TANAKA

Electrolysis Technology and Iridium at TKK

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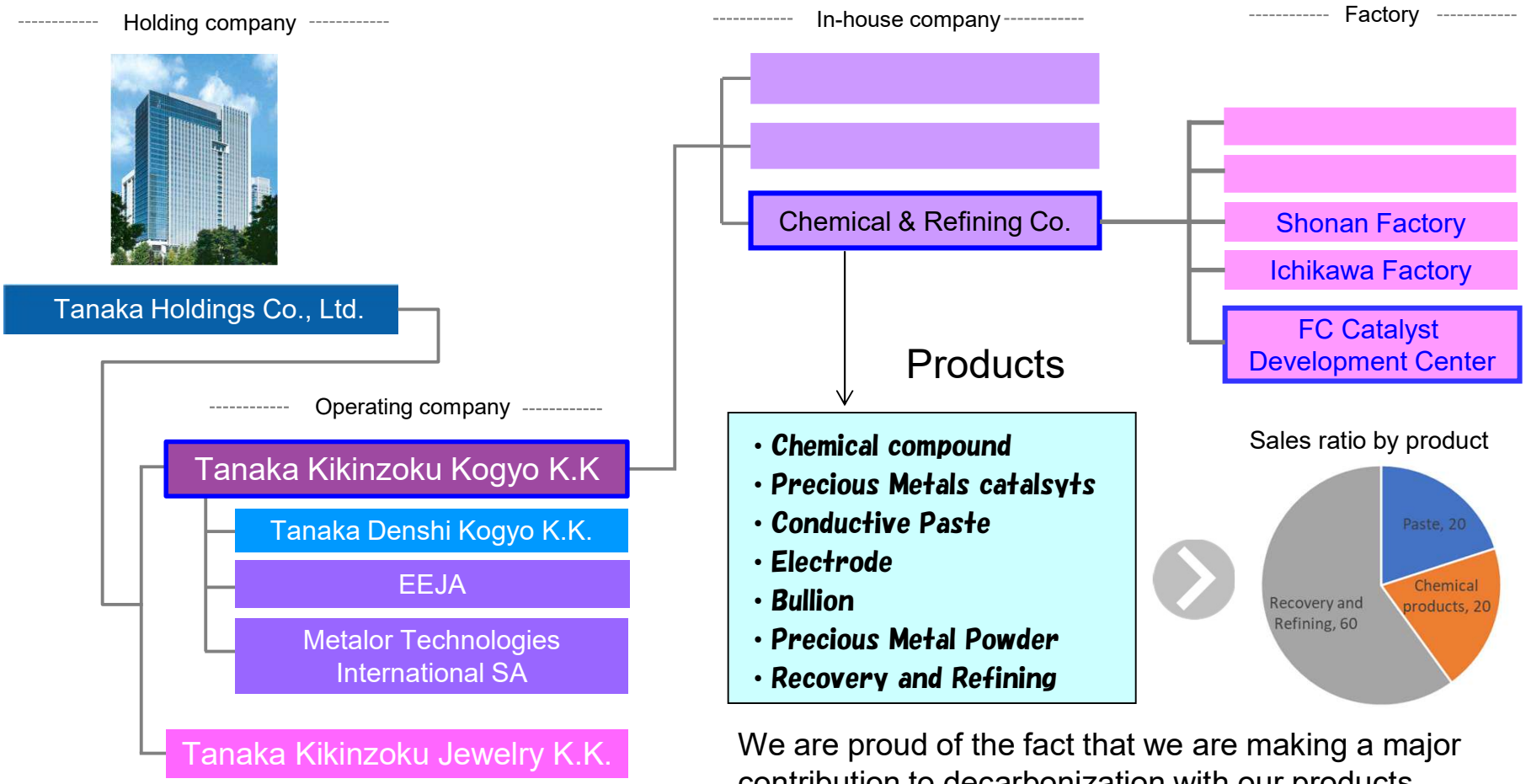
Koichi Matsutani
General manager of Fuel Cell Catalyst Development Center
Chemical ＆Refining Company
Tanaka Kikinzoku Kogyo K.K.
K-matsutani@ml.tanaka.co.jp

Regarding the TANAKA Precious Metals

The Japan arm of the TANAKA is made up of eight companies. Tanaka Holdings was established in April 2010 to enhance the administrative efficiency of the group. Tanaka Kikinzoku Kogyo provides comprehensive industrial precious metal solutions. With subsidiaries and factories all over the world, the TANAKA has a truly global presence.



We are proud of the fact that we are making a major contribution to decarbonization with our products.

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About Fuel Cell Catalyst Development Center

Belonging to Chemical & Refining company (internal company)
Develop and Produce Fuel Cell Electrocatalyst and Water electrolysis catalyst with recovered and refined precious metals.

1985

1985
Development team started in R&D division

1990

1992
Development target changed from PAFC to PEFC

1995
Stop stack development and concentrated on catalyst development

2010

2013
Transferred to production division.
Fuel Cell Catalyst Development Center operation started (1st production factory)

2018
Plant expansion
（3 additional bldgs.）

2020

2021
Merged water electrolysis catalyst team

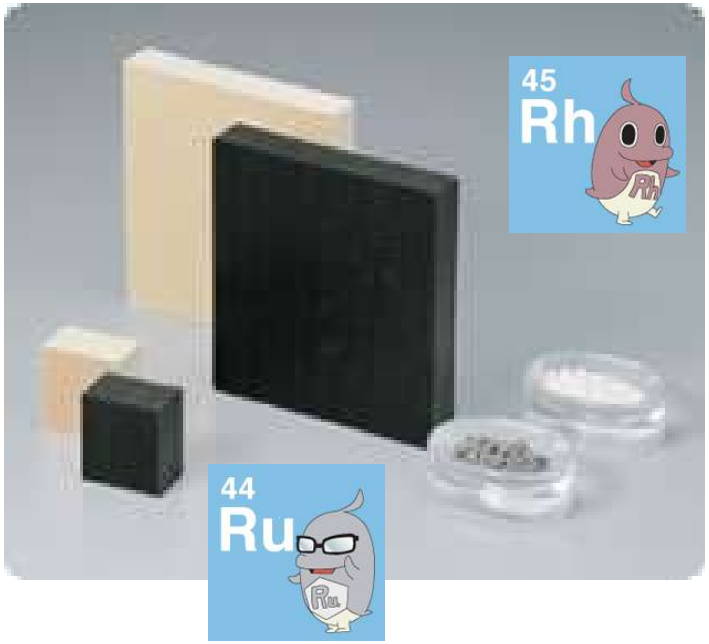
2024
Second Plant expansion
（Decided）

202X
Production outside Japan

Fuel cells/ Hydrogen related products in TKK 1

PROX/Reformate catalyst

(Pt-series, Ru-series)



