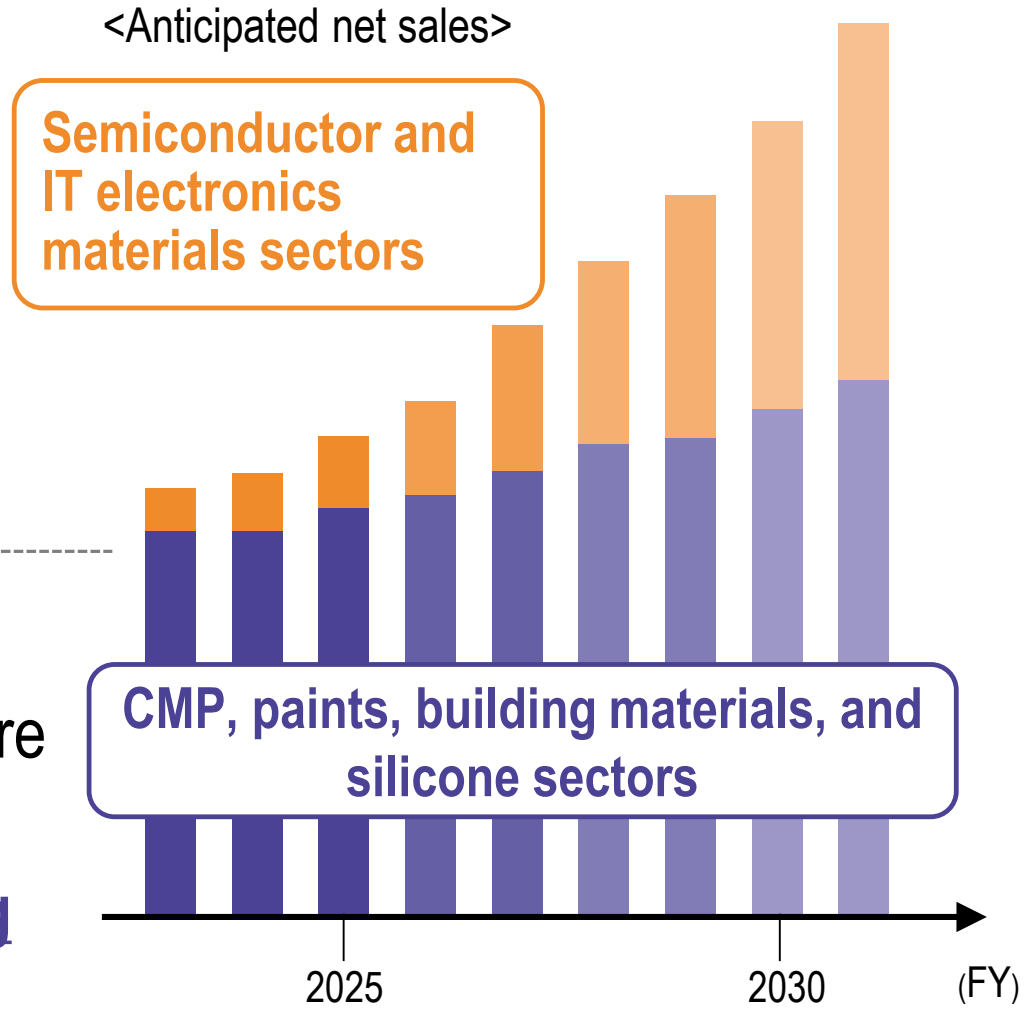
Focus on growth areas and secure profits in stable areas

Growth

Actively secure inroads into **the semiconductor and IT electronics materials sectors**, which are expected to see significant growth in the future

Stable

With a wide range of silica products and product development capabilities, we are sure to secure traditional silica demand for applications, such as **CMP, paints, building materials, and silicone**



