TORAY
Innovation by Chemistry

TORAY IR Seminar
Toray Group's Initiatives for Digital Innovation (DI) Business

R&D of Toray Group's Digital Innovation (DI) Business

September 13, 2024

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Corporate Vice President
General Manager of Research Division,
Toray Industries, Inc.

Contents

I

R&D Priority Areas in DI Business

R&D structure

Fibers & Textiles Division


Synthetic fiber


Recycled fiber
&+™


Silk-textured textile
Kinari™


Man-made suede
Ultrasuede™

Resins & Chemicals Division


PBT resin
TORAYCON™

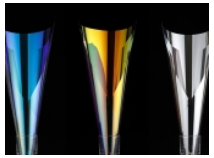

PPS resin
TORELINA™


ABS resin (clear-grade)
TOYOLAC™

Films Division


Polyester film
Lumirror™


OPP film
TORAYFAN™

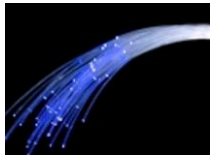

Functional nano-multilayer film
PICASUS™


PPS film
TORELINA™

Electronic & Information Materials Division


Polyimide materials for semiconductors and electronic parts
FALDA™ / SEMICOFINE™ / PHOTONEECE™


Environmentally-friendly printing plate
IMPRIMA™


Plastic optical fiber
RAYTELA™

Water Treatment & Environment Division


Reverse osmosis (RO) membrane elements


Household water purifier
Trayvino™


Meltblown non-woven fabric
Traymicron™


High-performance cleaning cloth
Traysee™

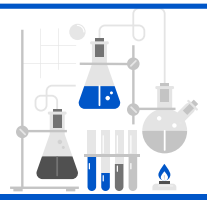
Research & Development Division

- Toray Engineering
- Toray Research Center

Role of the R&D Division

Seamlessly promote the Division Research in collaboration with each business division and the Forward-Looking Research

New Product Development



Research on next-generation products that strengthen the business foundation

Advanced Research Aiming for Future Creation

Division Research | **Corporate Research**

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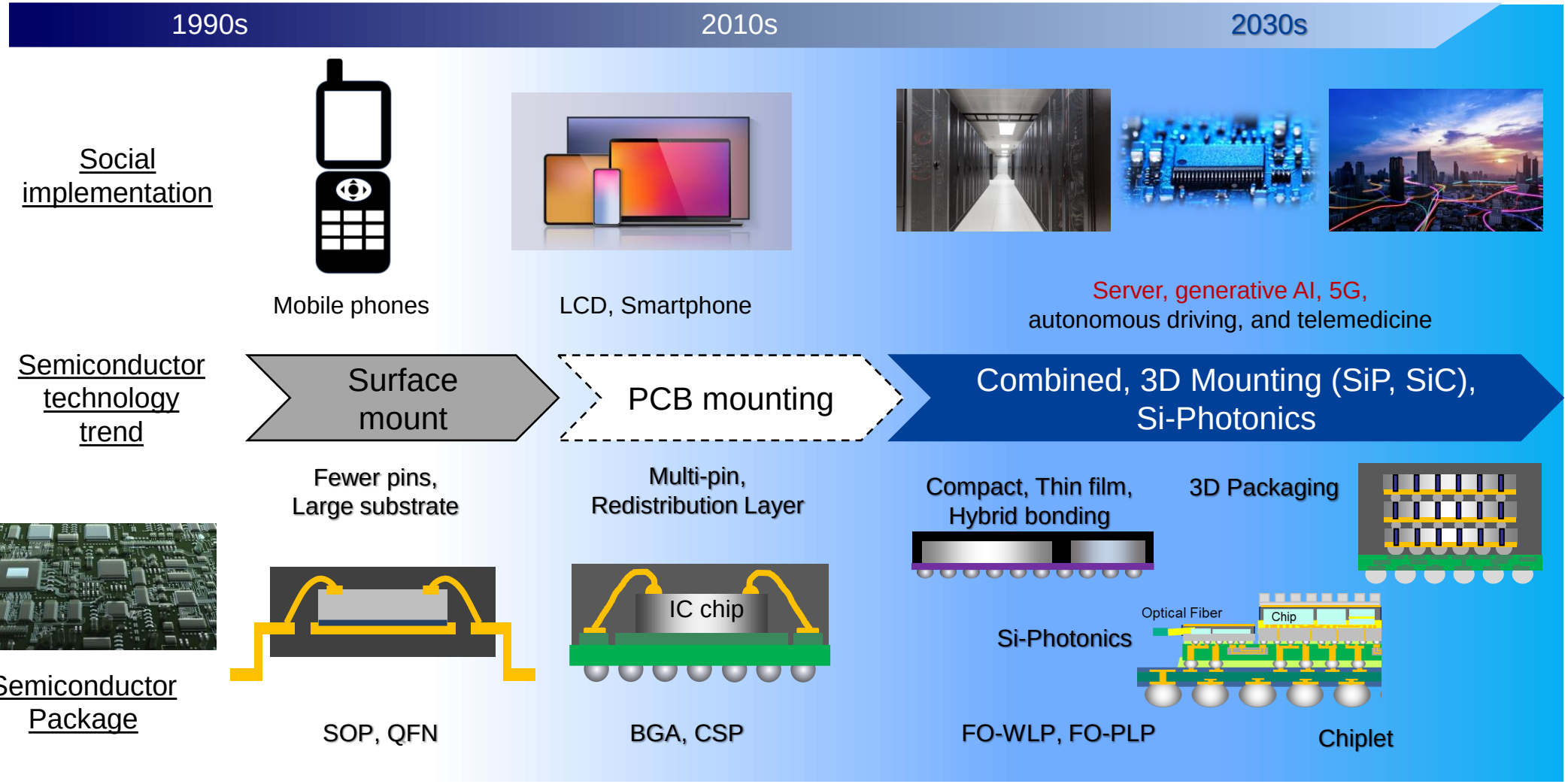
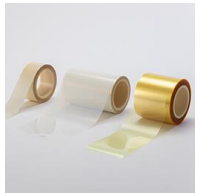
Trend in Semiconductor Technology and Future Society



Rapidly developing with trends towards High Integration, High Performance, and Miniaturization

R&D Priority Areas in DI Business

Electronic & Information Materials

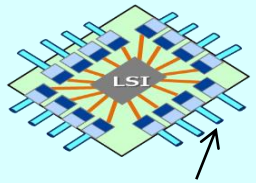


Electronic coating and mounting materials

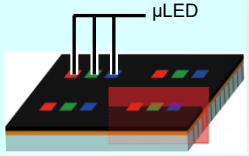
Display Materials

Cleaning and release solvent

Optoelectronic fusion technology



Optical fiber



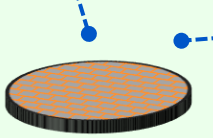
Micro LED Display

Laser transfer

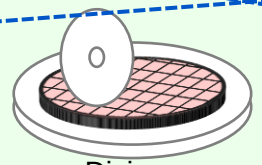
(3)

Products in the engineering business

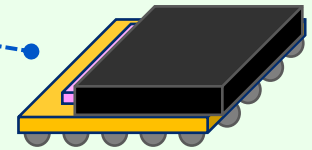
Semiconductor mounting equipment and inspection equipment



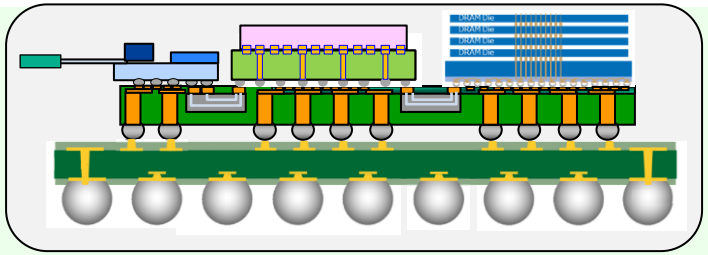
Circuit formation



Dicing



Assembly and sealing



Semiconductor infrastructure-related products

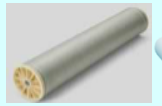
(1)

Cleaning technology

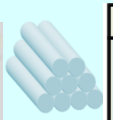
Water

Air

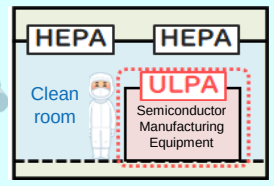
Chemical liquid

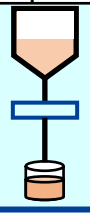


RO membranes for ultrapure water production



Reuse



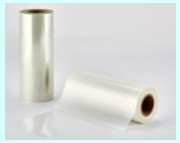


wastewater reuse

Gas separation and recycling

Semiconductor film-related products

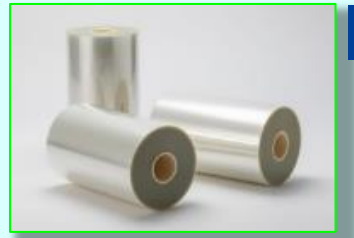
Flexible Printed Circuit Boards



Films for Multilayer Ceramic Capacitors (MLCC)

Release film for semiconductor molds

(2)



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II

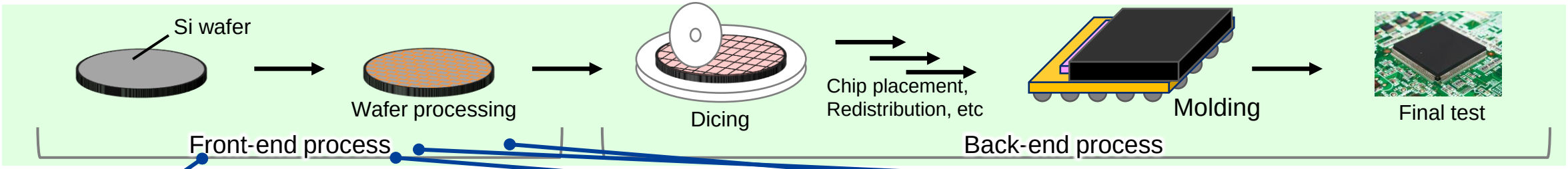
R&D Initiatives

(1)Semiconductor infrastructure-related technology

(2)Semiconductor-related technology: Release film for semiconductor molds

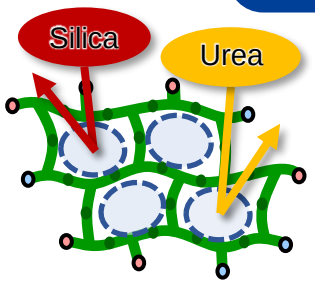
(3)Optoelectronic fusion-related technology

(1) Semiconductor Infrastructure-related Technology

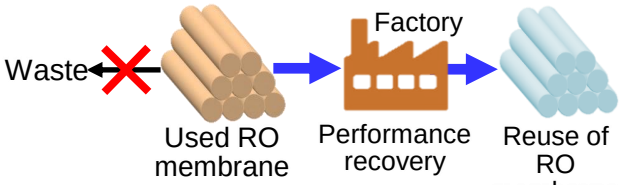


RO membranes

Water filtration



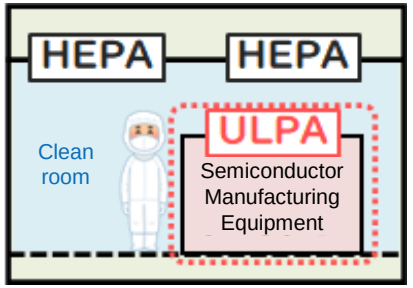
High silica removal rate
High urea removal rate
⇒ Suitable for wastewater reclamation

