Development of Circular Manufacturing For Green Devices Using Advanced coating Technology

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The National Institute of Advanced Industrial Science and Technology(AIST)

AIST, one of the largest public research organizations in Japan, focuses on the creation and practical realization of technologies useful to Japanese industry and society, and on "bridging" the gap between innovative technological seeds and commercialization.

Research fields(7 research domains)

- Electronics and Manufacturing
- Materials and Chemistry
- Information Technology and Human Factors
- Life Science and Biotechnology
- Environment and Energy
- Geological Survey of Japan
- National Metrology Institute of Japan

Personnel

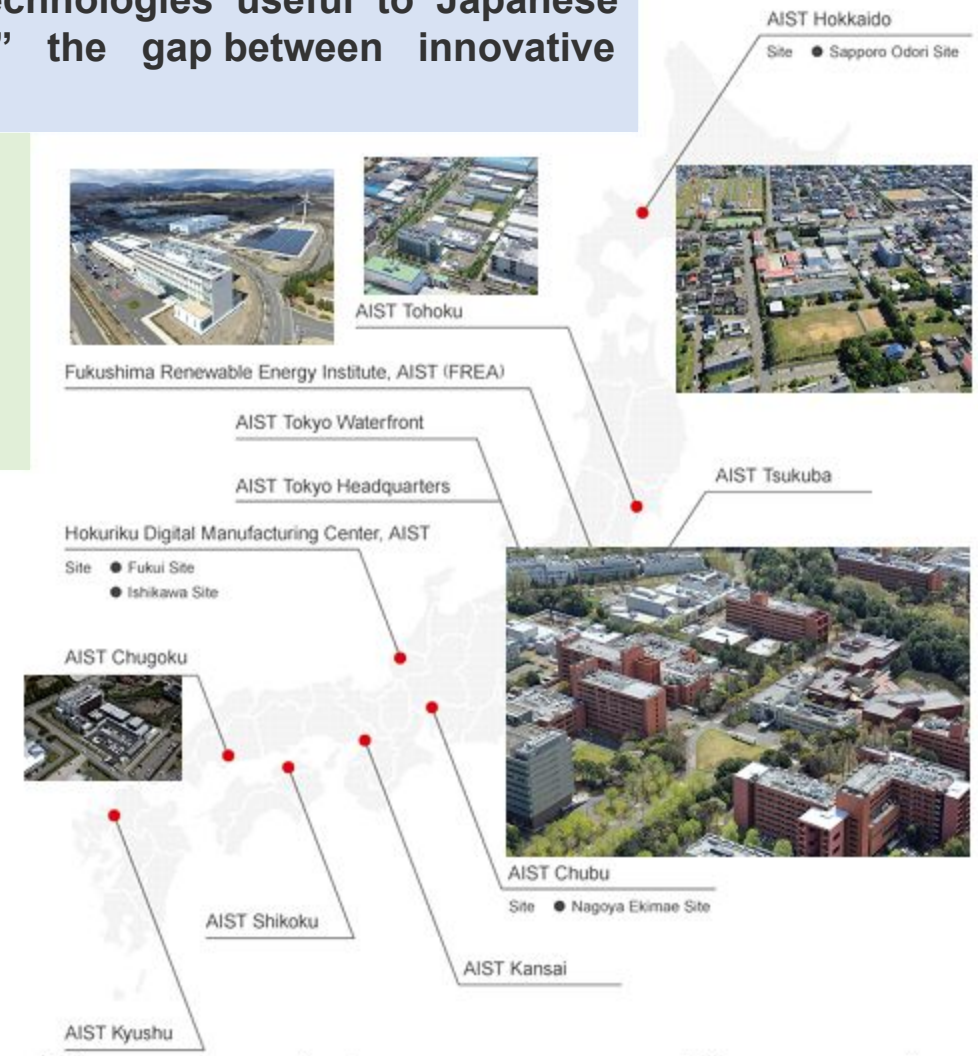
12,000

(Total number of personnel working at AIST)

Researchers	2,200
Administrative employees	700
Contract employees (Including postdoc)	3,200
Others	6,000
Visiting researchers/employees from companies,universities, etc.	5,800
AIST Solutions employees	200

*As of the end of March 2024. However, visitor data from companies and universities are based on the 2023 fiscal year results.