IrOx for water electrolysis

(SA=7-50m2/g)

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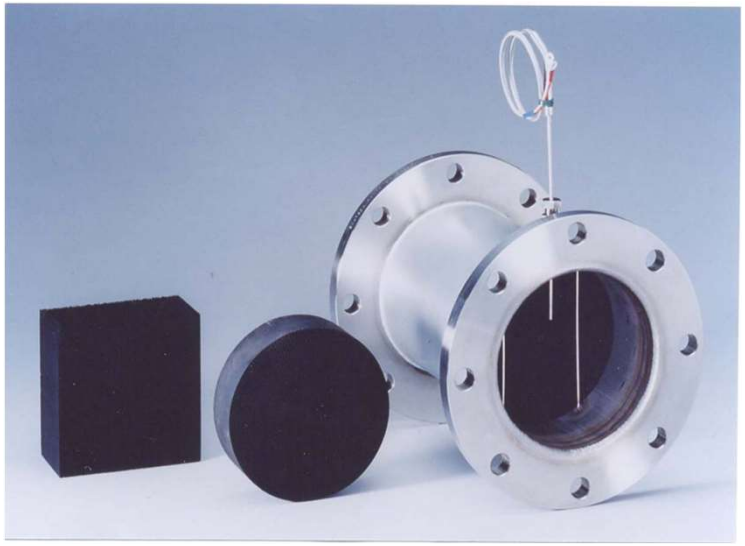
Fuel cells/ Hydrogen related products in TKK 2

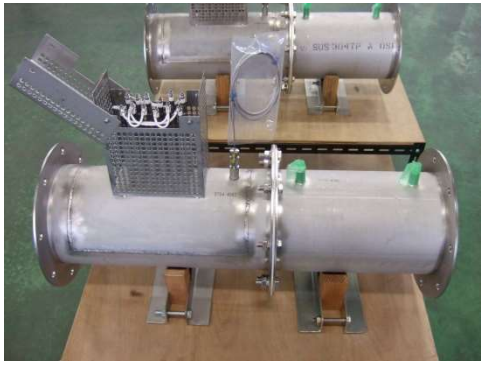
Hydrogen purification

Pd foil & tube (Pd,Pd-alloy)

Off-gas combustion

MH Combustion catalyst(Pd,Pt)





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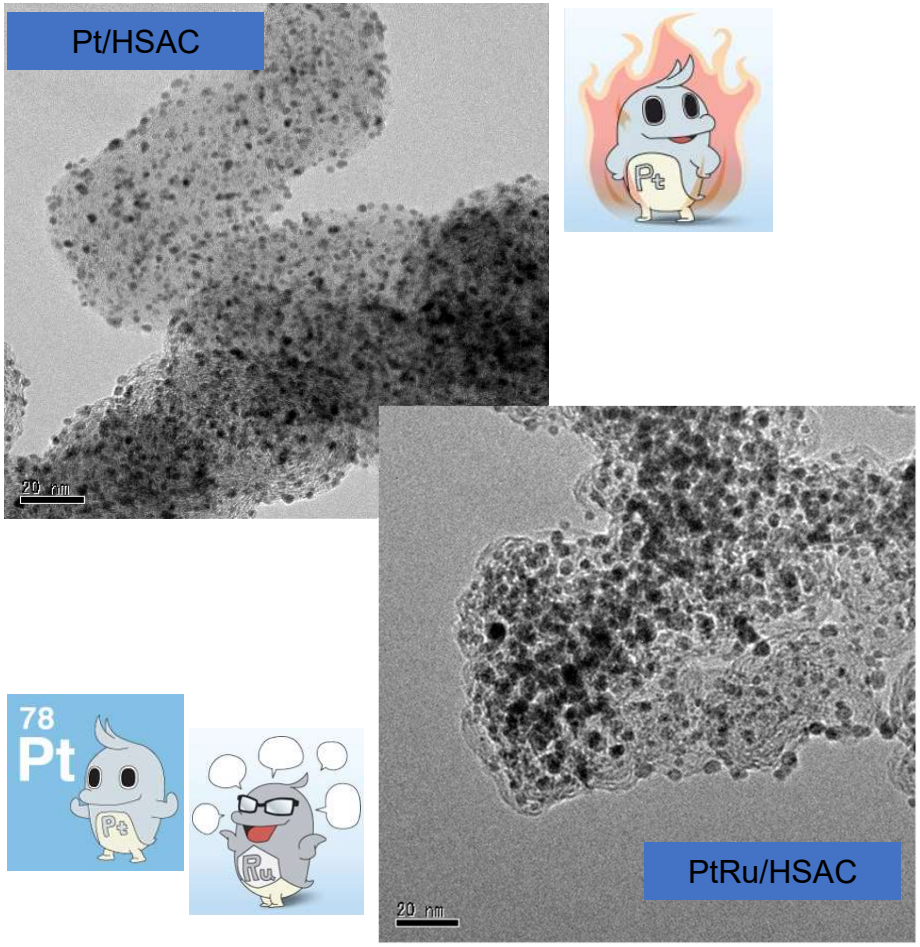
Fuel cells/ Hydrogen related products in TKK 3

Electrocatalyst for fuel cells

(Pt/C-seies, Pt-Ru/C-series.)