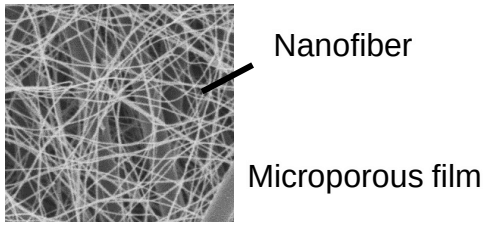


Reduction of waste

Air filter material

Air cleaning

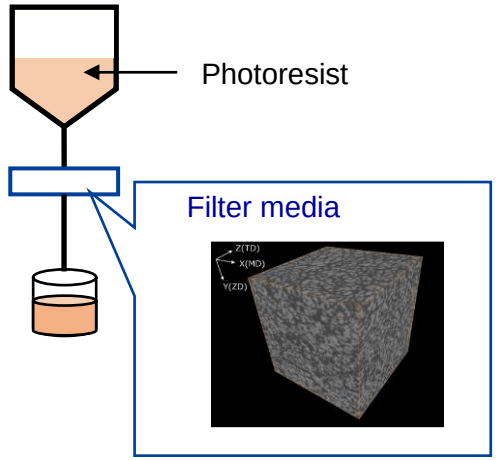




PFAS-free

Filter material for resist

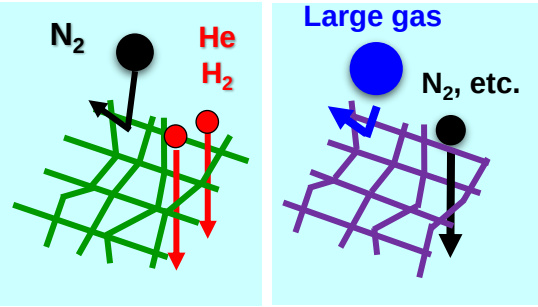
Clean chemical liquids



Removal of microscopic impurities

gas separation

Collection and recycling of gas



Selective separation membrane of the gas
➞Collection of rare/high-priced gases

We have not only materials but also technologies that contribute to yield improvement and environmental-friendliness

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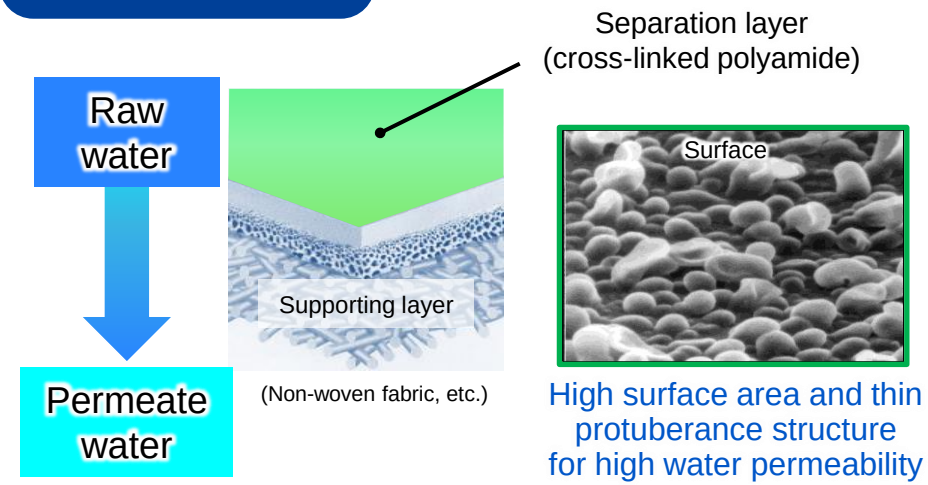
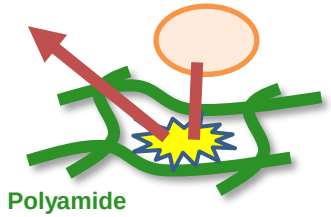
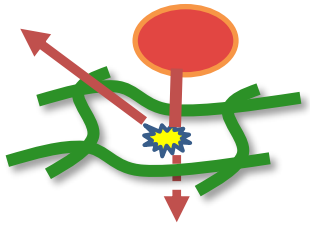
(1) Semiconductor-Infrastructure-Related Technology:
High-Silica-Removing Reverse Osmosis (RO) Membrane

RO elements

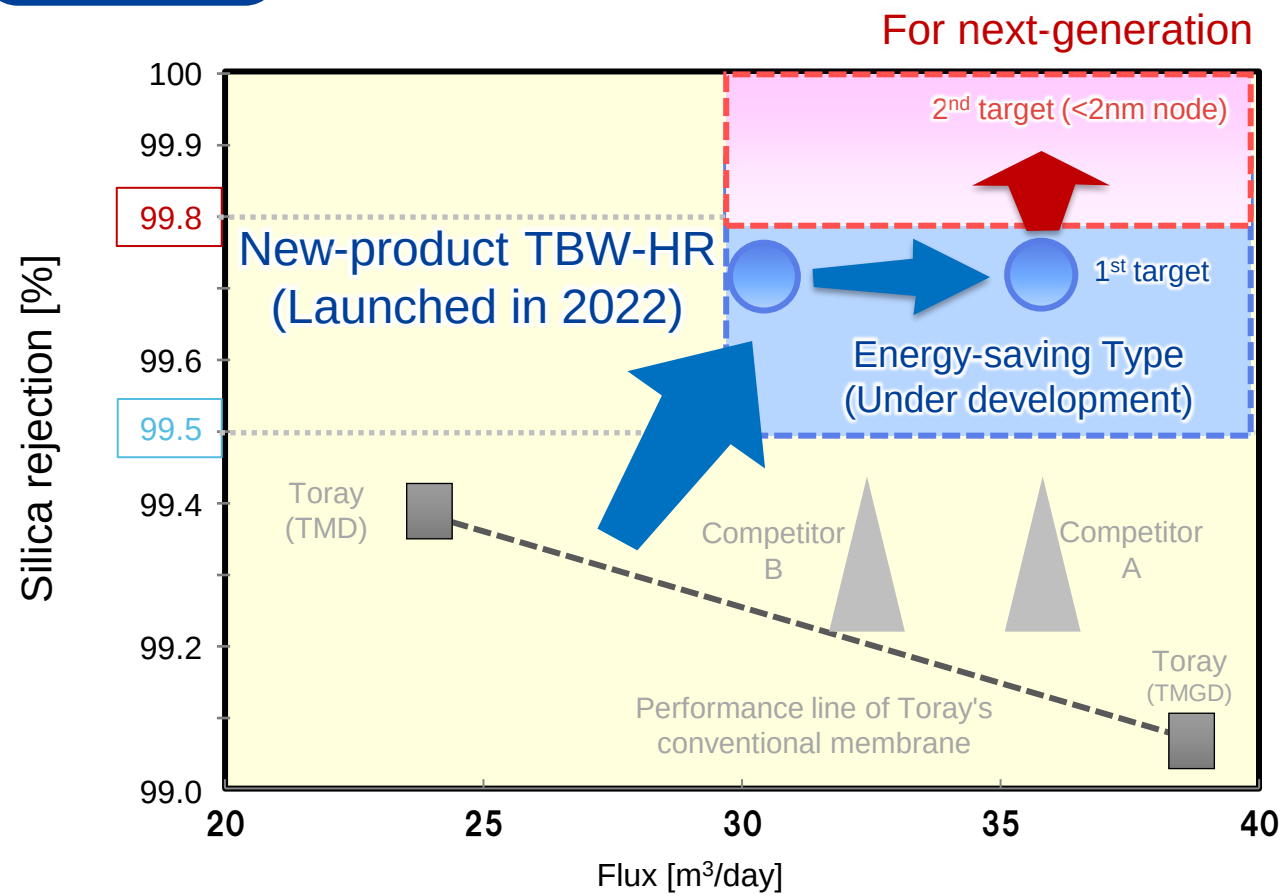


High surface area and thin protuberance structure for high water permeability

Solute	Ion	Neutral molecule
Examples	Na^+ SO_4^{2-}	Silica, boron, and urea
Removal mechanism	 Polyamide Size exclusion + Electric repulsion	 ONLY size exclusion Hard to remove

For high rejection, pore size control is important.

Performance



High-silica-removal and high-water production was achieved through pore structure and surface structure control

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(1)Semiconductor-Infrastructure-Related Technology:
Wastewater Reuse for Securing Water Sources

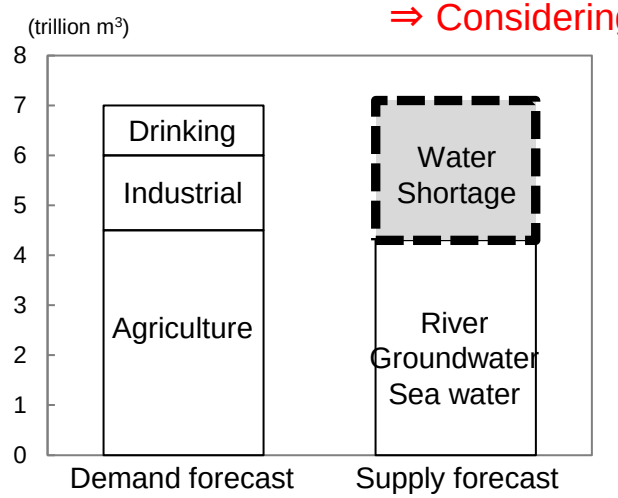
Ultrapure water sources

Water Demand/Supply Forecast (2030)

*From METI data

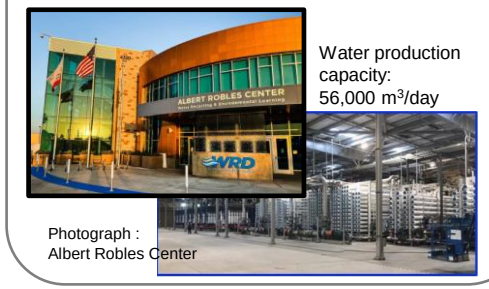
Estimated supply: about 60% of demand

⇒ Considering utilization of wastewater reuse



Example of wastewater reuse

Wastewater reuse plant for drinking water using our membranes

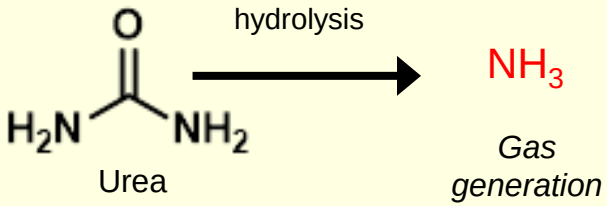


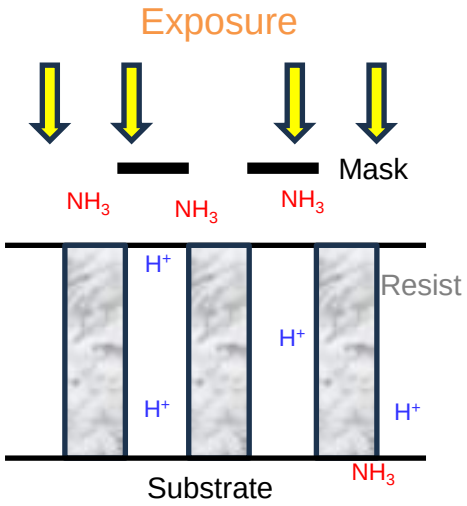
Comparison of water quality

	Recycled wastewater	Tap water
TOC* (Organic index)	5-10 mg/L	< 4 mg/L
Urea *	30 μg/L	10 μg/L