**Personnel numbers are rounded to the nearest hundred, so totals may not match exactly.

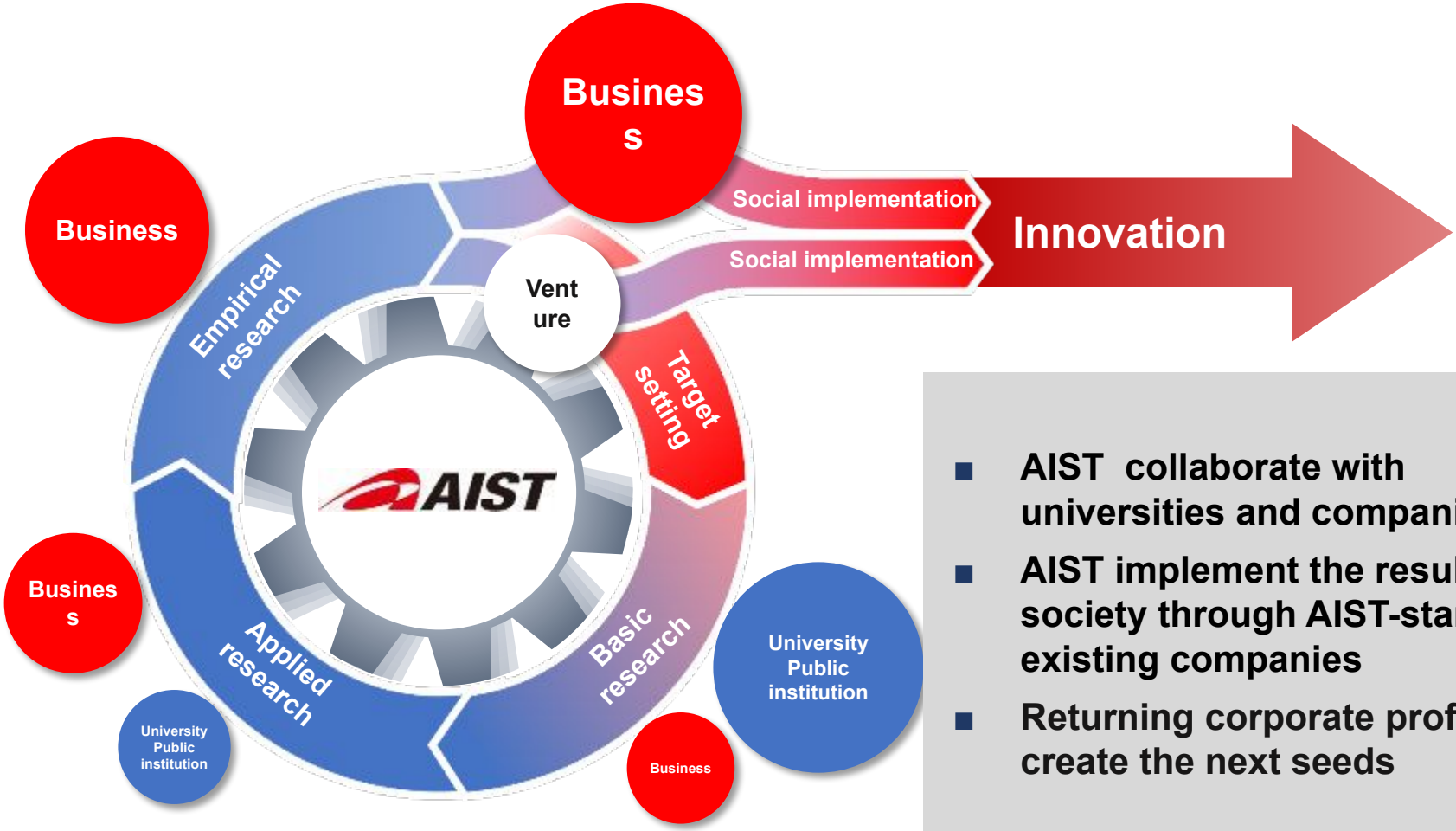


12 research bases across the country

AIST in 10 years' time

National Innovation Ecosystem

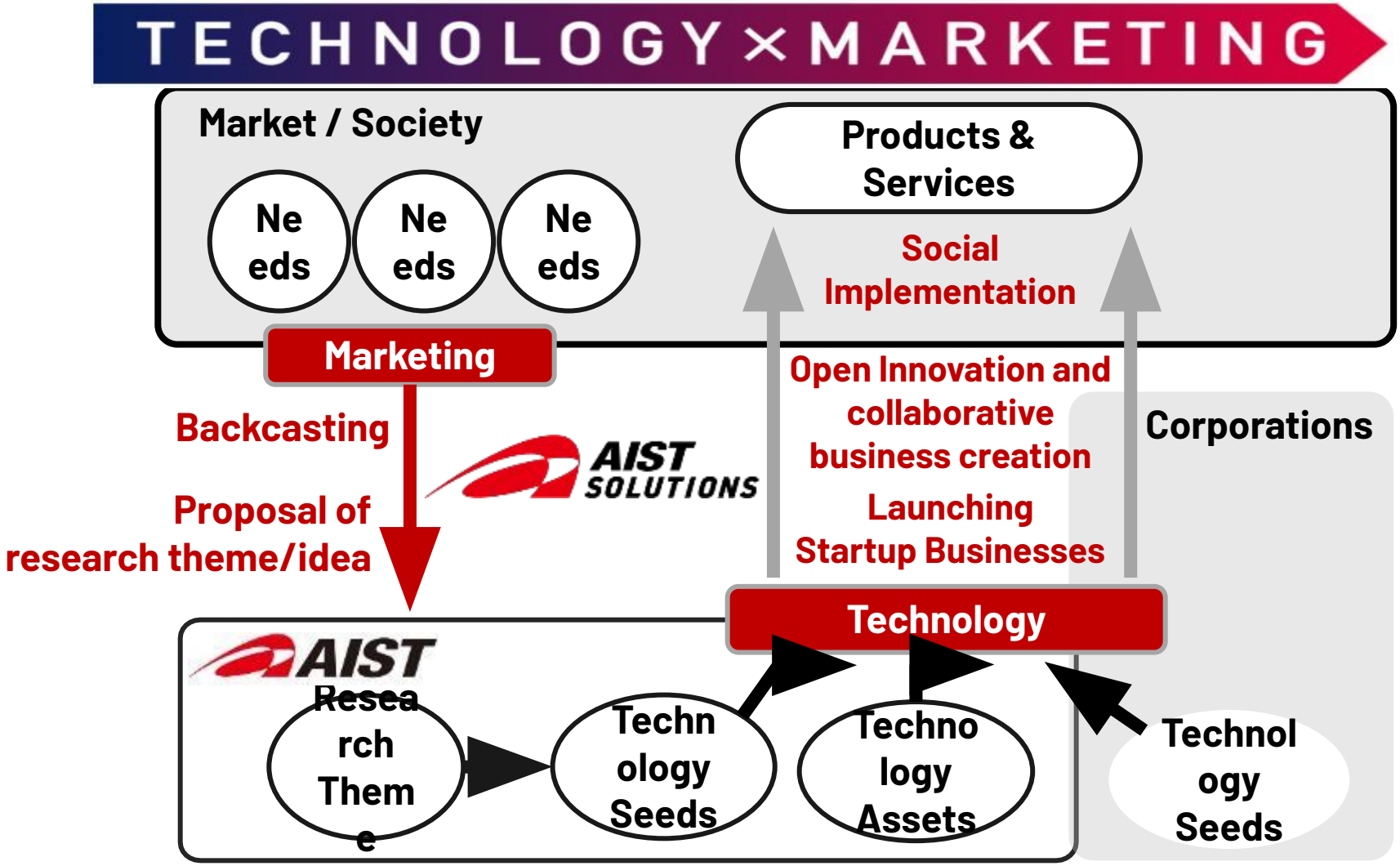
This initiative aims to accelerate technological advancements and strengthen industrial competitiveness.



- AIST collaborate with universities and companies
- AIST implement the results in society through AIST-start-ups or existing companies
- Returning corporate profits to create the next seeds

AIST Solutions Co.

- AIST Solutions is a company that launched in April 2023 to put the National Innovation Ecosystem into practice.
- The role of AIST Solutions is to mediate AIST and industry sectors, by integrating technology and marketing.



AIST' Recent Initiatives Based on National Strategies

AI

ABCI3.0