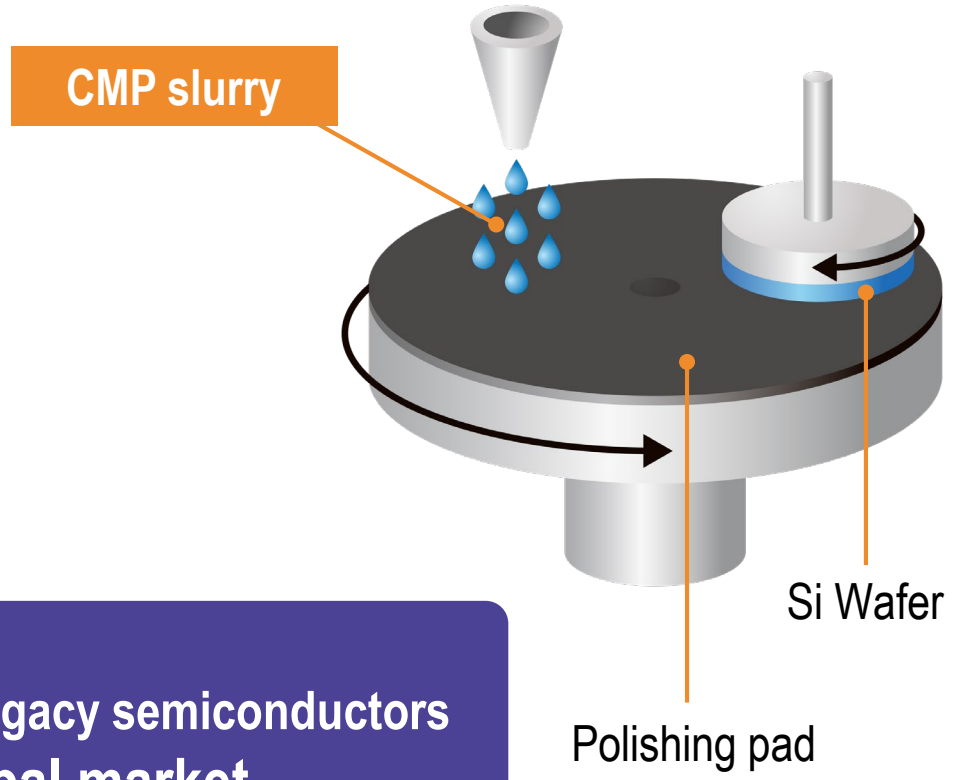
Silica Applications - CMP Slurries

CMP *Chemical Mechanical Polishing

- ▶Technology for polishing / planarization of semiconductor wafer surfaces
- ▶Process technology essential in the manufacture of advanced semiconductors, particularly those supporting AI and high-performance devices

Abrasives and characteristics

Abrasives	Characteristics
Fumed Silica	Irregular shape for high polishing power
Colloidal silica	Spherical and highly dispersible for stable polishing performance, low scratching, and high flatness
Ceria	High hardness for high polishing speed and selectivity
Alumina	Extremely hard and powerful polishing power

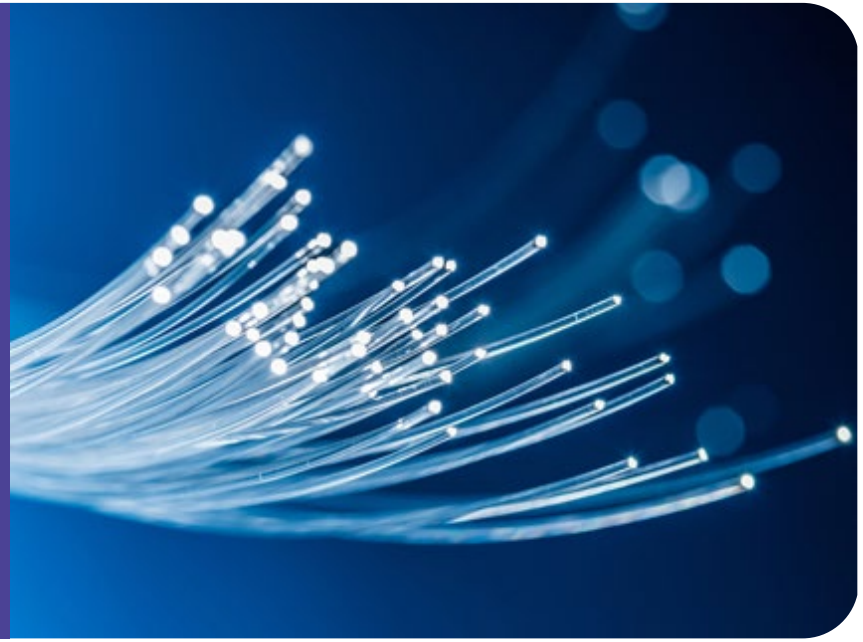


Fumed Silica:
Used as a polishing abrasive in CMP slurries, primarily for legacy semiconductors
Our products hold the top share of the global market for fumed silica-based slurries

Optical Fiber

- ▶A general term for extremely thin fibers that transmit optical signals at high speeds and over long distances
- ▶Produced primarily from high-purity silicon tetrachloride
- ▶In recent years, demand for cables connecting servers within AI data centers and between data centers has been expanding

High-purity silicon tetrachloride contributes to the increased sophistication, high functionality, and low transmission loss of information communications through its quality stability and reliable handling