Precious metals recycling

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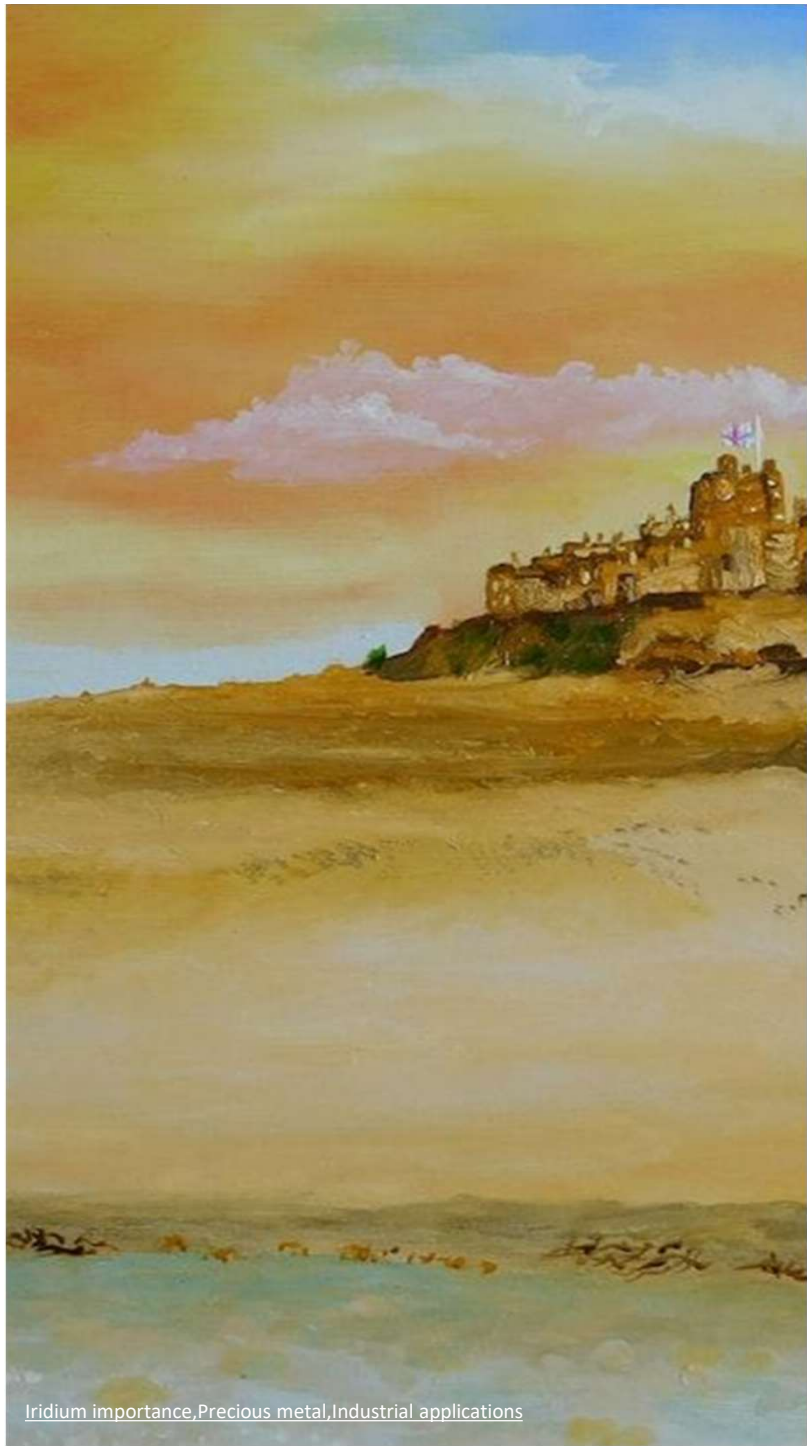
Importance of Iridium in Industry

Iridium plays a very important role in industry. Below are the main points of importance in the industry of Iridium.

1. Use as a catalyst: Used as a catalyst in petroleum refining, chemical synthesis, and organic synthesis reactions.
2. Water electrolysis: Iridium is a key element in water electrolysis, providing high efficiency and durability. Hydrogen is attracting attention as a clean energy source, and water electrolysis using iridium catalysts is essential for sustainable energy production.
3. Technology Fields: Iridium can withstand high temperatures and extreme environments and is used in highly technical fields such as aerospace, aircraft engines, medical equipment, communications technology, and semiconductor manufacturing. This enables the development of high-performance products and technologies.
4. Economic Value: Iridium is extremely rare and in limited supply, keeping its price relatively high. This has had a significant economic impact on the iridium industry, with implications for the iridium mining and supply industry as well.
5. Strategic Resource: Iridium's rarity and necessity in many industries make it a national strategic resource. The stability of iridium supply is an important element related to national security. Overall, Iridium plays a vital role in industry in many aspects, including chemistry, energy, technology, environment, economy, and national strategy. Its importance is expected to increase in the future.



Iridium importance,Precious metal,Industrial applications

Ir

Atomic number 77
Atomic weight 192.217

Melting	2446℃
Boiling point	4437℃
Density	22.42g/cm3(17℃)
Electrical resistivity	point 4.7×108Ω・m(0℃)
Coefficient of thermal expansion	6.4×10-6K^{-1}
Thermal conductivity	147W・m・K^{-1}(0℃)

The use of iridium is (Example)
1 Electronic material applications
(X-ray detector, semiconductor manufacturing)
2 Automotive premium spark plug
(Improve fuel efficiency)
3 Single crystal growth crucibles
4 Catalyst (Acetic acid, Hydrogenation)
5 Jewelry goods

Increasing applications
Iridium complex as a phosphorescent material for organic EL used in flat-screen TVs.
Catalyst for cupper current collectors for lithium ion batteries production.
Electrocatalyst for water electrolysis

Since this application uses iridium's very specific properties, it is not easy to find a substitute.