6.22EFLOPS

AI Bridging Cloud Infrastructure (ABCI), is an open computing infrastructure for both developing AI technology and bridging AI technology into the industry and the real world

Semiconductor

SCR

The Super Crean Room is equipped with 300 mm silicon wafer pilot line

Quantum

G-QuAT

In 2023, AIST established G-QuAT, which stands for "Global Research and Development Center for Business by Quantum-AI Technology

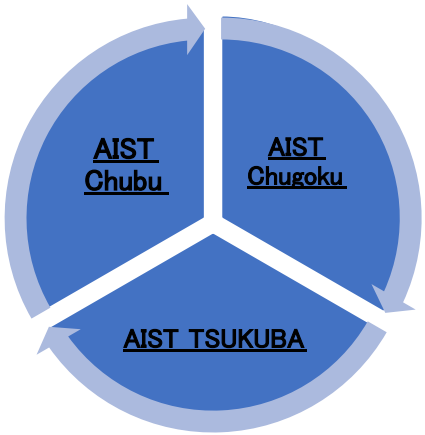
Material DX

MPI Platform

MPI (Materials and Process Innovation)

High-throughput data-driven materials research and development

- Ceramics/Alloys,
- Organic/biomaterials



Development of Advanced Materials for Green Devices and Circularity

To achieve carbon neutrality by 2050, the creation of a low-carbon society has become an urgent issue, so development of a high-performance green device is important.