*Science of the Total Environment 785 (2021) 147254

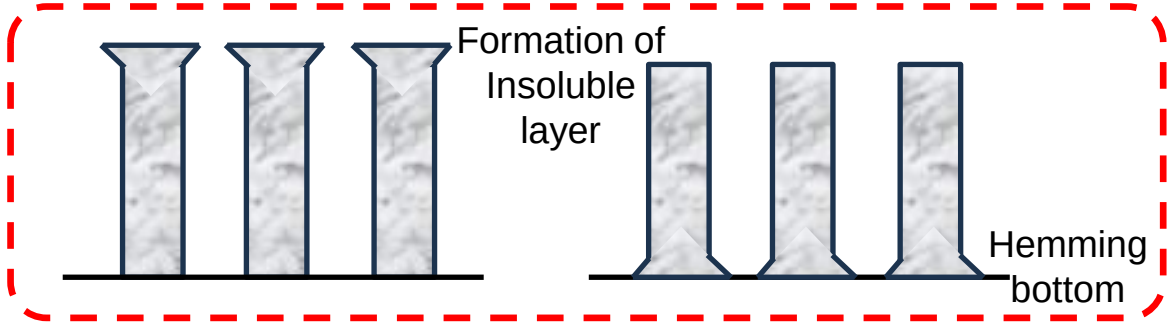
Negative effect of urea





Acid inactivation (neutralization) in resist ⇒ Photosensitive inhibition

Pattern defect generation



Urea concentration is 3 times higher than tap water. Large risk of yield decrease

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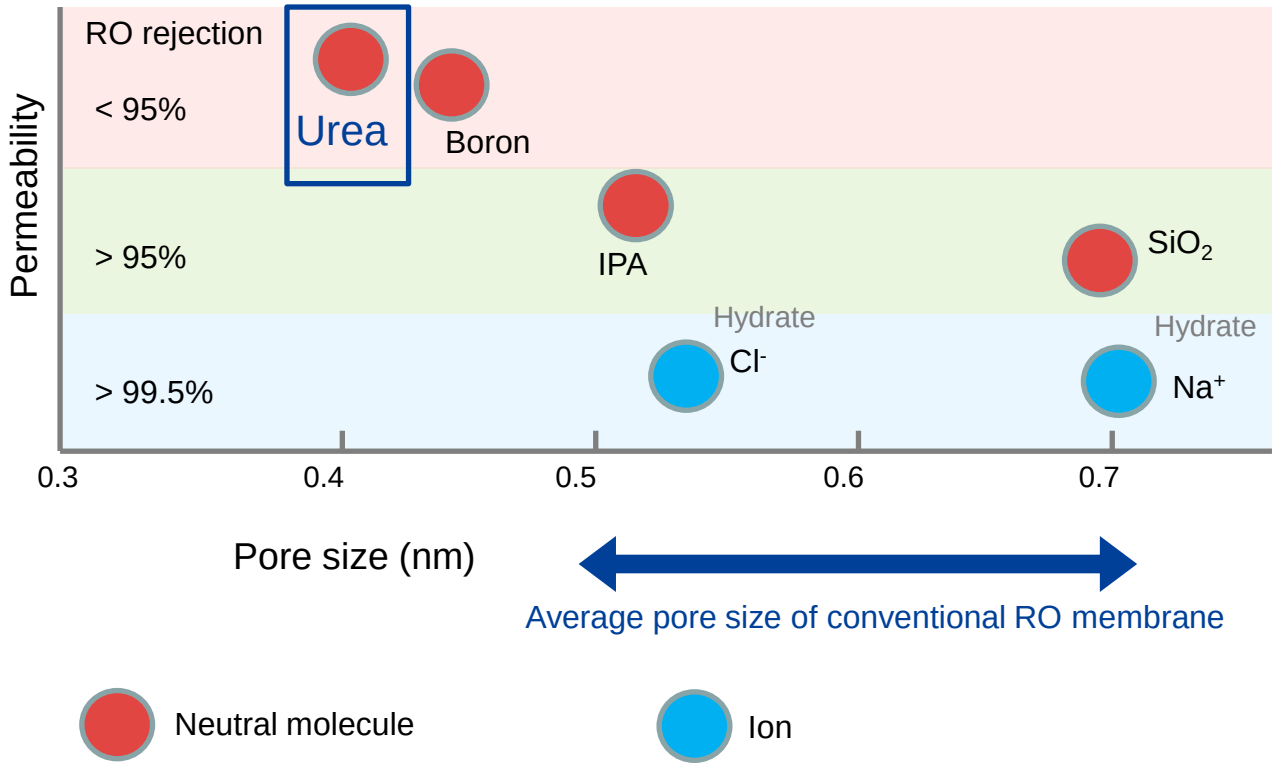
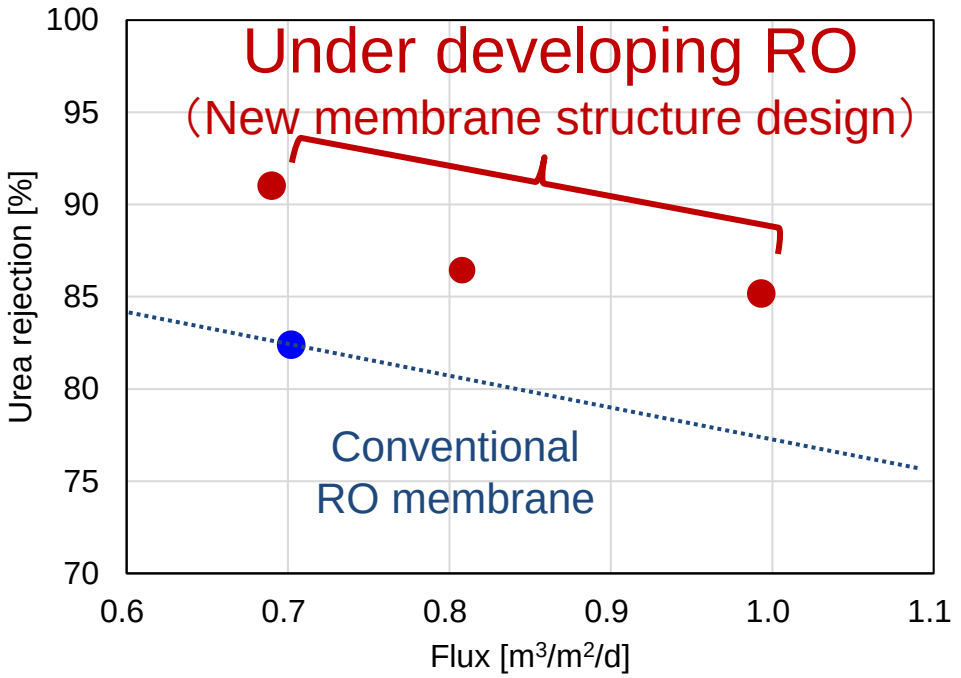
(1)Semiconductor-Infrastructure-Related Technology:
High-Urea-Removal RO Membranes for Wastewater Reuse