スライド 8

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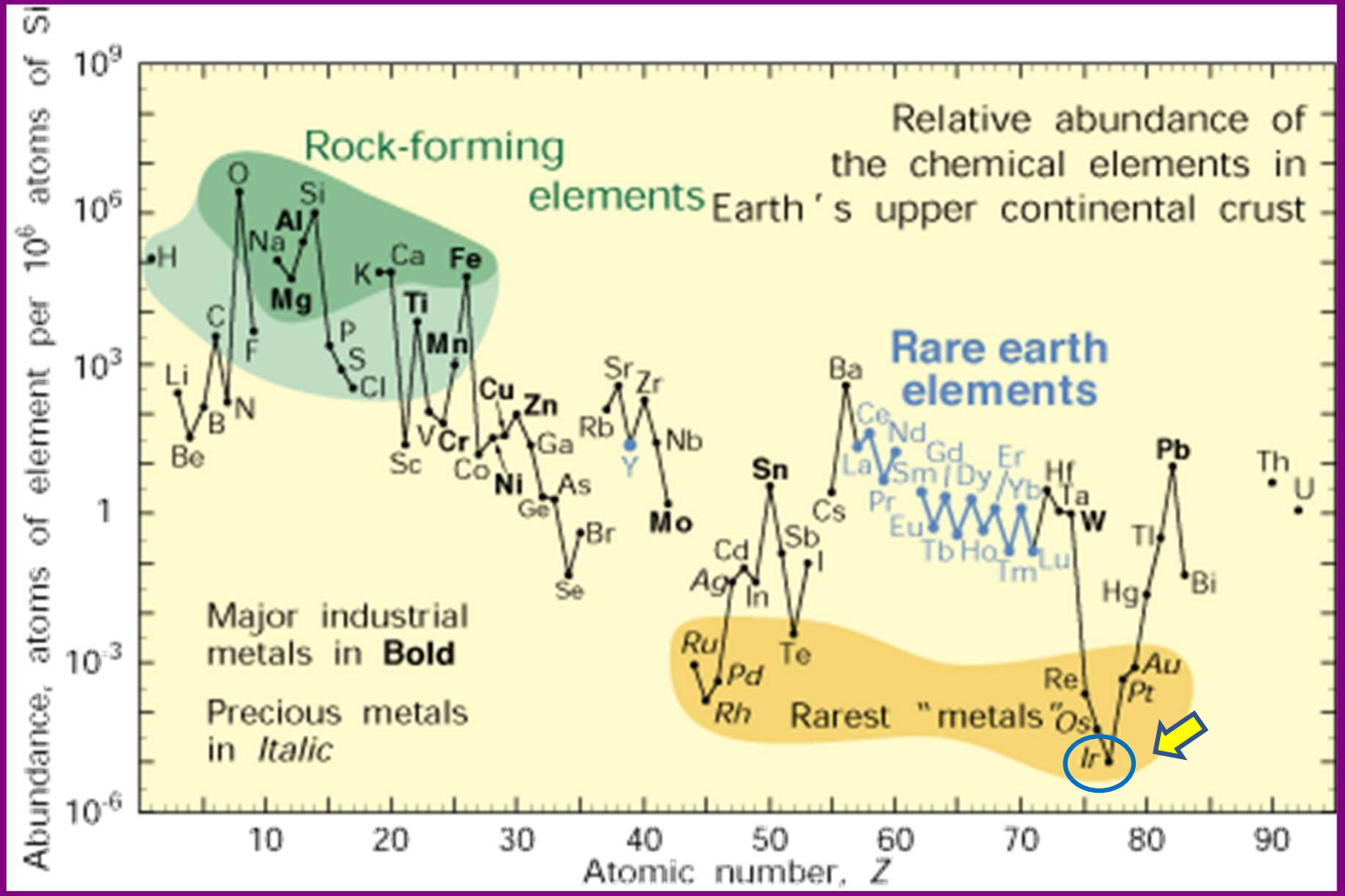
Abundance of elements

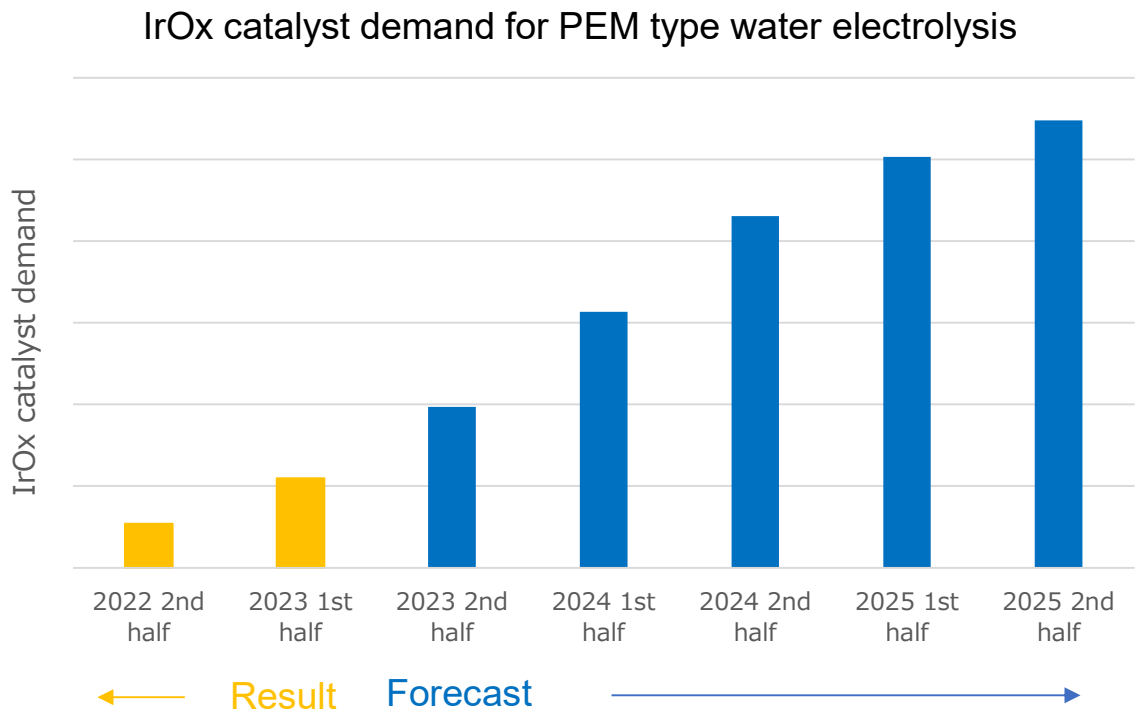


It is ironic that Iridium the least abundant metal in the earth's crust, exhibits the highest performance in water electrolysis