R&D and Expectations for Tokuyama

TOKUYAMA

Solutions fully integrated with user needs

Bestowing increased functionality through surface quality control

Pursuing even higher silica purity

Proposing a wide range of grades by means of particle size distribution adjustment and coarse grain cut grade technology

Responding to increasingly sophisticated and diverse quality needs,
we produce results that pave the way for the future
in the semiconductor and information and electronics materials fields

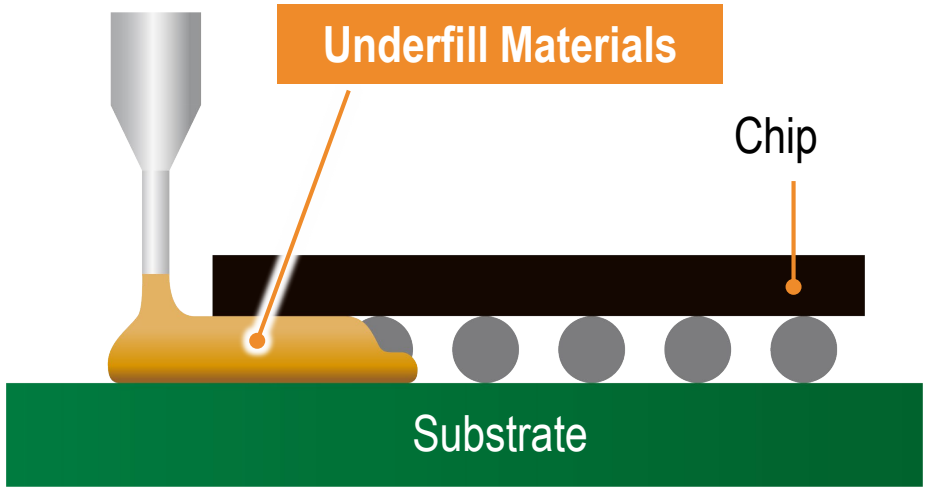
Underfill Materials

▶A liquid encapsulant that fills the spaces between electronic components such as substrates and IC chips

▶These materials enhance the reliability of electronic components and are essential for their miniaturization, high functionality, and high reliability

Currently, as chips become more highly integrated and denser, the gaps between components are becoming increasingly narrower

Tokuyama silica contributes to the increased sophistication and functionality of electronic components through advanced technologies, such as coarse grain cut grades and surface treatment



Materials for Cosmetics

▶Issue: The impact of microplastics used in foundation and other products on marine ecosystems is gaining attention

Microplastics

Substitute

EXCEBEADS™

Features
- High purity, high sphericity
- Uniform particle diameters

Functions
- Provides a smooth feel to the skin
- Soft focus effect
- Polishing and scrubbing effects

Provides highly functional products made possible through unique proprietary technologies, making proposals to global cosmetics manufacturers

Newly Developed Product – Silica-Titania Composite Oxide

Silica-Titania Composite Oxide

Controlling the ratio of silica and titania (TiO_2)

➡**Adjusting the refractive index of particles**

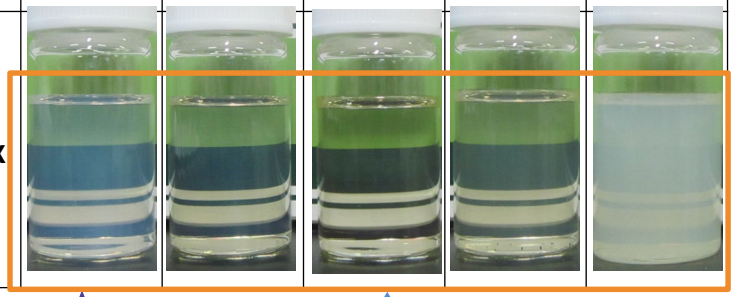
Adding particles with a matching refractive index to resin makes it possible to **create a transparent resin composition with consistent strength**
(Application example: Transparent adhesives, etc.)