Urea is also a small-sized neutral molecule and has high removal difficulty

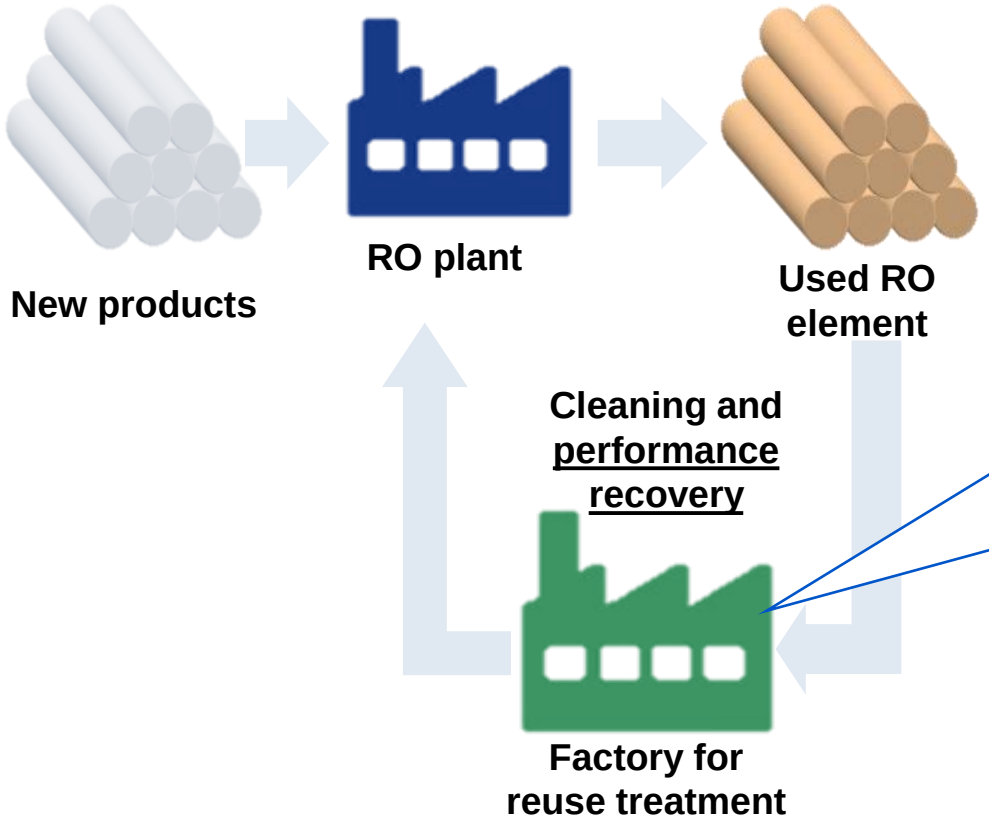
Urea-removal performance of RO membrane



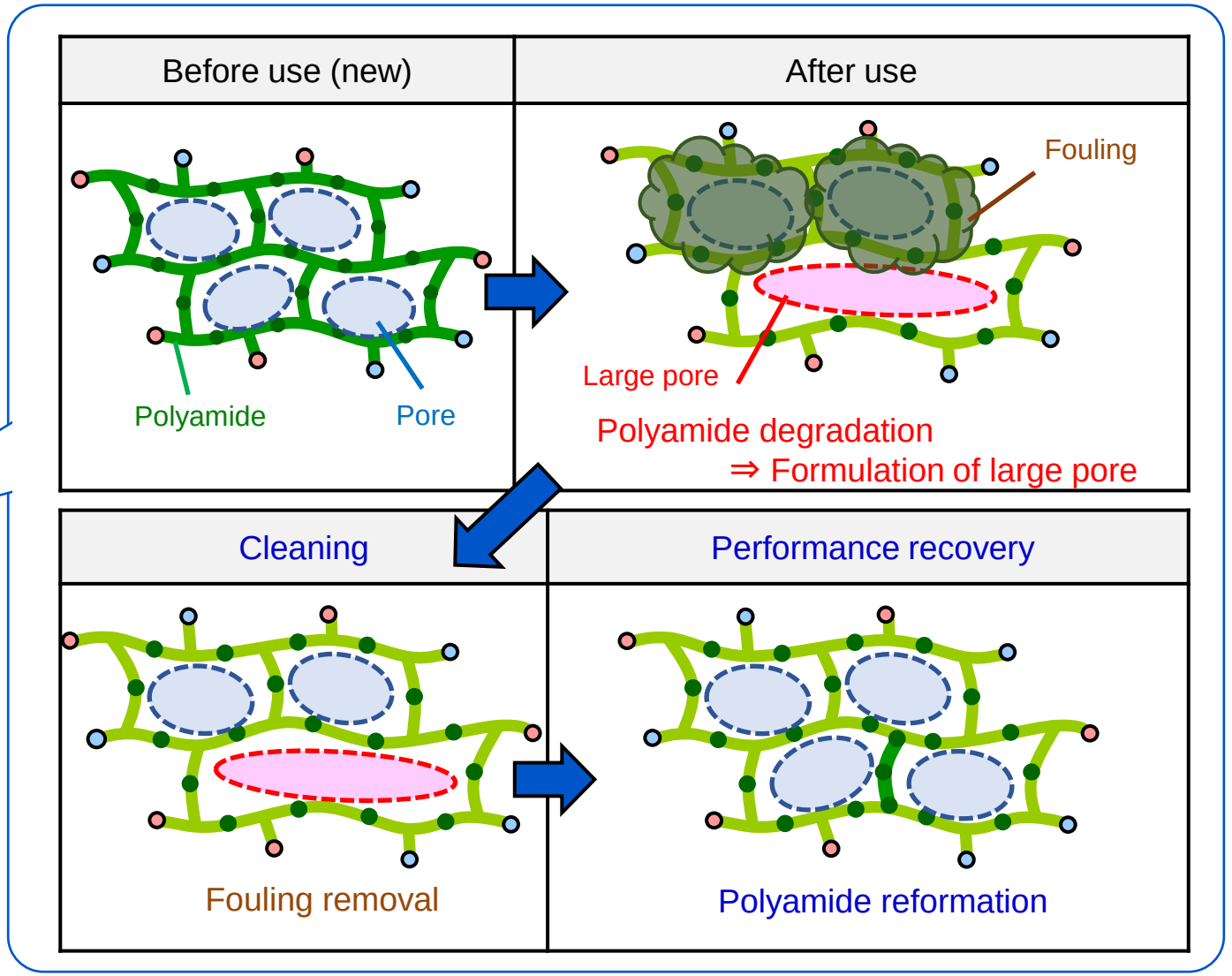
Test conditions (flat membrane):
2.0 Mpa, NaCl 500 mg/L, urea 50 mg/L, pH7, 25°C

Significant improvement in urea rejection was confirmed

(1)Semiconductor-Infrastructure-Related Technology:
RO Membrane Element Reuse

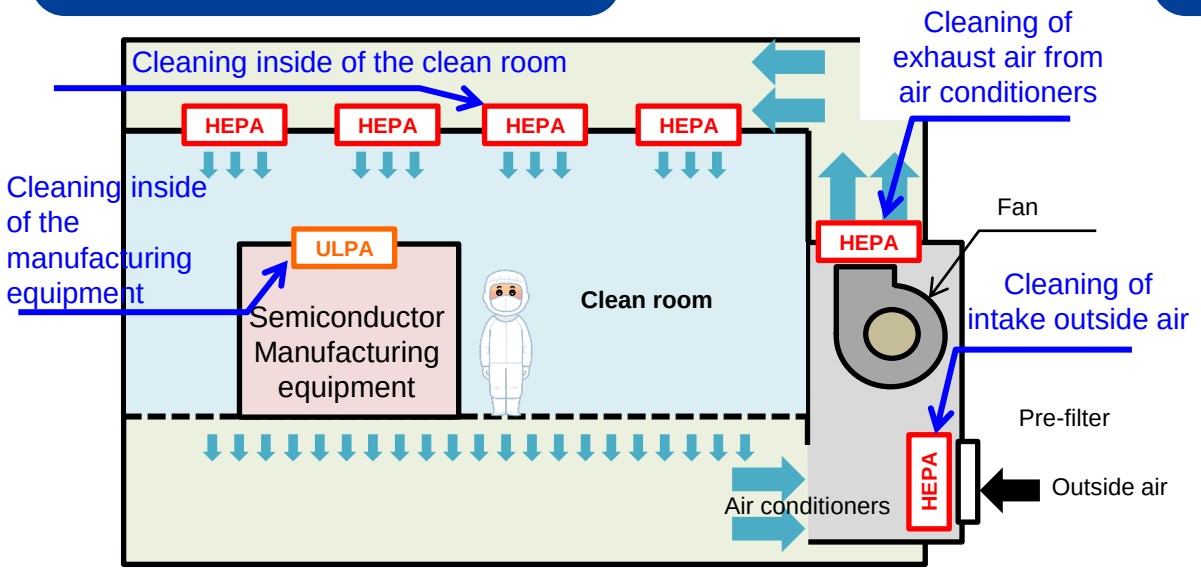


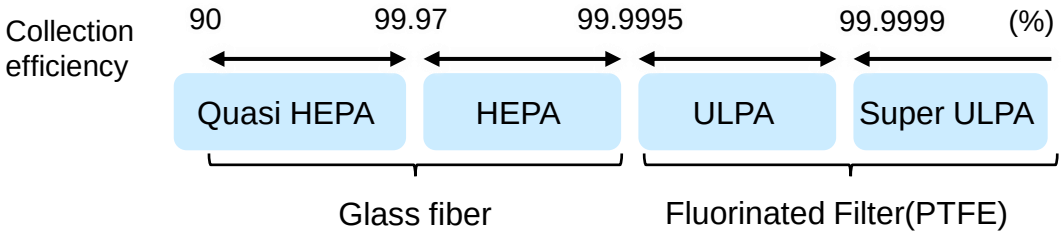
Reducing the number of discarded RO membrane elements through membrane reuse technology → Waste reduction



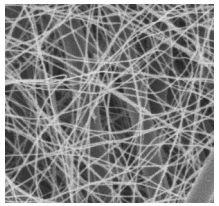
(1)Semiconductor-Infrastructure-Related Technology:
Air Filters and Resist Filters

Air filters for clean room



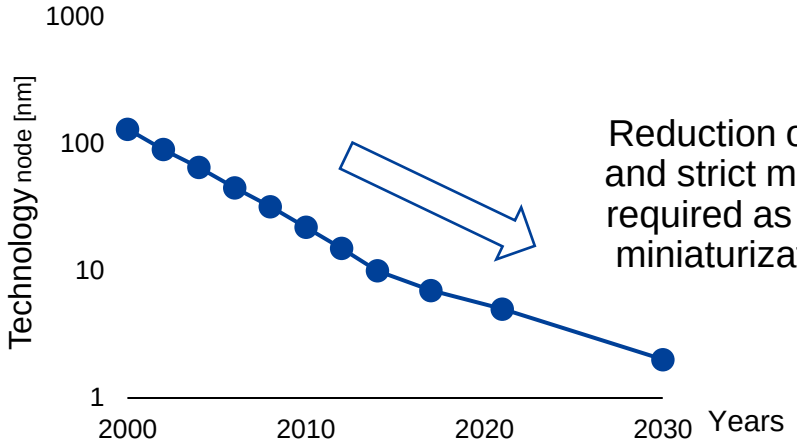


Development of PFAS-free and boron-free filter media
(collection efficiency: ≧99.9995%)



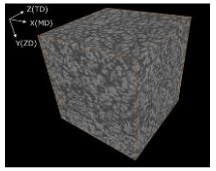
Photoresist Filters

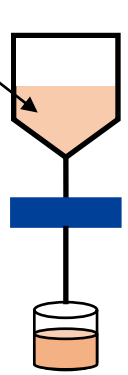
Evolution of semiconductor process nodes



Reduction of particle size and strict management are required as semiconductor miniaturization continues.

Development of filter media for high-precision filters using Toray's elemental technologies
(≦ Correspondence to 2nm processing)





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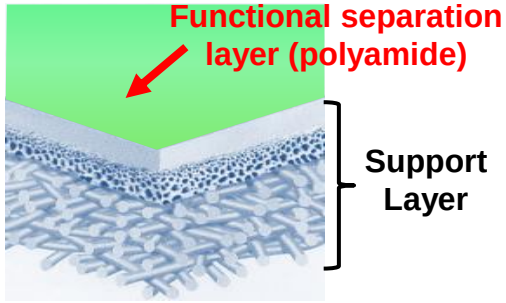
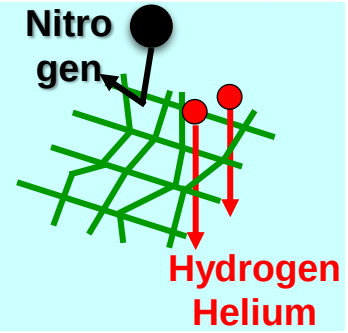
(1) Semiconductor-infrastructure-related Technology:
Gas Separation and Recycling

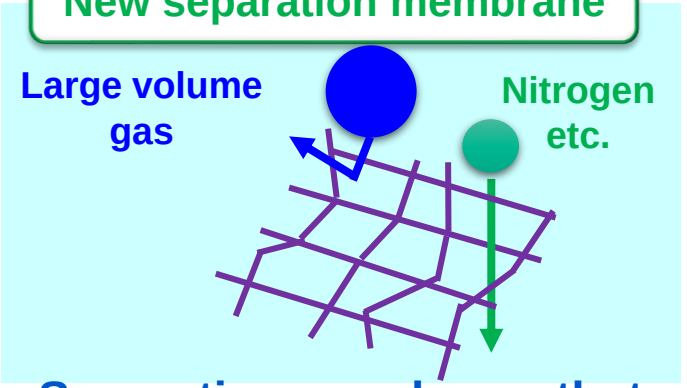
Hydrogen/helium separation membrane



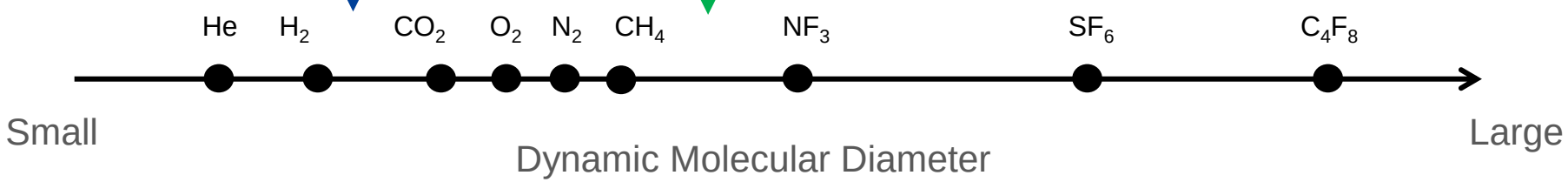


Separation membrane that selectively permeates hydrogen and helium

New separation membrane



Separation membrane that selectively permeates gases less than or equal to nitrogen