U.S. Geological Survey Fact Sheet 087-02
https://pubs.usgs.gov/fs/2002/fs087-02

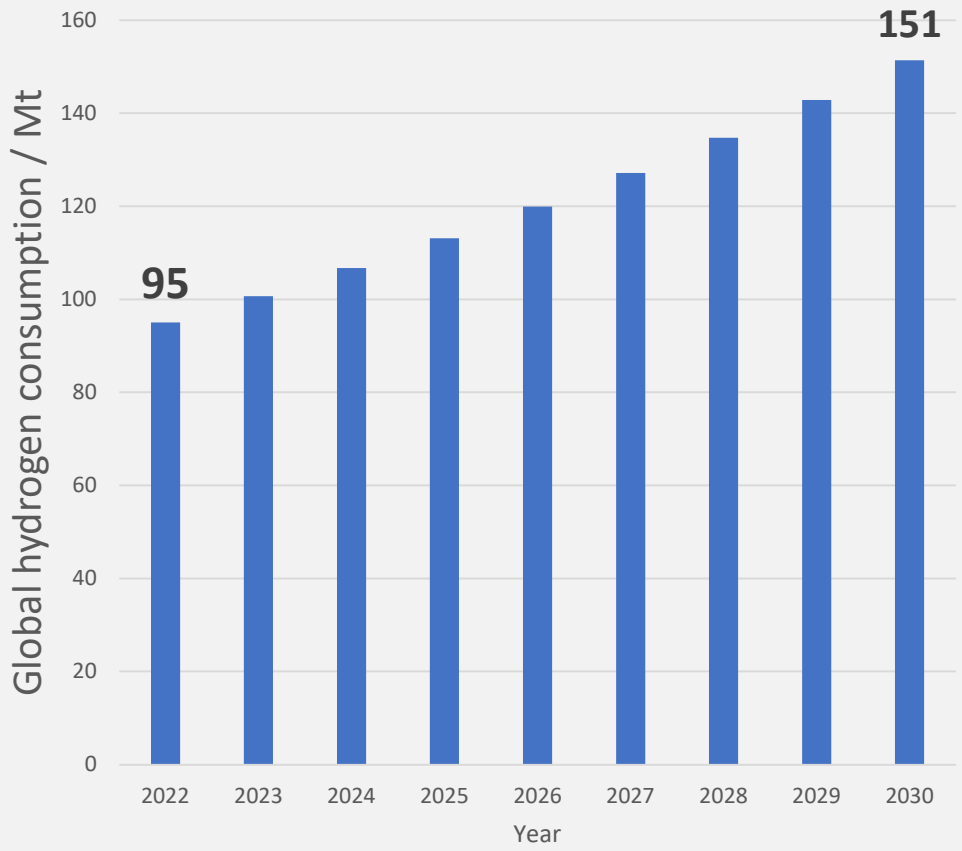
Increase of Ir demand

Iridium is being developed for new applications due to its characteristics not found in other elements. In recent years, its use as copper foil for lithium-ion battery current collectors and as an anode catalyst for PEM water electrolyzers has increased significantly. In particular, PEM water electrolysis equipment is expected to increase significantly in the future.



It's not a global demand. TKK customer demand.

Expansion of Hydrogen use



Global hydrogen consumption in 2022 was 95Mt.
It grows by 6% annually until the end of this decade.
In 2030, 150Mt of hydrogen will be used. And about 40% coming from new applications.

20-30% of hydrogen is expected to be generated with PEM water electrolysis.

100-300tons of Ir is needed.

IEA Global Hydrogen Review 2023

Iridium sustainability

- Supply Constraints: Iridium is a very rare element on Earth and is in limited supply. Therefore, it is important to develop sustainable mining methods and recycling technologies to meet increasing demand. It is necessary to ensure sustainable sources of supply.

- Recycling: Iridium is an expensive element, so it is economically and environmentally important to recover and recycle it from used products and catalysts. Developing recycling processes will help improve the sustainability of iridium.

- Research into alternative materials: Research into alternative materials is underway to address iridium's scarcity and high price. The development of sustainable alternative materials will help reduce dependence on iridium.

- Demand Suppression: A sudden increase in demand for iridium could lead to supply shortages. Efforts are needed to adjust demand to sustainable levels and curb waste.

One stop service of Tanaka Precious Metals

The TANAKA Precious Metals provides a “One Stop Service” for everything about precious metals, from bullion supply to process and manufacture, sales and recycling. Thanks to the supply routes, extensive technological capabilities, solid research systems, product development strengths, and a domestic and international network of facilities that we have built up since the company was established, we provide total support to our customers in solving their issues and making improvements.

PGM（Platinum Group Metal） recycling at TKK

We believe that it is a very important task for us to manufacture and sell carbon neutral products and to promote the recycling of precious metals.

【Market trend of PGM recycling】

- The enquiry of low precious metal content and high impurity content materials are at increase.
- Due to the rise of the precious metal price, the materials that were previously not considered for recycling is now materials to recycle.

Shifting toward a carbon neutral society, PGM has become an essential material. To procure and to reduce the cost of manufacturing carbon neutral products, there will be a high demand for PGM recycling.