- In most case, resent high performance green devices is using the many rare metals and critical materials, considering from the perspective of resource depletion, recycling and reuse are becoming increasingly important.
- However, these devises is a made from, resin and ceramic materials by using their respective functions, recycling and reuse are difficult.
- In the future, it will be necessary to consider easy reuse and easy recycling design in manufacturing.
- Another important CE factor is reduction of the CO_2 emission in manufacturing.

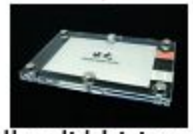
Integration of the AI and IoT technology

Green devices

Energy creation

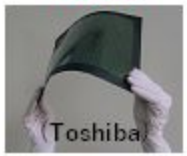
Ni, Mn, La, Zr

SOFC



Ni, Co

All-solid Li-ion Battery (Idemitsu)



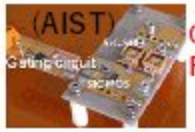
In, Sn

Perovskite solar cells

Energy storage

Y, Cu, Ni(W)

Superconducting tape (Fujikura)

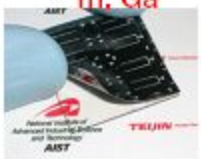


Ga2O3, GaN
RuO2 etc

Power electronics

Energy-saving

Sensor



In, Ga

CIGS solar cell

In, Sn

OELD

Wearable Sensor

Application to Infrastructure in Circular Manufacturing

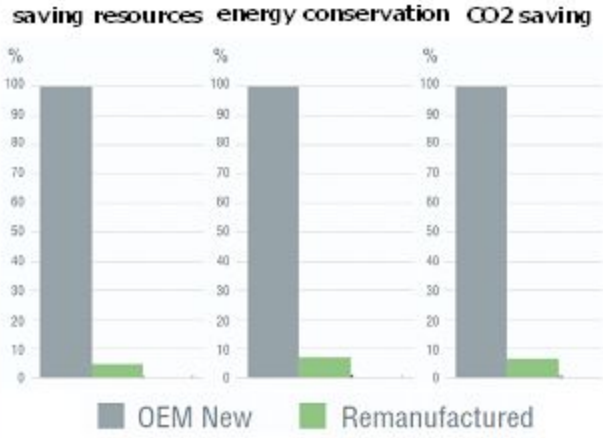
http://www8.cao.go.jp/cstp/society5_0/medical.html

Data-Driven Society

Establishment of circular manufacturing

・To establish a circular economy, it is essential not only to economic value(Resources, their supply chain, and performance)but also to solve social issues (reduction of CO2 emissions) .
・From the standpoint of resource circulation, CO_2 emissions, and costs, remanufacturing is more effective than recycling them back into raw materials.

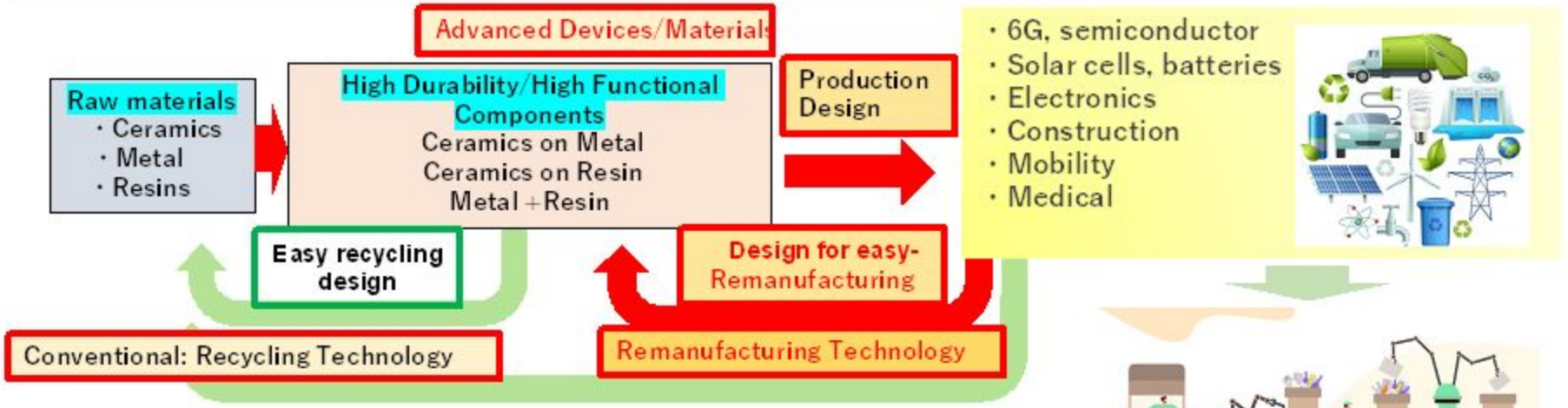
・Reman(or Direct material recycling) saves resources, energy, and CO2 emissions compared to new manufacturing.
・Compared with recycling to row materials, remanufacturing saves resources, energy, and CO2 emissions.