II

R&D Initiatives

(1)Semiconductor infrastructure-related technology

(2)Semiconductor-related technology: Release film for semiconductor molds

(3)Optoelectronic fusion-related technology

Toray Group's Semiconductor Film-related Products

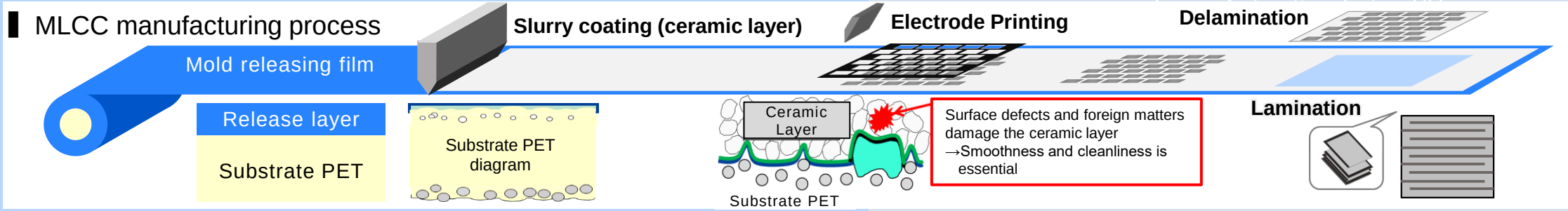
Films for multilayer ceramic capacitors (MLCC)

Business Environment

Expansion of 5G telecommunication equipment, acceleration of 6G development, increase in data transmission volume, and higher performance
→Increase in the number of ceramic layers and mounted units due to miniaturization and higher capacity

Our Strengths and Value Proposition

- Industry-leading smoothness enabled by surface design technology
- High quality, uniform thickness, free from contamination and scratches



<Contributing to technological evolution> Miniaturization and higher capacity → Thinning and increasing the number of ceramic layers → Smoothness and cleanliness of release films

Dry film resist (DFR) film

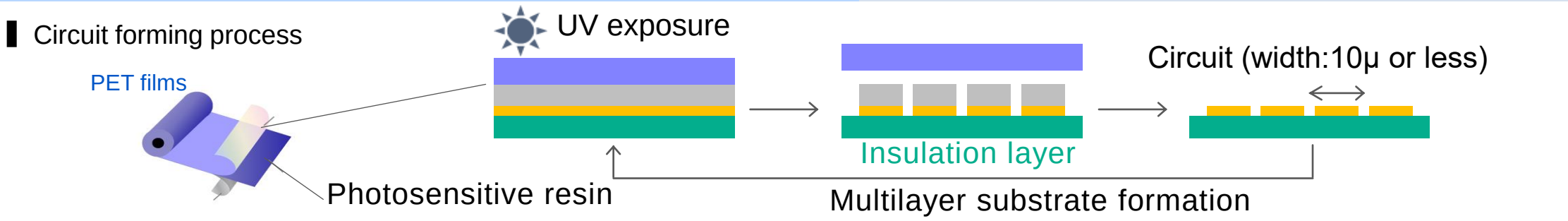
Loss of circuitry during UV exposure

Business Environment

- Improving the performance of semiconductors
- Miniaturization of circuit board wiring

Strengths and Value Proposition

- Advanced film surface design technology and quality control
- Global de facto standard material in the high-end market

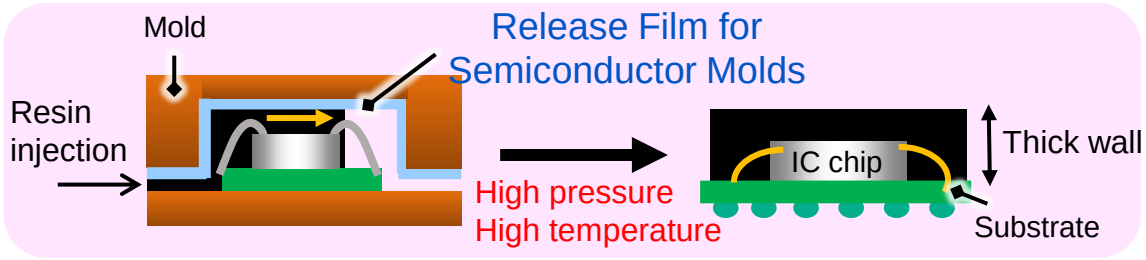


(2) Semiconductor-related Technology : Release Film for Semiconductor Molds

Semiconductor packaging technoogy

【Conventional Technology】 Transfer Mold

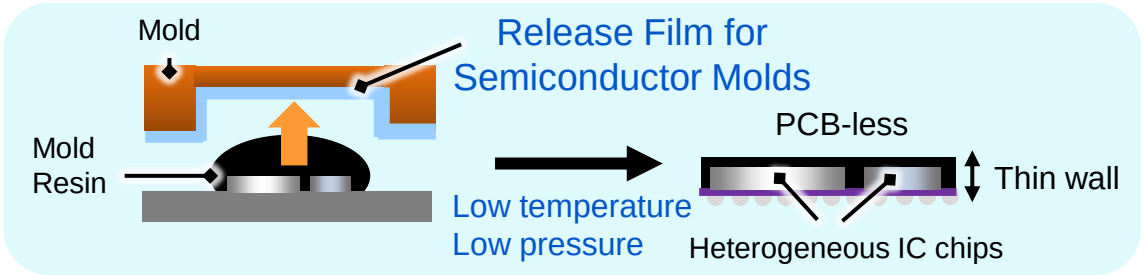
Chip level



[Technical Innovation]
- High performance
- miniaturization
- Heterogeneous chip bonding

【Advanced Technology】 Compression Mold

Wafer level



Expansion of compression molding method for cutting-edge semiconductors. (server, logic IC for generative AI, etc.)

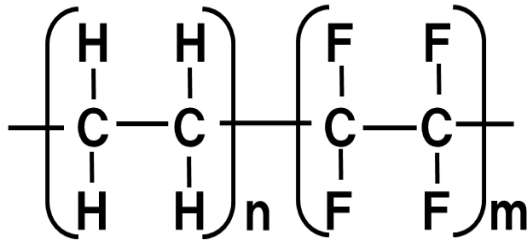
Release Film for Semiconductor Molds

[Current release film]

Restriction of mold adhesion of mold resin

Fluorine (ETFE) films

Ethylene-tetrafluoroethylene copolymer



(Performance)
Mold releasability, mold follow-up ability, and heat resistance

(Current problem)
Mold contamination due to permeation of decomposed substances peculiar to fluororesins

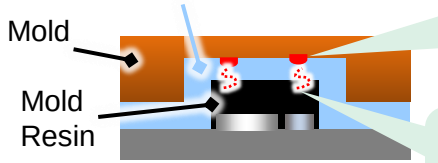
Creation of highly functional non-fluorinated and non-silicone release film that solves current problems while satisfying mold releasability, mold follow-up ability, and heat resistance.

TORAY

(2) Semiconductor-related Technology: Release Film for Semiconductor Molds

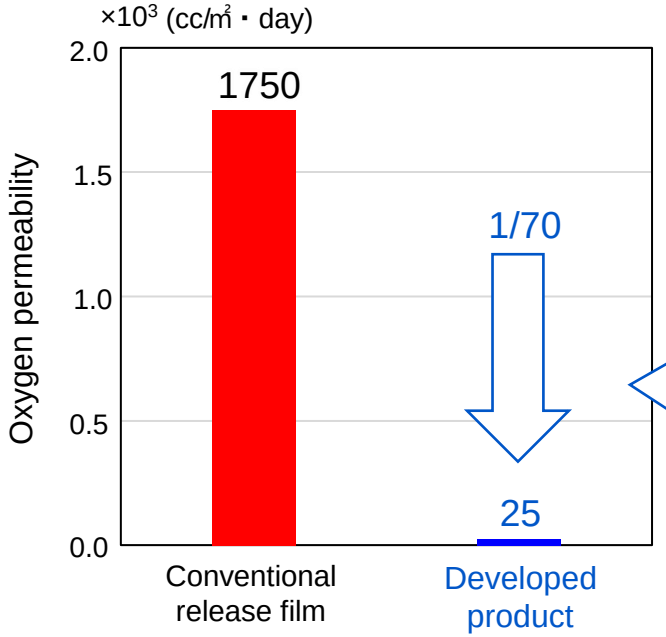
Gas barrier property

Release Film for Semiconductor Molds



Contamination caused by solidification and adhesion in the mold

Mold resin is vaporized (sublime)
Permeation through film in gaseous state

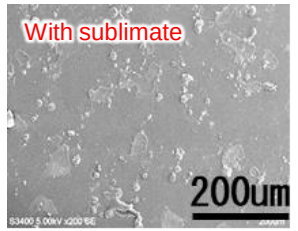
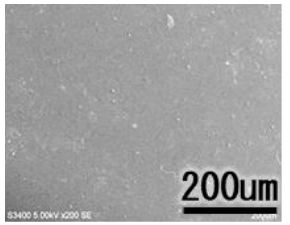
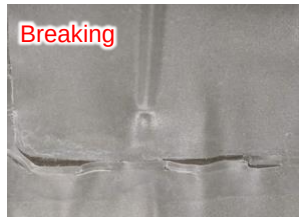
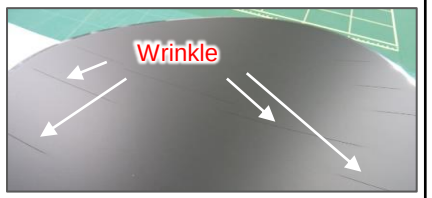


Example of mold cleaning frequency

Conventional release film:
Cleaning once after 100 times of molding

Toray Development Film:
Cleaning once after forming 500 times is sufficient

Performance

	Conventional release film	**Developed product**
Mold releasability	Good	Good
Metal contamination	 Weak	 Good
Film breakage	 Weak	 Good
Wrinkle transfer	 Weak	 Good

Developed products do not use PFAS materials. Resolve mold contamination
→ Started mass production in 2023.