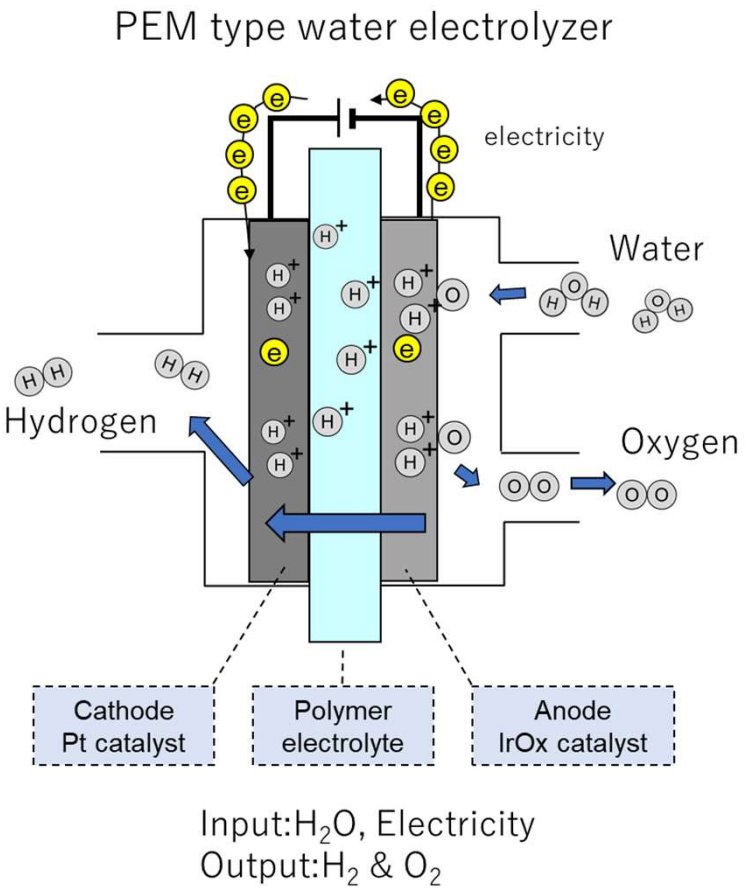
In order to meet the demand, we must improve our pretreatment and precious metal refining technologies.

- Improve the recovery rate of the precious metals.
- Shorten the processing lead time.
- Establish the process to treat materials containing harmful elements safely and with minimum environmental impact.

R E ™
100% RECYCLED
TANAKA PRECIOUS METALS

TKK will expand the recycling technology cultivated in Japan to the world. We plan to roll out a scheme in major regions that will recycle and remanufacture products near the point of use.

PEM type water electrolyzer



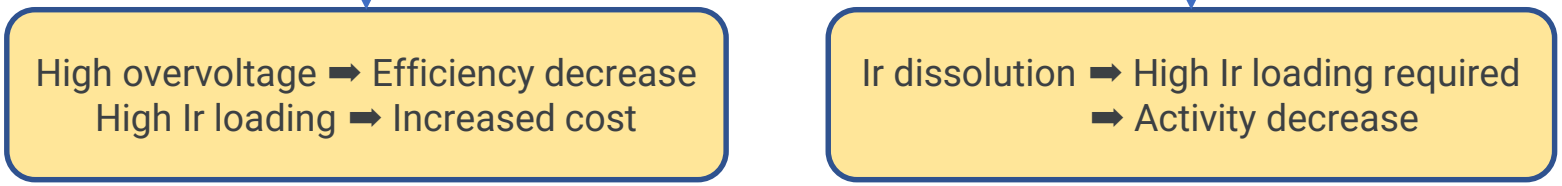
Benefit

- **High current density operation**
- **Fast response, easy starting and stopping**
- **Small size saves the footprint**
- **High purity hydrogen**

Not just a simple hydrogen generator, but also a role in improving grid stability by acting as a regulating force for sudden increases in the supply of power sources, including instability.

Basic issues with PEM water electrolysis catalyst

Issues : Improvement of catalyst activity and durability at anode



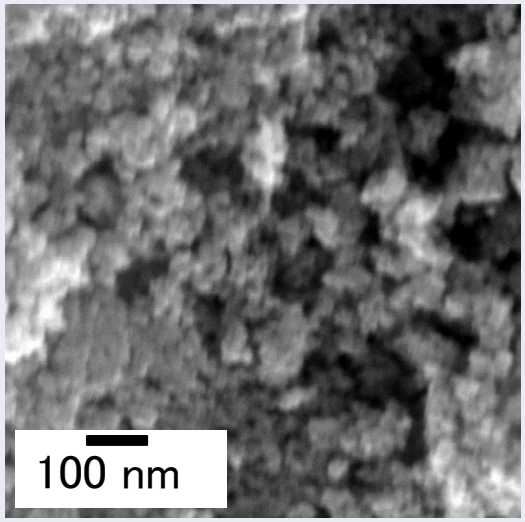
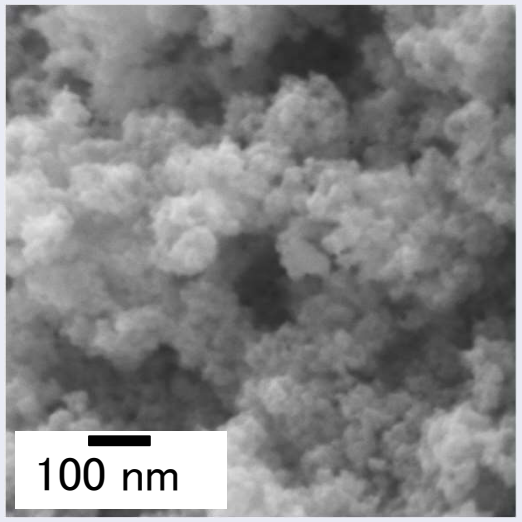
※Due to load variation

Basically, there is a contradictory relationship because the equipment is used to its limits (load fluctuation, high current density operation).