Source: UNEP-IRP, 2018 (Fig. 22)

Promotion of circular manufacturing

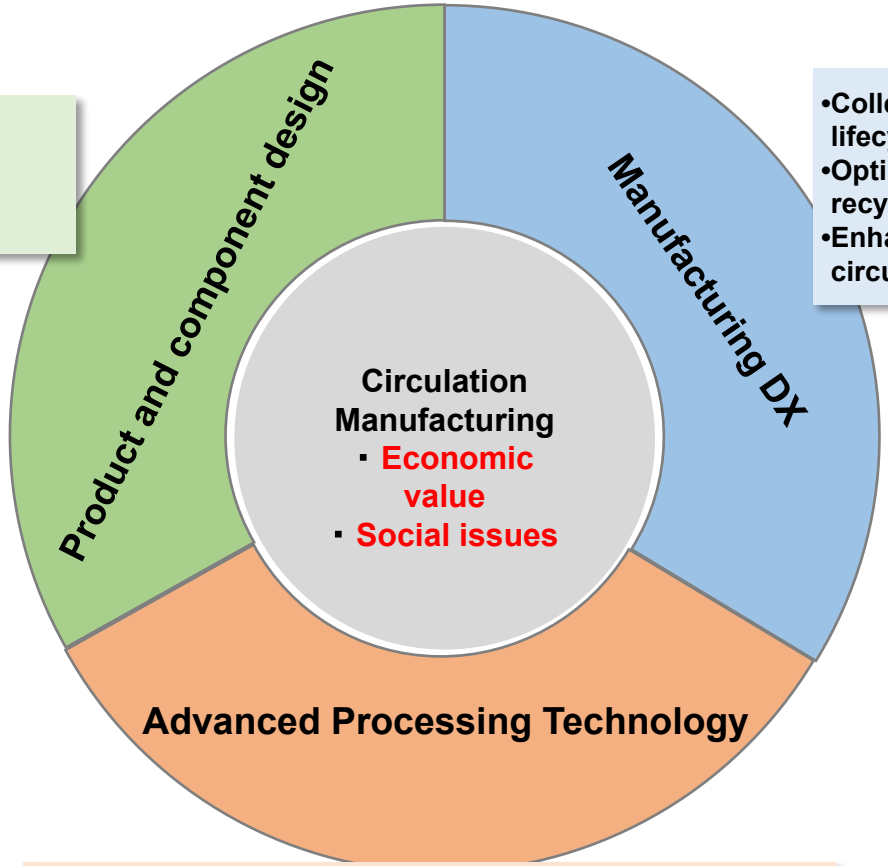
LCA :CO2 emission, resources and Value



"Standardization" of recycled materials is extremely important !

Circulation Manufacturing with Advanced Processing Technology, DX and Design

To establishing a circular manufacturing, Advanced processing technologies, Digital transformation, and Design would be key points.



- Multifunctionality
- Durability
- Easy decomposition

- Collecting and analyzing product lifecycle data
- Optimizing material reuse and recycling
- Enhancing traceability of resource circulation in the supply chain

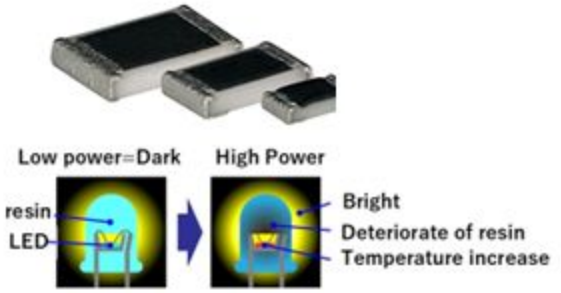
・Smart Synthesis：Realization of new functions
Pushing the limits of conventional processes
・Green Manufacturing：