II

R&D Initiatives

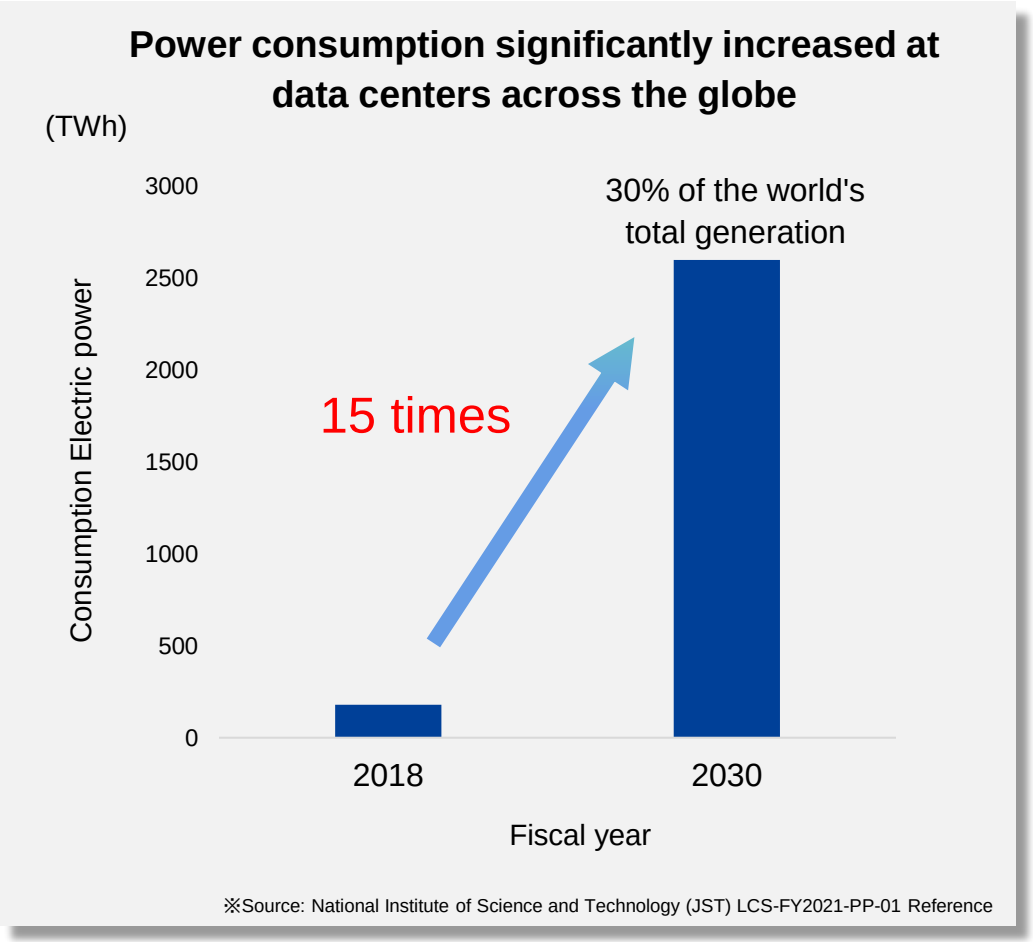
(1)Semiconductor infrastructure-related technology

(2)Semiconductor-related technology: Release film for semiconductor molds

(3)Optoelectronic fusion-related technology

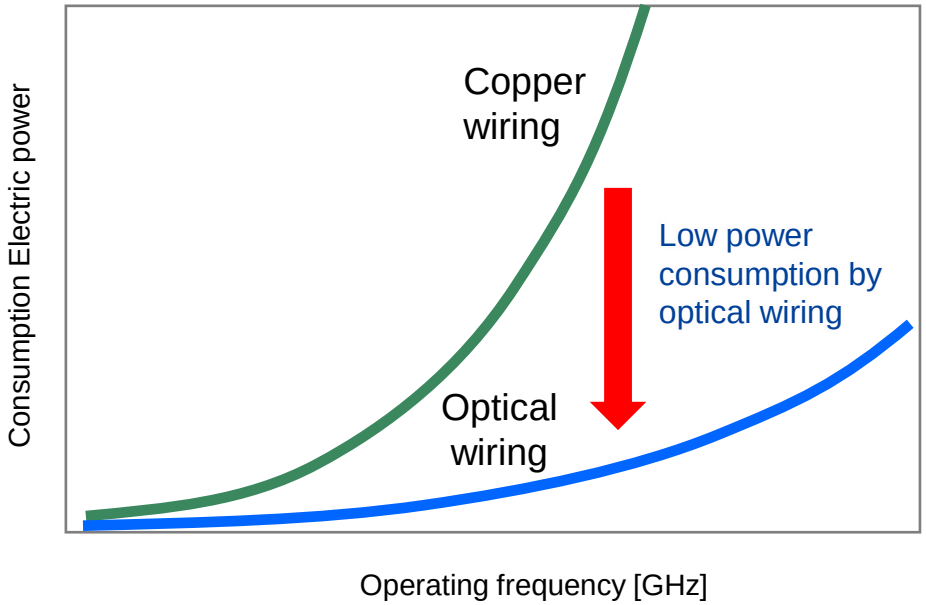
(3) Optoelectronic Fusion-related Technology

Global Data Center Energy Consumption Forecast



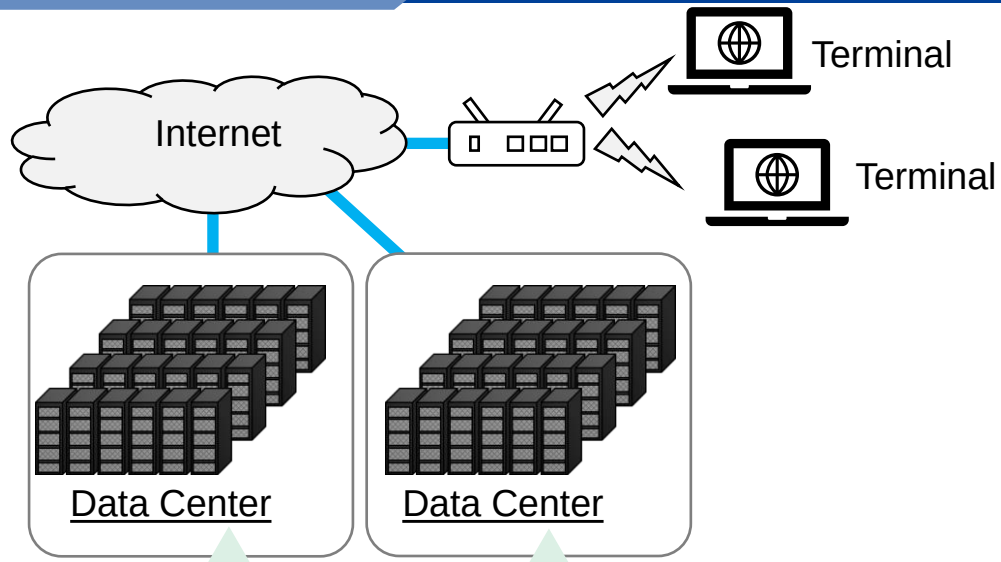
※Source: National Institute of Science and Technology (JST) LCS-FY2021-PP-01 Reference

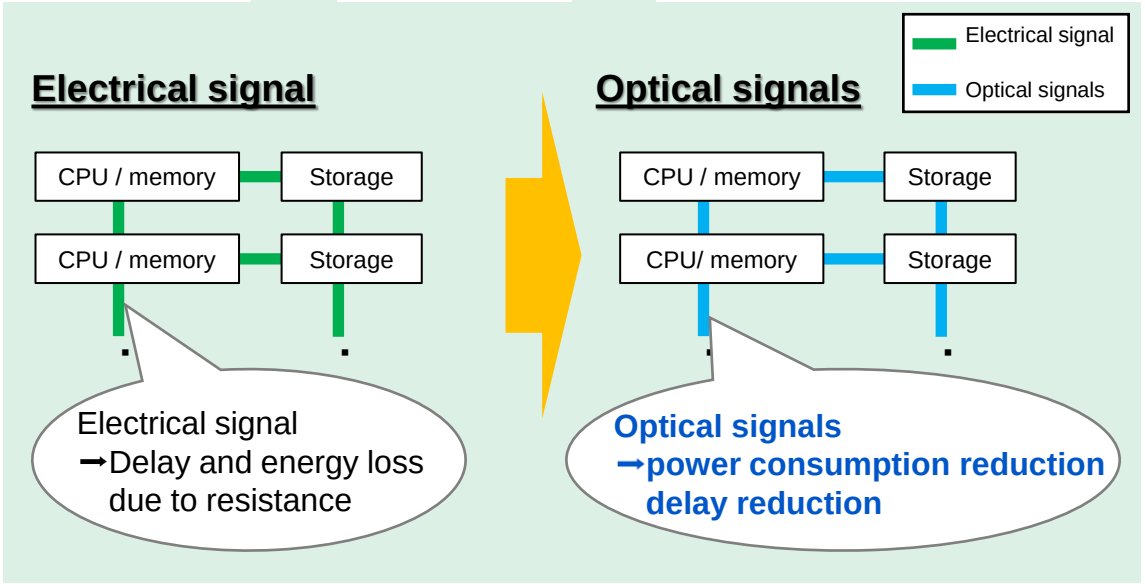
Future Trends



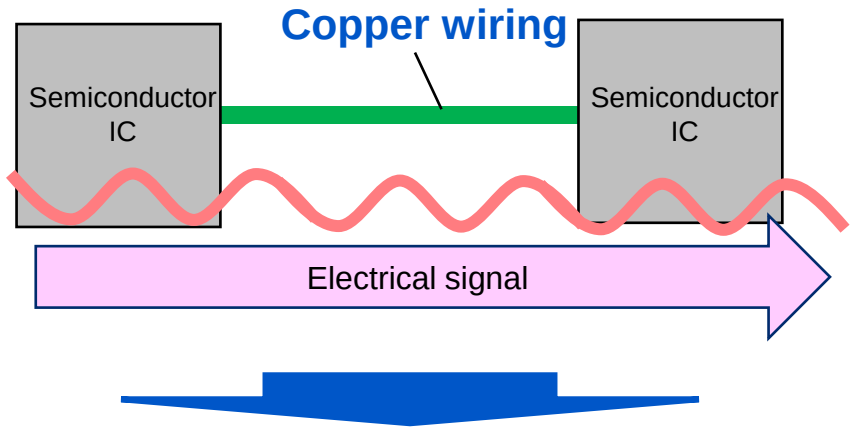
Low power consumption is enabled by optical wiring in large-capacity, high-speed communications

(3) Optoelectronic Fusion-related Technology

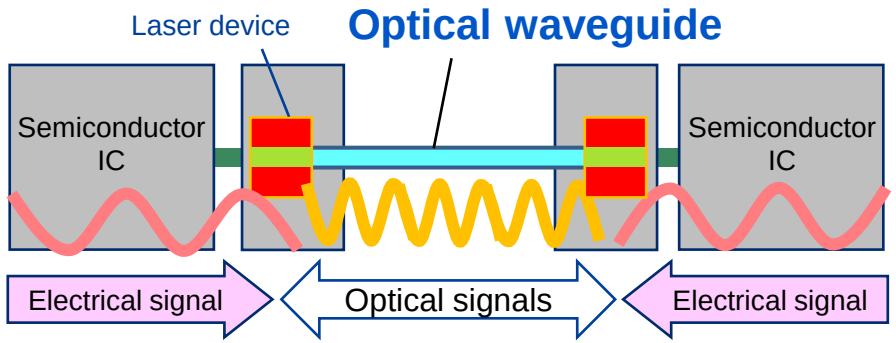




Conventional semiconductor packages



Optical Communication Semiconductor Packaging (Si Photonics)

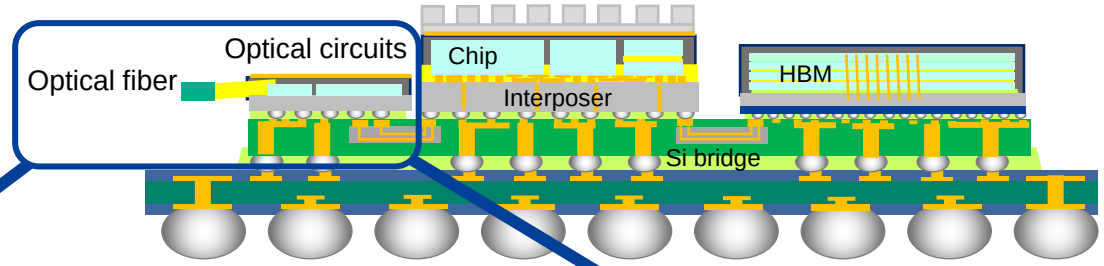


Optical wiring technology is important for low power consumption in next-generation high-speed communications.