Development expected in materials such as silicon photonics*, a technology expected to see significant growth in the years to come

Comparison of electrical and optical signals

	Electricity (Electrical)	Light (Optical)
Speed	Fast but limited	Faster than electrical
Heat	Prone to emitting heat	Low emitting heat
Interference	Susceptible to noise	Resistant to noise

Refractive index adjustment effect (slurry)

Particle refractive index	1.46	1.48	1.51	1.56	1.60
Ti molar ratio [mol%]	0	5	10	15	20
Dispersed in a solvent with **a refractive index of 1.51** (exterior)					

Silica slurry

Transparent

* **Silicon photonics:** A technology that utilizes silicon to transmit data via light

3. Thermal Management Materials Business

Tokuyama's Thermal Management Materials

Successful development of **the world's first translucent aluminum nitride ceramic and mass production of its raw material powder;** Boron nitride and silicon nitride have been added to the product portfolio to meet customers' diverse heat dissipation material needs

Aluminum nitride (AlN)

A ceramic material with excellent thermal conductivity and electrical insulation

Product line

- Powder
- Granules
- Thermally conductive filler
- Ceramics (substrates)
- Machinable ceramics

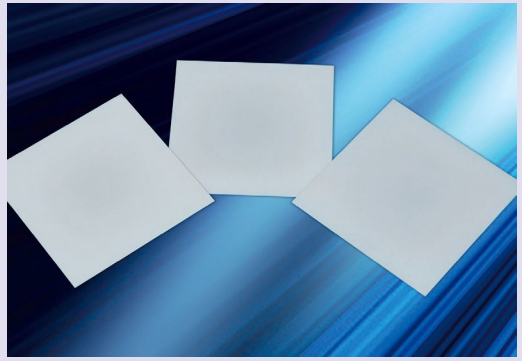
Boron nitride (BN)

High thermal conductivity and electrical insulation, with high water resistance and a low dielectric constant

Product line (including development items)

- Thermally conductive filler (single particle)
- Thermally conductive filler (large particle size agglomeration)

Silicon nitride (Si_3N_4)



A ceramic material with excellent mechanical properties and high thermal conductivity, particularly high fracture toughness

Product line (including development items)

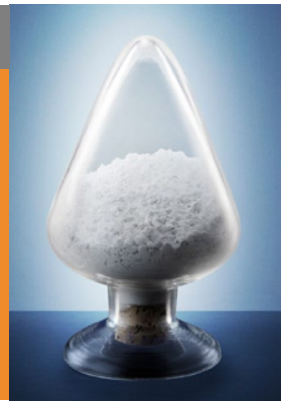
- Powder
- Ceramics (substrates)
- Bearing balls

Aluminum Nitride Business

Features of Aluminum nitride (AlN)

(1) High thermal conductivity
(Highest thermal conductivity among ceramic materials)
(2) Electrical insulation
(3) Thermal expansion coefficient equivalent to that of silicon
(4) High corrosion resistance to halogen-based plasma gases

Materials that contribute to improving semiconductor performance, saving energy, effectively utilizing natural energy, and advancing IoT and AI technologies



Supply chain (from raw powders to final products and applications)

Tokuyama's business domains

Worldwide share No.1

Raw materials
(AlN powder / granules)

Various structural and circuit board components
(AlN ceramics)

Thermally conductive filler
(AlN filler)

- Semiconductor manufacturing equipment
- Thermally conductive circuit substrates for power semiconductors (power controls for industrial machinery, electric railways, wind power generation, etc.)
- Thermally conductive circuit substrates for semiconductor elements (thermal management for laser diodes, LEDs, etc.)

- TIM (gap filler / thermally conductive sheet)
- Various thermal conductive materials

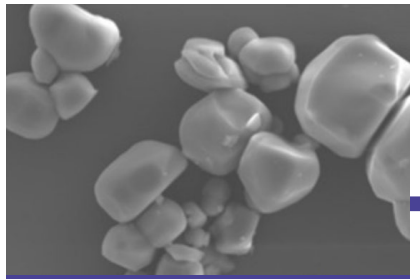
Aluminum Nitride Applications (Raw Powder to Final Product)

TOKUYAMA

Manufactured by Tokuyama

Raw materials (AlN Powder)

Article size control, coarse particle reduction, etc.



AlN filler

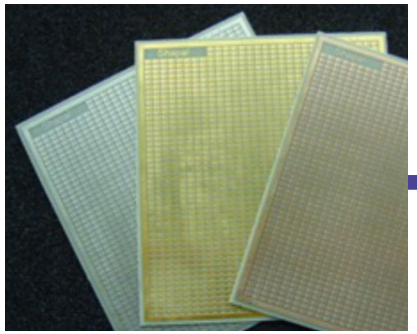
Sintering

Tokuyama-Dowa Power Materials Co., Ltd.
*Tokuyama Group
(Manufacture and sale of aluminum nitride substrates)

AlN ceramics

Susceptors for semiconductor manufacturing equipment

Film application (metal circuits)



AlN metallized substrates

Resin filling

TIM
(thermally conductive sheet)