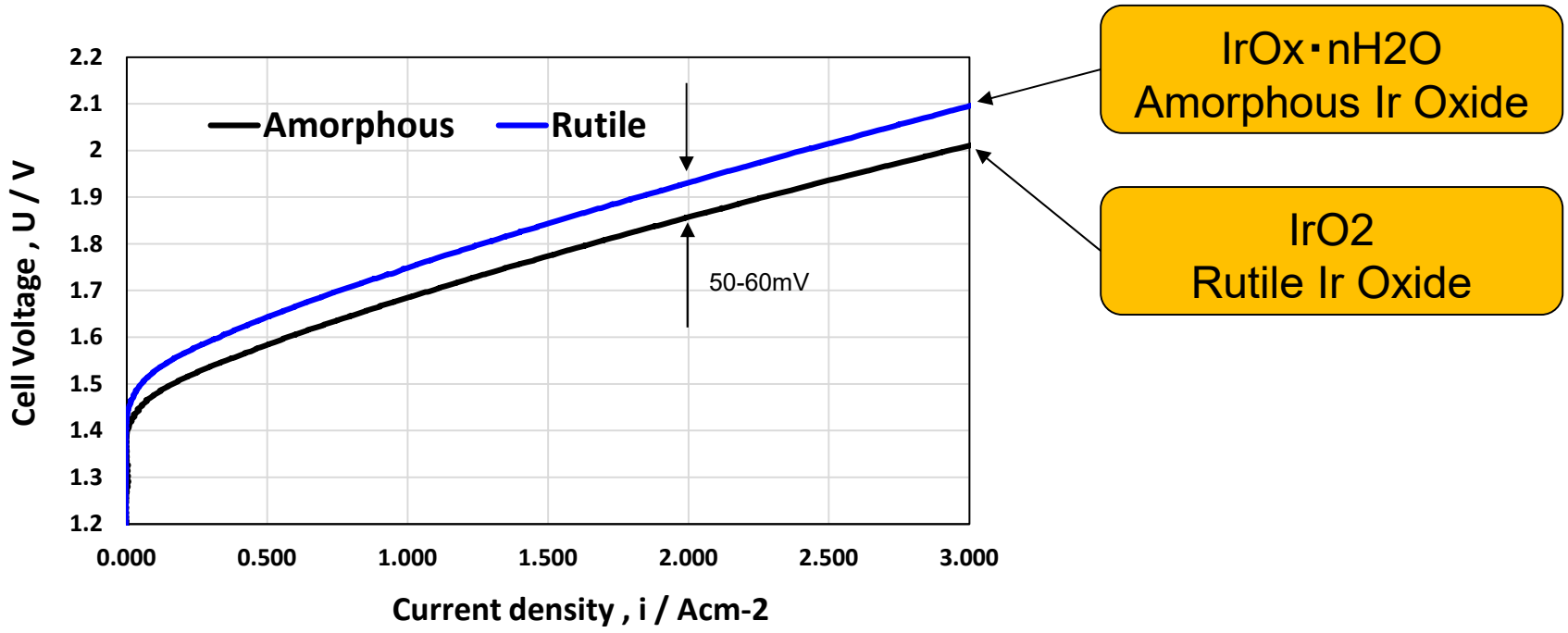
Since the supply amount of Ir is limited, high Ir usage will limit the number of devices in use.

Requirement：Decrease Ir loading ➡ Target：0.1mg/cm2（1/10）

IrOx catalysts for anode (TKK's 1st gen products)

	IrOx(SA=100)	IrO2(Rutile)
Formula, Structure	$IrOx \cdot nH_2O$ Amorphous	IrO_2 Rutile type
Metal Loading	Ir 76%	Ir 86%
Surface Area (N_2 BET)	90～120 m^2/g	45～60 m^2/g
SEM Image		

Initial IV Performance



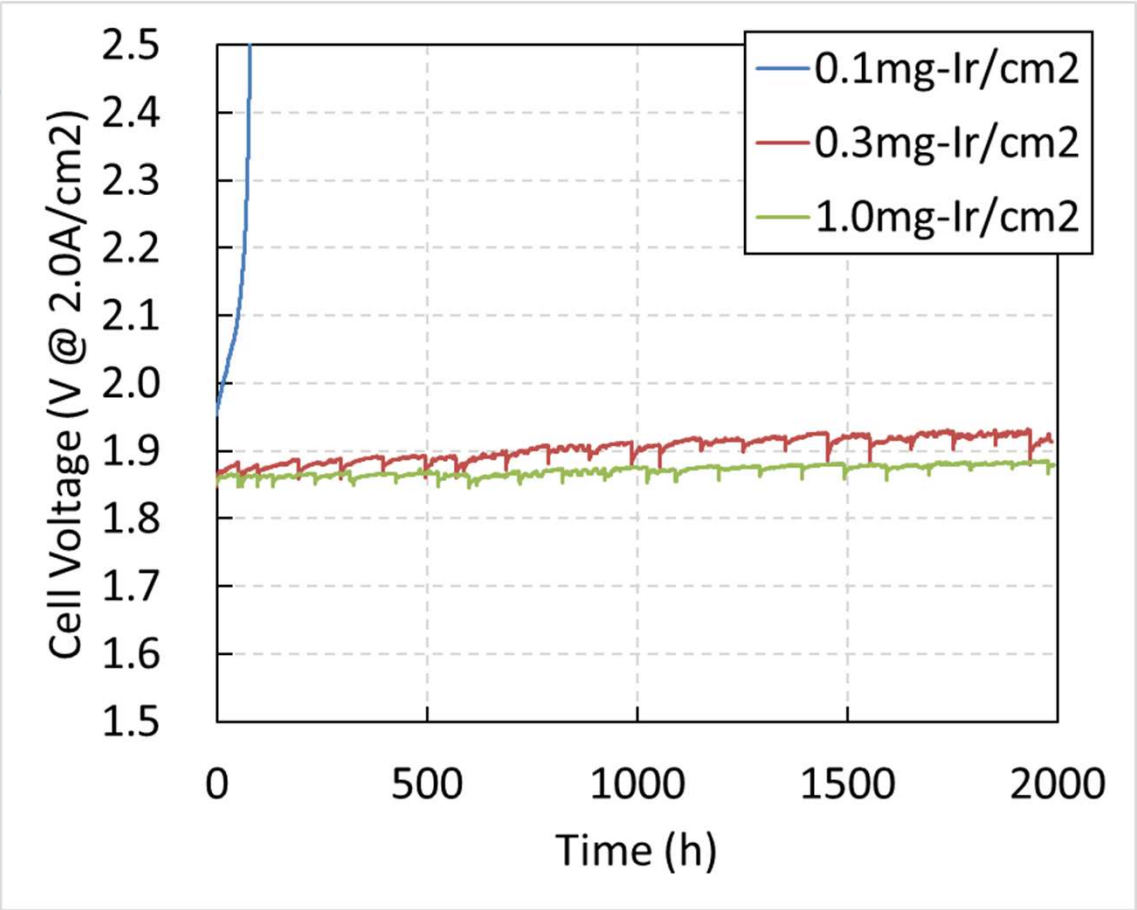
Single Cell tests
- Anode; Ir 1.0mg/cm2
- Cathode; Pt/C、Pt 1.0 mg/cm2
- PEM; Nafion N115