(3) Optoelectronic Fusion-related Technology

■ Applications to next-generation high-capacity optical communication systems are under consideration.

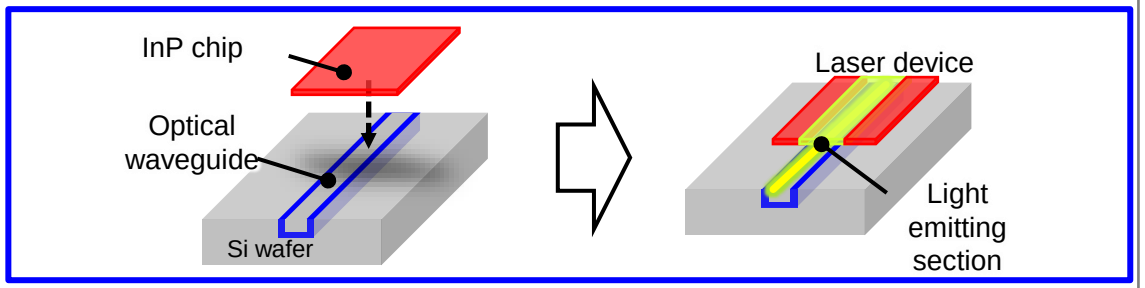
Chiplet type Optoelectronic Co-package



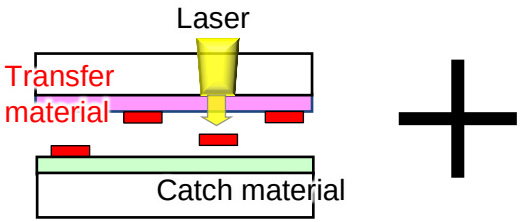
Materials & equipment for mass transfer

Optical fiber for communications

High-speed laser transfer materials and equipment

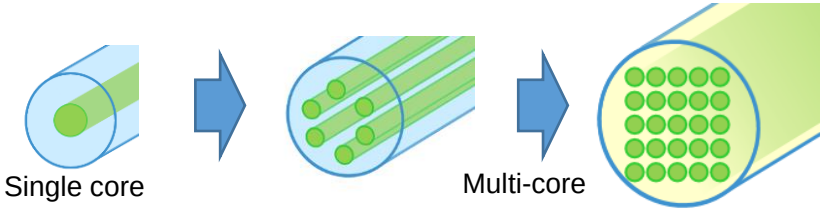


High-speed, high-position precision mounting process for ultra-thin film chips



Laser (Toray Engineering Co., Ltd.)

Multi-Core Plastic Optical Fiber



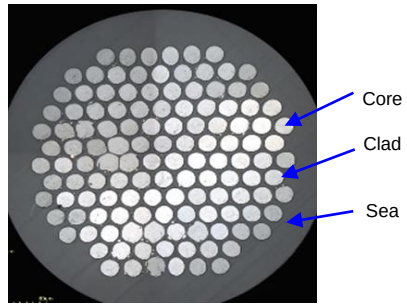
Increasing the capacity of communications through the use of multi-core

Elemental technology

NANODESIGN™ technology

Ultra-precise composite spinneret section

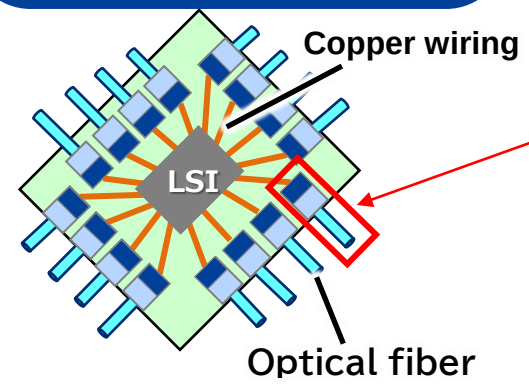
Cross-section is formed by fine flow



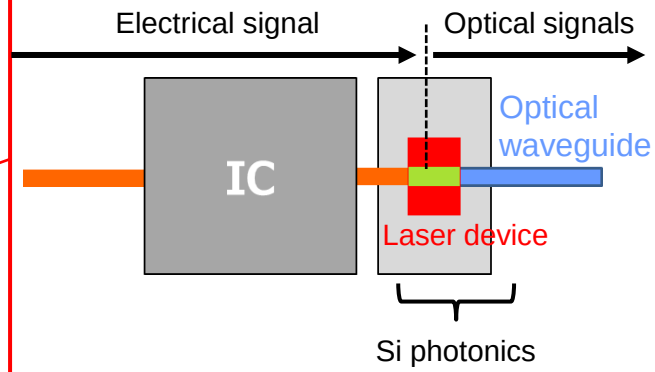
21

(3)Optoelectronic Fusion-related Technology:
High-speed Mounting Technology for Optoelectronic Fusion Device Package

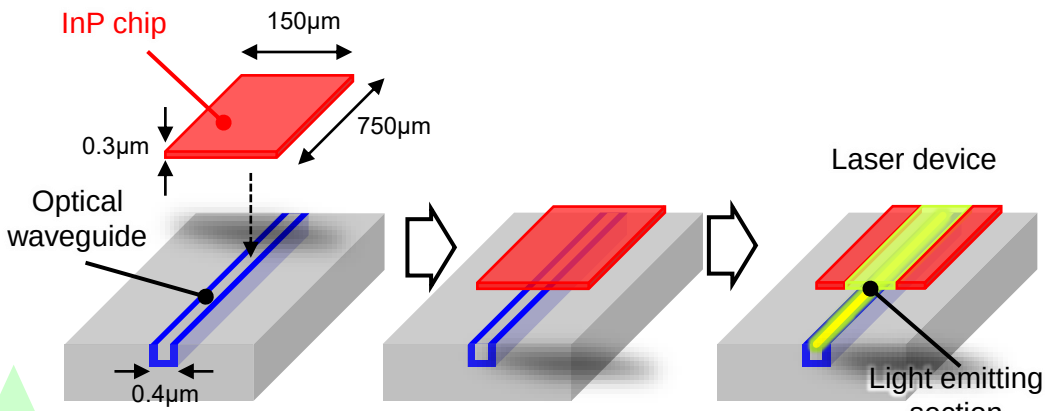
Next-generation optical communication package



Photoelectric converter



Laser device forming process

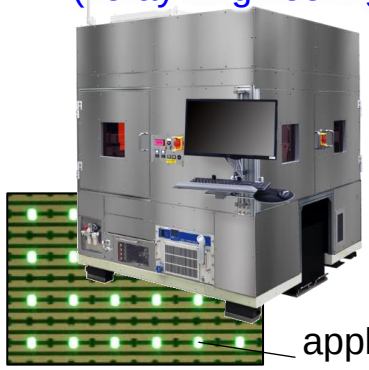


Laser device forming process

Development is under way to implement ultra-thin-film chips with high speed(*) and high position accuracy

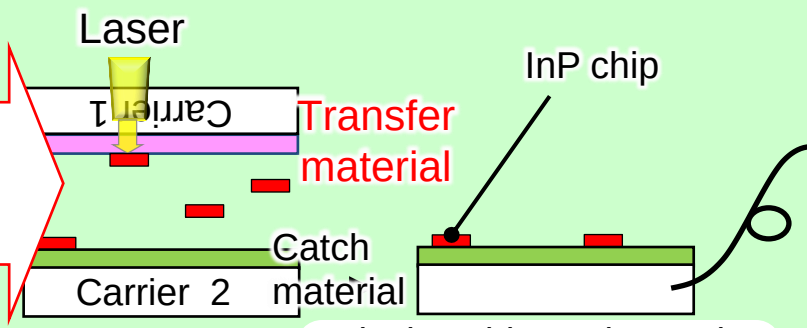
(*) Throughput: approximately 8,000 unit/min

Laser transfer apparatus (Toray Engineering Co., Ltd.)



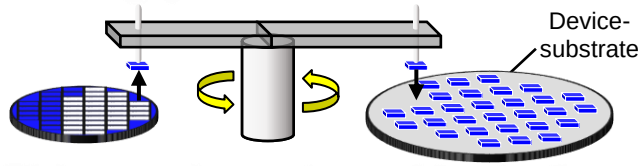
Considering Laser transfer

Example of application to μLED chip (20×30μm)

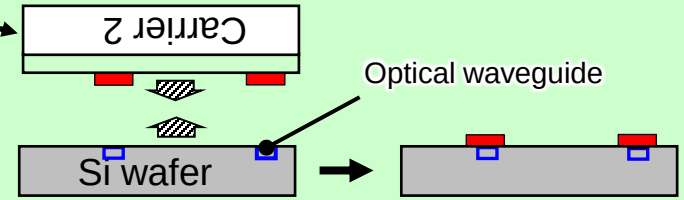


Placing chips at intervals aligned with the waveguides of Si wafer

Conventional
Low throughput



Pick up and mount one chip at a time

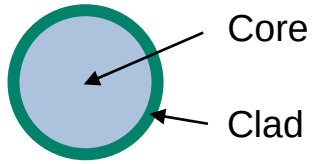


Since it is arranged on the chip carrier 2 in accordance with the waveguide, it can be mounted collectively

(3) Optoelectronic Fusion-related Technology:
Multi-core Plastic Optical Fiber

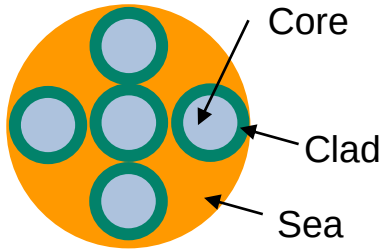
■ Developed multi-core optical fiber by Toray's unique NANODESIGN™ technology and resin flow control technology.