Design for Circular Components

Realization of durable, high-performance and resource-recycling materials

Conventional technology

Difficult to separate



Monometallic structure

Easy Reman,
High functionality, high durability

Development Technology 1:
Componentization in a single material system

Stacked structure, molecular bonding

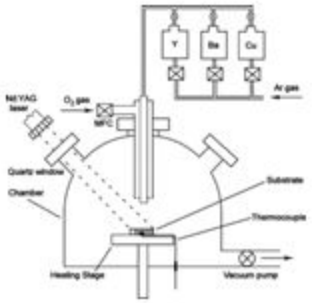
Easy Reman,
High functionality, high durability

Development technology 2:
Componentization in a multilayer structure

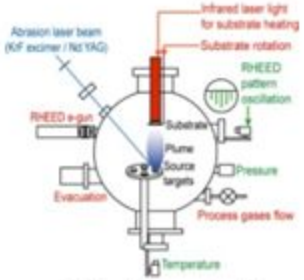
Energy-saving process from raw materials to components

Advanced Coatings technology

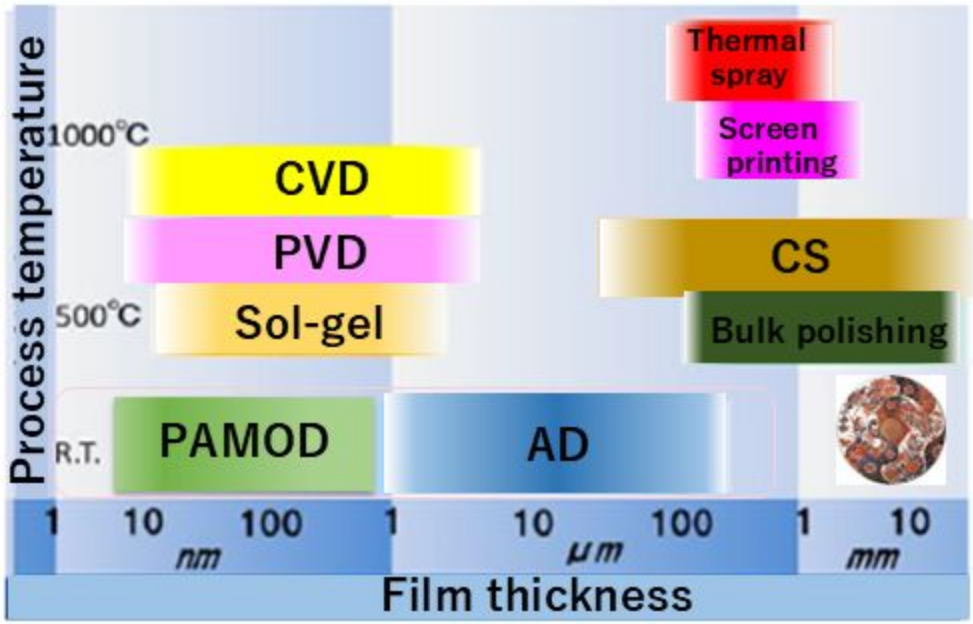
- Conventional physical and chemical processes are high-temperature processes.
- AIST has developed a ceramic coating at low temperatures!
- Advanced composite materials (ceramics/plastics) are possible with low environmental impact processes.