Aluminum nitride-related market

- Semiconductor manufacturing equipment
- Power module
- Automotive
- Communication Base Station
- Data center

Aluminum Nitride Powder Manufacturing Process

TOKUYAMA

Manufacture of aluminum nitride powder by our proprietary reduction-nitridation method


Alumina


Carbon

Raw material mixing → Nitridation reaction → Decarburization / Oxidation

Nitrogen ↓ Nitridation reaction

Oxygen ↓ Decarburization / Oxidation

$$Al_2O_3 + 3C + N_2 \rightarrow 2AlN + 3CO$$


Aluminum Nitride Powder

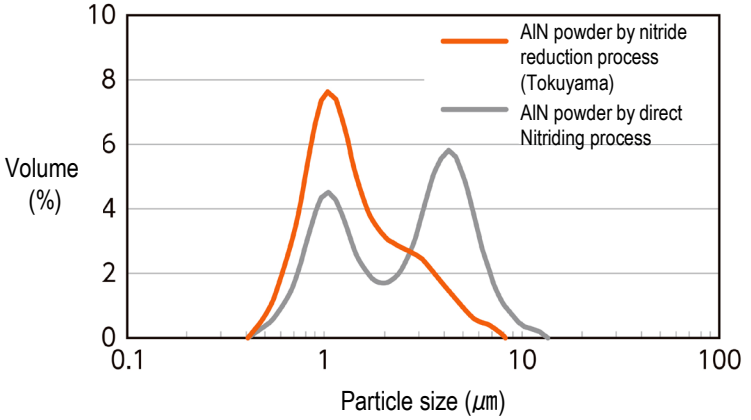
Technical advantages (compared with other manufacturing methods)

- ◎ Low metal impurities
- ◎ Low oxygen content
- ◎ Sharp particle size distribution
- ◎ Water and moisture resistance and stability

High sinter ability ⇒High thermal conductivity → Suitable for ceramic applications

High filling rate and low viscosity in resins → Suitable for thermally conductive fillers

Particle size distribution comparison

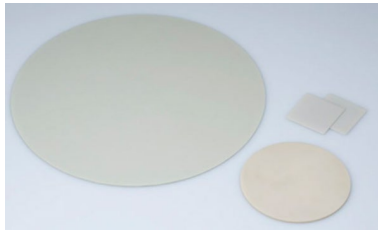


History of Aluminum Nitride Business

TOKUYAMA

1982 Successfully developed translucent aluminum nitride ceramics — **A world first**

1985 Established an AlN powder manufacturing process using the reduction nitridation method — **A world first**



1987 Began mass production of AlN substrates

1989 Operated an AlN powder plant — **The world's largest**

1990 Began mass production of AlN metallized substrates (thin film) *Subsequently withdrew from the business

2007 Established Tokuyama-Dowa Power Materials Co., Ltd. (AlN substrates)

2015 Expanded the AlN powder plant — **Market expansion**

2018 Aluminum Nitride Powder — **World No. 1 in terms of market share and production capacity**

2020

Developed applications to create and expand aluminum nitride markets
(substrates / metallized substrates / various ceramics / thermally conductive filler)

Why Choose Tokuyama's Aluminum Nitride?