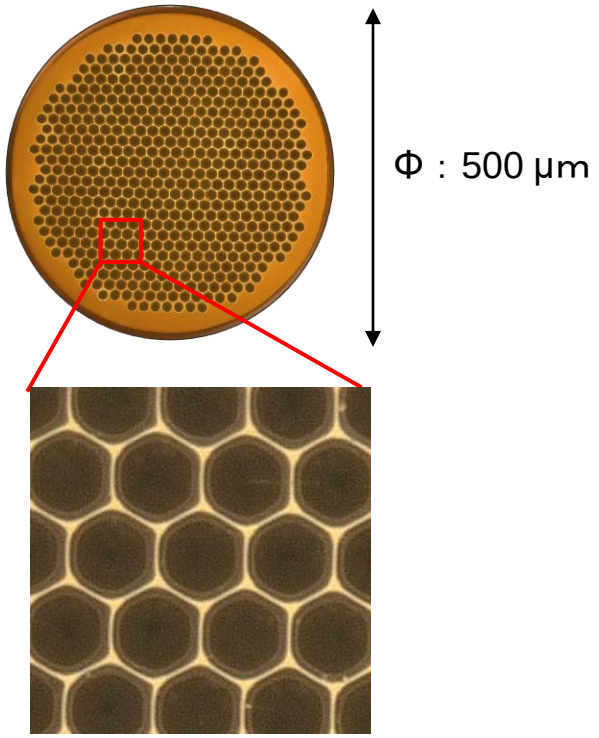
Plastic Optical Fiber



NANODESIGN™ technology
Flow control technology

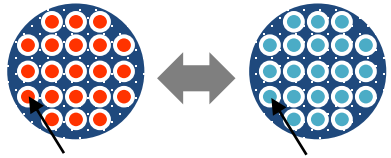
Multi-core Optical Fiber



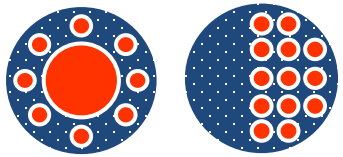


Cross-section of 3-layer multi-core prototype

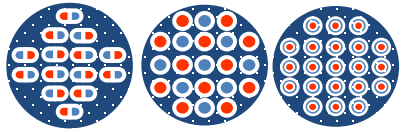
Various polymer designs



Various cross-section designs

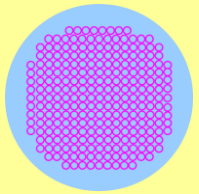


Ability to combine 3 types of polymers



Flexible design using NANODESIGN™ technology

Ultra-precise composite spinneret cross-section
➞ Enables high-precision core placement



Transmission capacity: Multi-core multiple communications enables high-capacity communications over 100Gbps.

TORAY

III

Future Prospects and Summary

Research and Development Goals

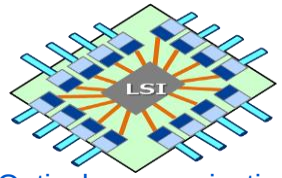
Target **Aim to more than double the revenue while maintaining profit margins**

Developing and expanding new products that solve the issues accompanying the rapid transformation of the semiconductor field

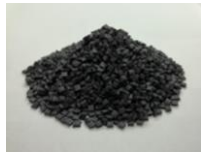
Electronic coating and mounting materials

Semiconductor manufacturing and inspection equipment

Release film for semiconductor molds



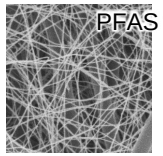
Optical communication package



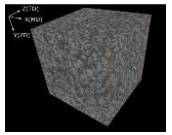
PPS resin for power modules

RO membranes for ultrapure water production

Reuse of wastewater

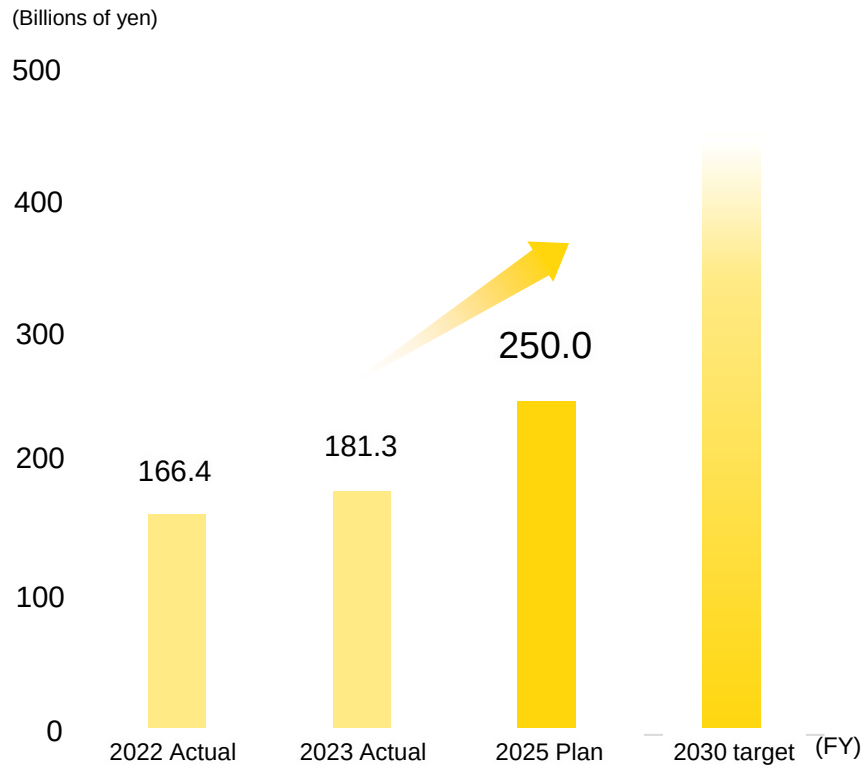


Air filter media

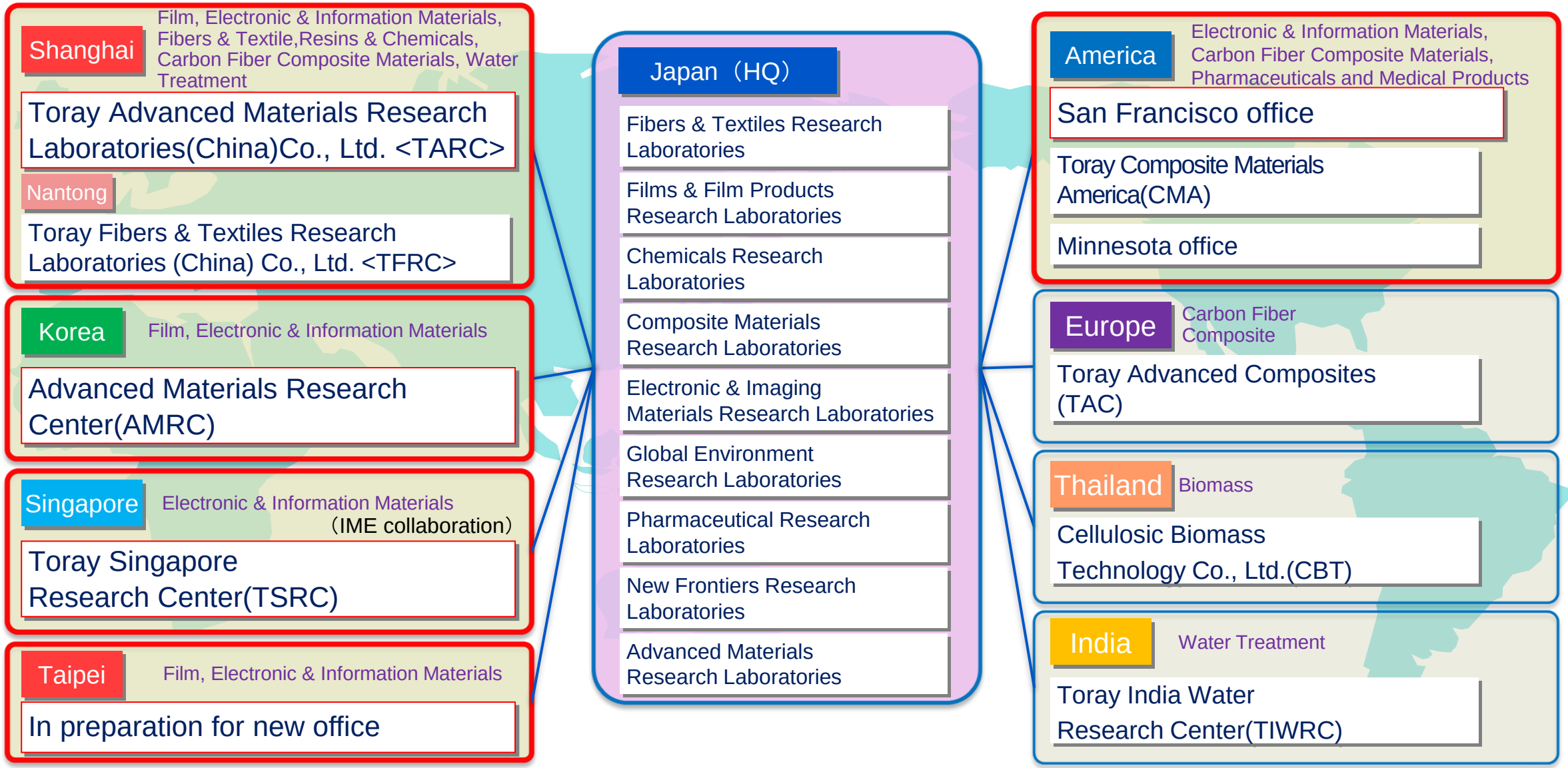


Resist Filter media

DI Business Revenue Targets



Global Research Center



Toray's strengths in technology and materials

DI business/Semiconductor manufacturing

Process materials and equipment parts

Mold release film

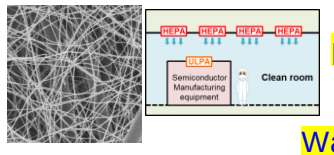
Components

Polyimide Insulating material

PPS resin

Infrastructure

Filter



PFAS free

Ultrapure water production

Wastewater treatment

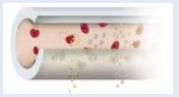
Developing and expanding new products that solve the issues accompanying the rapid transformation of the semiconductor field.

Separation membrane technology

Water treatment field

Seawater Desalination

Food and medical fields



Dialysis

Pharmaceutical manufacturing membrane

Food manufacturing membrane

Environmental field

valuable material recovery

Gas separation

Expand business scale by deepening separation membrane technology and expanding applications.

Next-generation mobility materials

Materials for xEV, e-Axle

Connector

xEV inverter
xEV capacitor

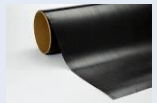
Safe and comfortable materials

Motor

xEV battery

High Performance Carbon Fiber

High performance Prepreg



prepreg for sports applications

Business expansion exceeding xEV growth / High-value-added materials for the aircraft applications.

Environmentally-friendly Technology

Polymer

- Polyester
- Polyamide
- ABS
- PAN (Carbon Fiber)
- PPS

Fossil resources

OIL

Biomass

CO_2 use

Material recycling

Chemical raw material → Polymer → Plastic products

Chemical recycling

Achieving circular economy (CE) goals with economic rationality towards a circular society.

TORAY

Summary

- Toray Group is developing businesses in various fields, such as semiconductor, display, electric parts market. In addition, the Group is globally operating diversified businesses, including materials used directly in products, indirect materials used in manufacturing processes, infrastructures for clean water and air, manufacturing and inspection equipment, as well as analyses.

- In R&D, by anticipating the needs of the times, we will develop and expand new products that solve the issues accompanying the rapid transformation, in areas such as semiconductor, display, and electronic parts, in addition to the ones I explained today: (1) semiconductor infrastructure-related technology, (2) semiconductor-related technology, and (3) optoelectronic fusion-related technology.

- Having positioned the DI business as growth business field, Toray Group is working together, leveraging the three combined strengths of materials, equipment, and analysis, to create new value and contribute to society.

Descriptions of predicted business results, projections, and business contained in this material are based on predictive forecasts of the future business environment made at the present time.

The material in this presentation is not a guarantee of the Company’s future business performance.


'TORAY'
Innovation by Chemistry