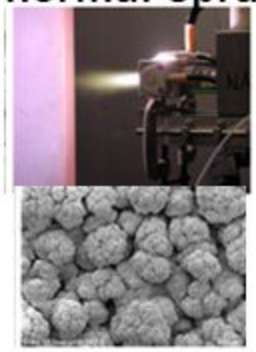
CVD method

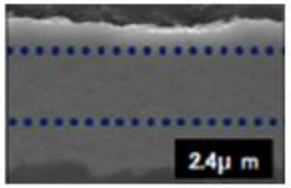


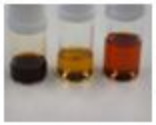
PLD method

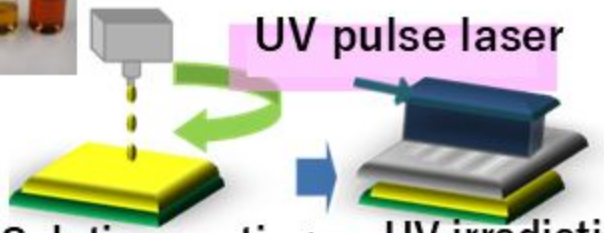


Thermal spray





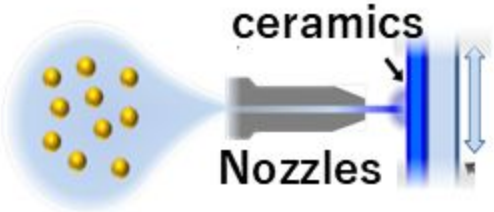




Realization of lightweight components

with photoreaction techniques

PAMOD



Hybrid Aerosol Deposition

with plasma spraying techniques

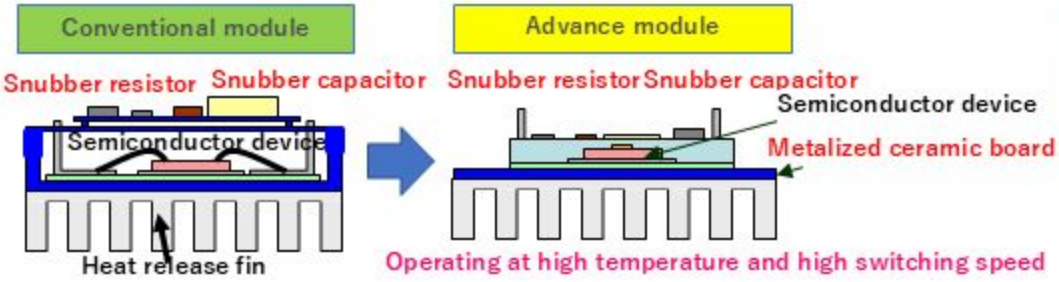
Design-Manufacturing-Recyclable Materials

Direct material recyclable glass-free resistor film for SiC power module

・Chip resistor is produced by using screen printing and high temperature sintering(800°C) of the paste, It is difficult to separate Ru from , chip resistor including glass and Pb. ⇒Directly material recycle

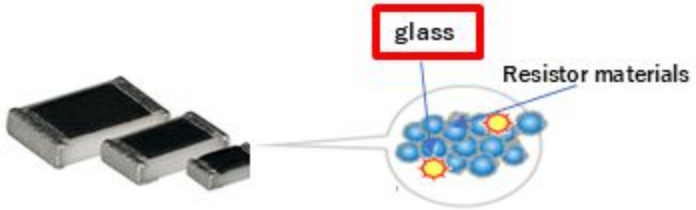
・SiC power modules are designed to work at operating temperatures around 250°C.

○SiC power modules



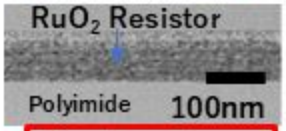
SiC power conditioner EV Inverter for Railway

○Ru resistor film

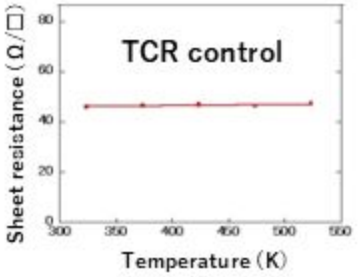


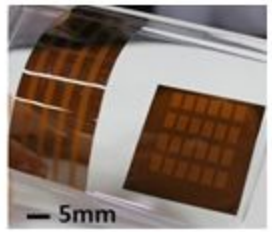
http://www.rohm.co.jp/web/japan/r_what10-j

○Photoreaction process



No glass phase





Directly separable film

RuO_2 films (flexible resistors) are developed using a photoreactive process on polyimide or Al_2O_3 substrates, without the use of glass or Pb, to control the temperature coefficient (TCR).

Application of Ceramics Coating

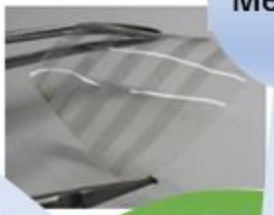
Function × Durability × Resource recycling

Advanced ceramics films

Supercon ducting film
$YBa_2Cu_3O_y$
Current limiters Filters

Nuclear Fusion

Metal film
6G antenna,
Semiconductor Wiring
Cu, Ru film



ITO, SnO_2:F

RuO_2

Flexible resistor

Semicond ucting film
• Solar cells
• Displays

Power Electronics

LaSrMnO3

Flexible thermistors

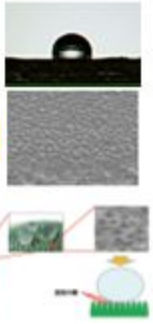
Photo reaction

Anti-Corrosion Coating

Hard coatings

Insulating films
Al_2O_3, Y_2O_3

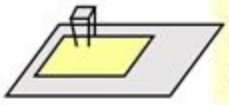
Magnetic films
WO_3 TiO_2
Photo catalysts