TOKUYAMA

Advanced powder synthesis control technology

Long-standing accumulated manufacturing know-how

High-efficiency automated processes

World's largest production capacity

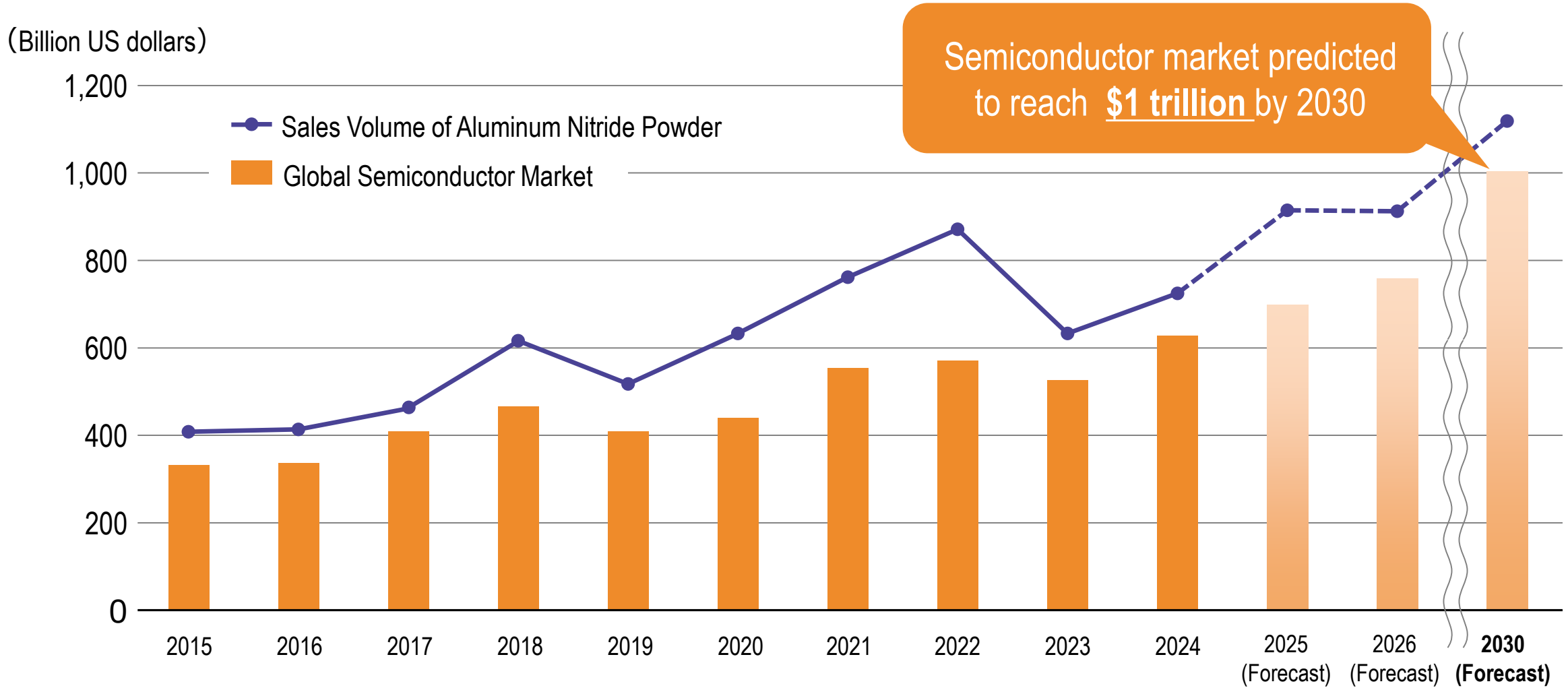
Ensuring a stable supply of extremely high-quality, high-purity aluminum nitride powder with minimal variation in physical properties

Proprietary ceramic sintering and characterization technologies cultivated through the development and market cultivation of aluminum nitride application products ▶ Contribute to the resolution of customer issues