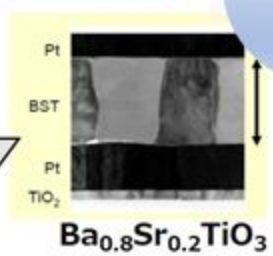


VO_X
Smart window

Infrared temperature sensors

Dielectric films
$BaTiO_3$, PZT
Capacitors





$Ba_{0.8}Sr_{0.2}TiO_3$

Optical films
$CsVO_3$
$CaTiO_3$:Pr

Light-emitting components

Lighting, Roads, Agriculture

Mechanoluminescence

Infrastructure

Industrial Applications

○Infrastructure

Bridges, piping, high-rise buildings, housing
Rustproof, highly durable, highly functional
Corrosion: Fluororesin → Inorganic coating
Thermal Barrier: Smart Window: VO_2 ,WO_3, TiO_2

Ceramic coat/metal, resin

Infrastructure Anti-Corrosion Coatings Market
US$43.3 billion in 2028

Smart Window Market
US$3.8 billion over 2028

○Automobile

Power electronics passive components, lightweight frames, fuel cells

Passive components

Lightweight: CFRTP
Electrolytic corrosion → Coating

Headlight
High-power LEDs

Rare earths:$Y_3Al_5O_{12}$:Ce;1300° C

EV Vehicle Market
1 trillion by the end of 2033
Research Nester

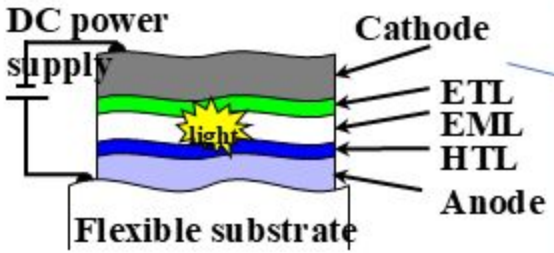
Fuel Cell Vehicle Market
Projected to exceed US$100.5 billion by the end of 2036
Research Nester

Automotive LED Lighting Market
US$62 billion by the end of 2033

○OLED device

OLED: US$57 billion in 2026
(IDTechEx Ltd)

Transparent Conductive Film — US$11.3 billion by 2032



OLED

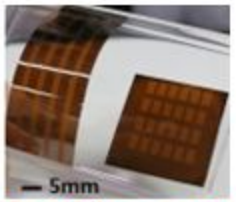
○Passive components

A smartphone is said to contain **approximately 800 to 1000 multilayer ceramic capacitors (MLCCs)**. Additionally, the number of resistors exceeds several hundred, with ultra-small **chip resistors** such as **0402 and 0201 size** being widely used.

2023: US$32.3 billion

In smartphones and wearable devices
0402 size (0.4mm x 0.2mm) electronic components.
Need for miniaturization to achieve high functionality in a limited space.

Chip resistors



Flexible resistors

AIST International Partnerships

- AIST concludes MOUs with world's leading institutes seeking to strengthen the international research
- AIST contributes to establishing the global system for sustainable development, serving as the hub of the international research network.
- AIST builds up efficient environment to collaborate with foreign researchers and provides opportunities for foreign personnel.

As of January 30th, 2025

If you would like to collaborate with us, please feel free to contact us.

Thank you for your kind attention!

https://www.expo2025.or.jp/en/

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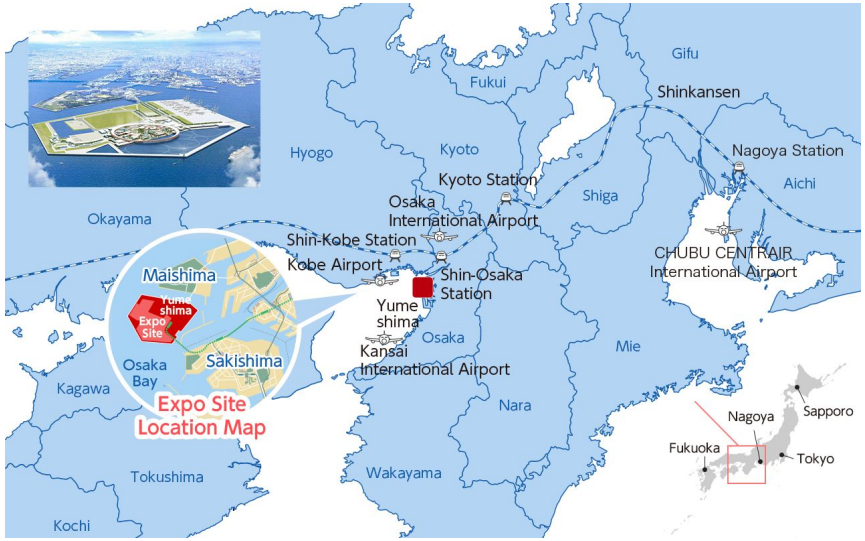

Schedule

184 days from April 13 to October 13, 2025