Semiconductor Market Growth and Aluminum Nitride Demand

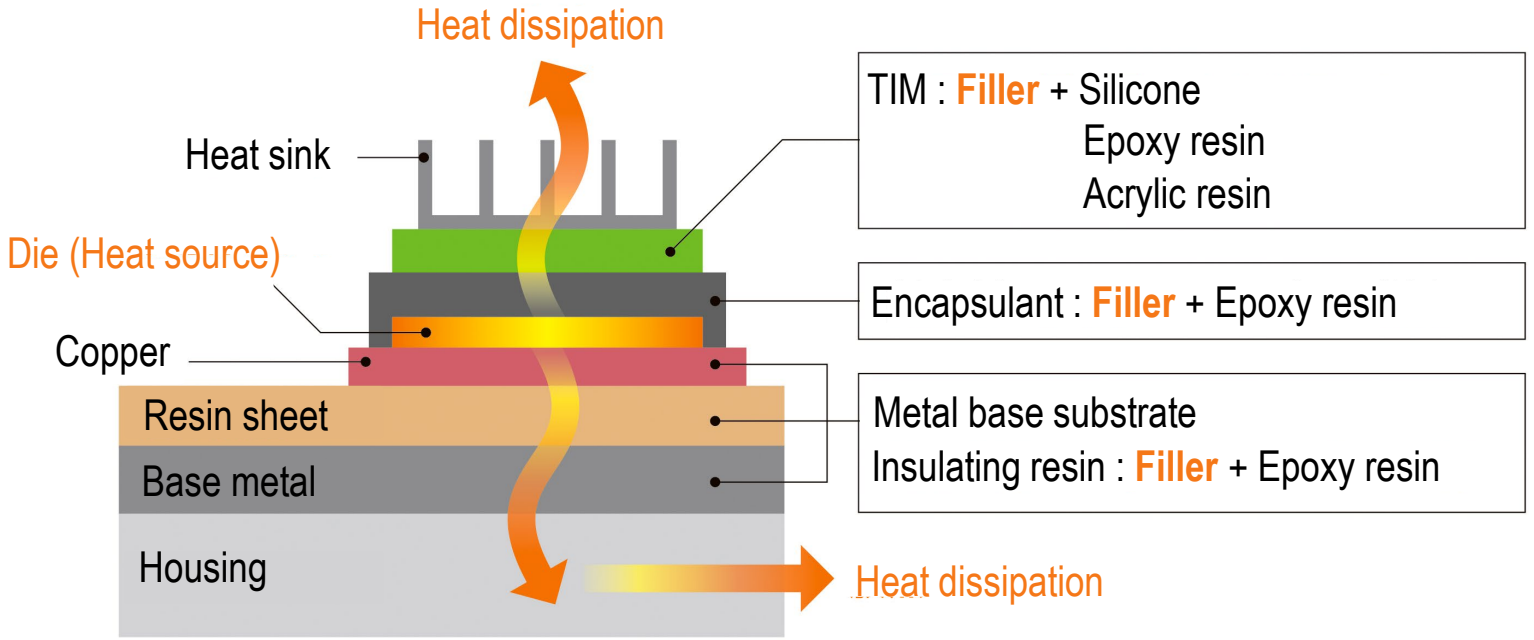
TOKUYAMA

Aluminum nitride powder sales volumes increasing in line with growth of global semiconductor market



Ref) World Semiconductor Trade Statistics (WSTS) Spring 2025 Market Forecast

New Market Opportunities: Expanding Applications for Thermally Conductive Fillers



TIM (Gap filler)

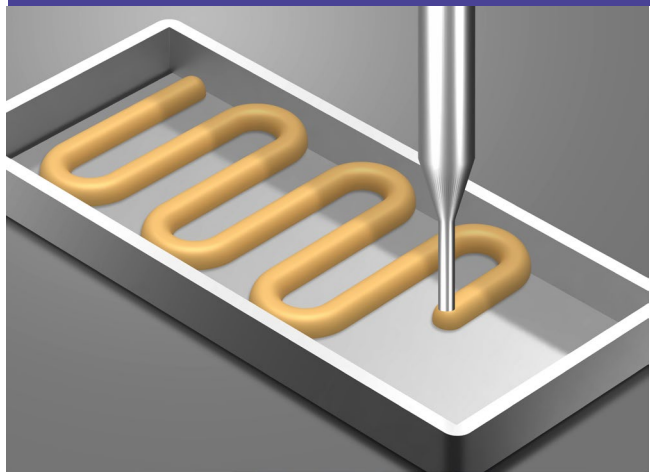
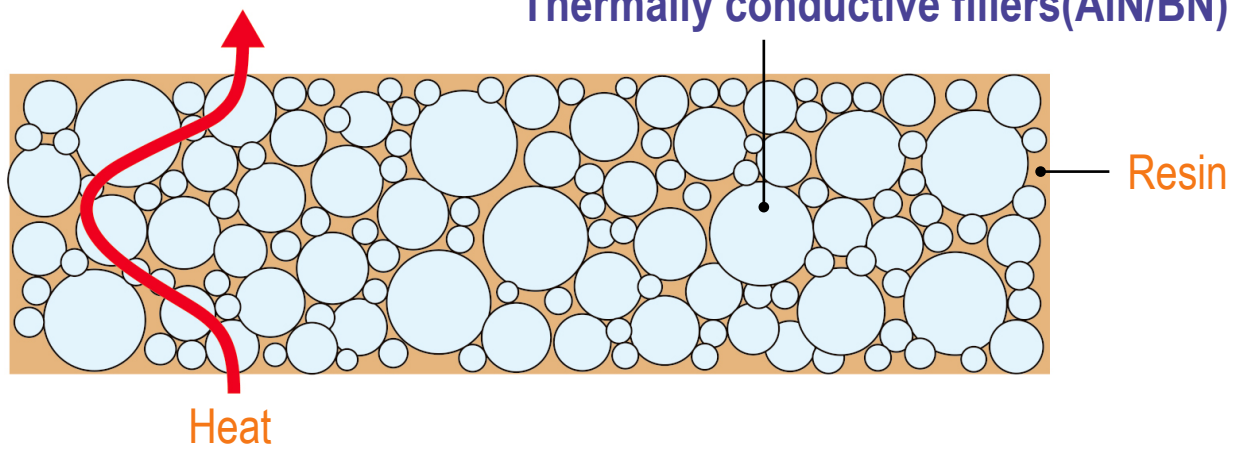


Image of the TIM structure



Applications where demand for AlN/BN fillers expected to grow

TIM (Thermal Interface Materials)

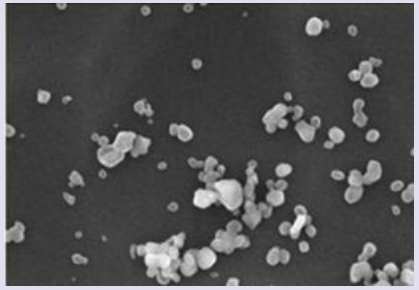
TIM1: Heat dissipation for IC chips
TIM2: Efficiently transfers heat to heat sinks

Insulating resin for metal base substrate

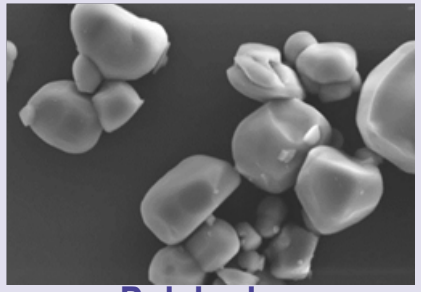
Thermal Conductivity of Each Material and Tokuyama's Fillers

			Tokuyama's thermally conductive fillers	
Characteristics	Silica SiO_2	Alumina Al_2O_3	**Aluminum nitride AlN**	**Boron nitride BN**
Thermal conductivity (W/mk)	1	30 - 40	**170 - 180**	**Surface direction 200 Thickness direction 3**

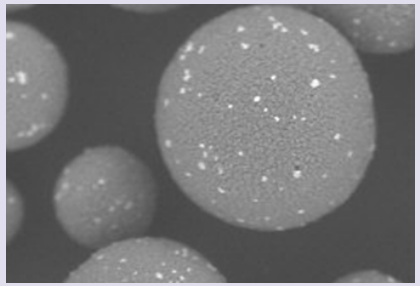
Aluminum nitride (AlN) filler



Pseudospheric
1μm



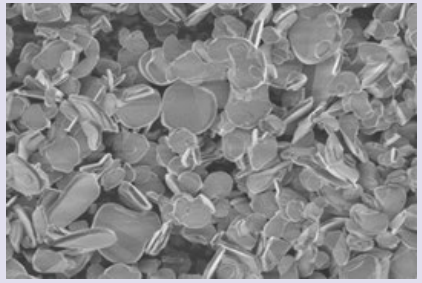
Polyhedron
several tens of micrometers



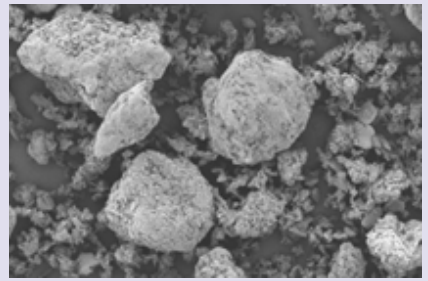
Spherical particles
80-120μm

- Features good filling properties, high fluidity, and low coarse particle content
- Various particle sizes
- Surface treatment technology enables improved compatibility with resins and water resistance

Boron nitride (BN) filler



Thick-walled
single particles



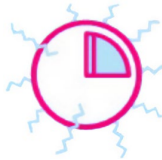
Large particle size
agglomeration

- Synthesized using a reduction nitridation method
- Features high purity, high thermal conductivity, and low foreign matter content

Filler Engineering Technology

*BLT：Bond Line Thickness

BLT* / Optimized filling rate	・AlN filler 1μm - 120μm ・BN filler 5μm - 40μm
Improved mixability and viscosity	・Less agglomeration ・Top-cut classification
Improved balance of thermal conductivity and viscosity	・AlN filler polyhedral structure/ spherical particles ・BN filler thick-walled single / agglomerated particles
Water resistance and improved compatibility with resins	・Various surface treatment grades ・Proposals for compatibility with resins
Low alpha radiation compatibility	・High purity ・Impurity control



Use of the company's high-quality raw powders

Utilization of reduction nitriding technology know-how

Utilization of ceramic sintering technology

Growth Strategy for Thermal Management Materials Business

Improve quality and provide stable supply of aluminum nitride powder

- **Continue to meet market demands for quality** → Further improve powder property control technology and improve productivity
- **Maintain a stable supply system** → Respond to growing demand with an eye toward expansion investment

Launch new heat dissipation materials and expand product portfolio

- **Customize powder properties according to customer requests (AlN/BN filler)**
- **Full-scale market launch of Si_3N_4 substrates/bearing balls**

→ Explore new market opportunities and strengthen R&D

For the People of Tomorrow

TOKUYAMA