Durability Test

<CCM>
・Anode Catalyst: Amorphous type
・Cathode Catalyst: Pt/C
・PEM: N115

<Test condition>
・50 ℃
・2.0 A/cm2 (Constant Current)

Amorphous Ir oxide deteriorates quickly at 0.1 mg/cm2 even when operated at constant value (not very severe condition).



Single Cell tests
Anode; Ir 0.1-1.0mg/cm2
Cathode; Pt/C、Pt 1.0 mg/cm2
PEM; Nafion N115

When a lot of iridium is loaded, it is advantageous for durability.

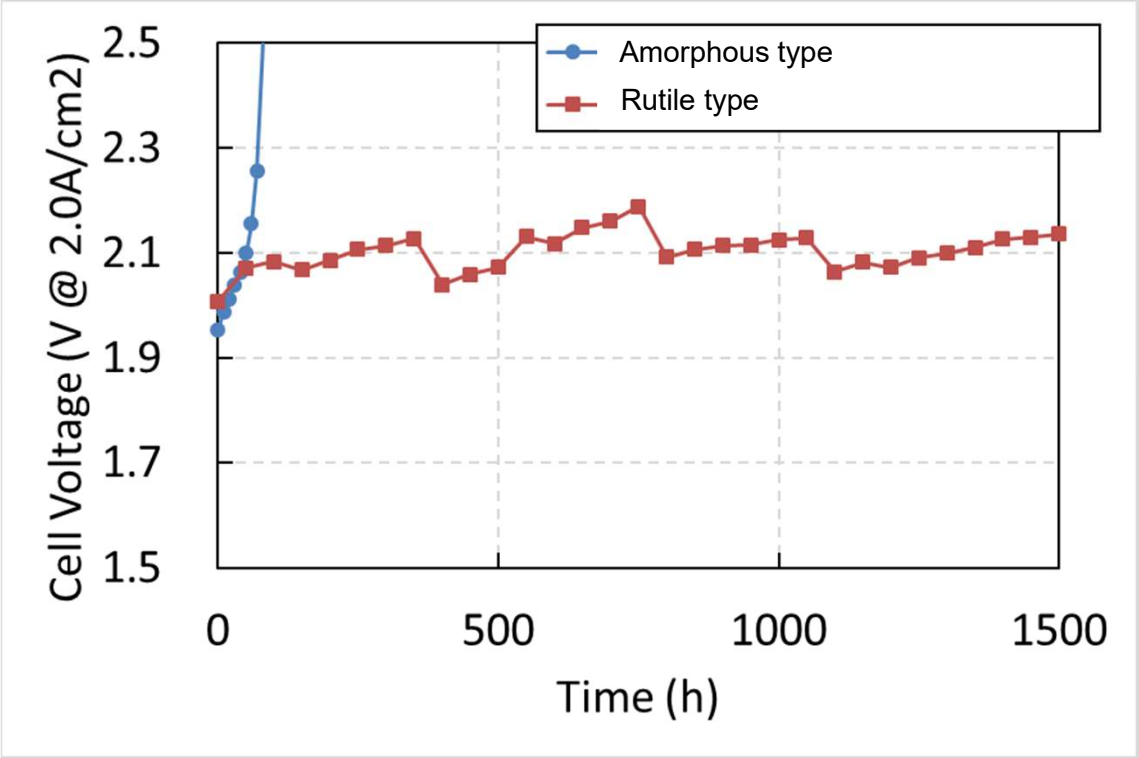
Improved Durability

Improved durability Catalyst; IrO2(Rutile)

By using rutile type Ir oxide, long-term operation is possible even at 0.1mg/cm2.

However, when high current density operation and load variation are added, even the rutile type will deteriorate quickly.

We need to know what happened and improve.



Single Cell tests
Anode; Ir 0.1mg/cm2
Cathode; Pt/C、Pt 1.0 mg/cm2
PEM; Nafion N115

Since the target durability time is long (>80,000hrs), the amount of Ir is controlled on the safe side. It is typically more than 1.0mg/cm2. We believe that it is necessary to avoid installing excessive Ir and to reduce Ir.

Next generation catalyst development

Issues：Improvement of catalyst activity and durability at anode

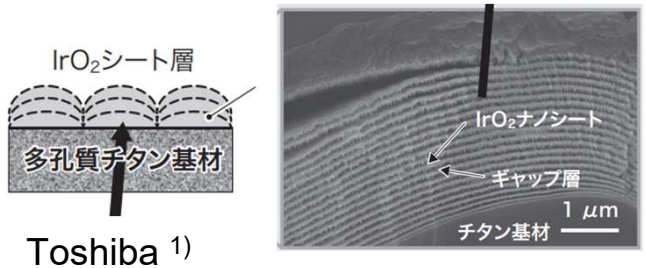
Concept: Increase Ir utilization

1/10 of Ir usage

preventing the formation of hot spots

Possible solution

Thin film coating



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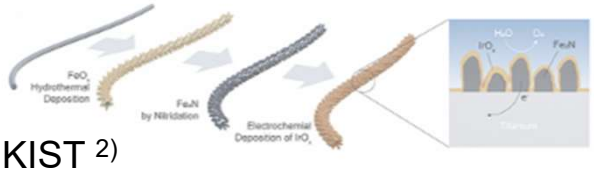

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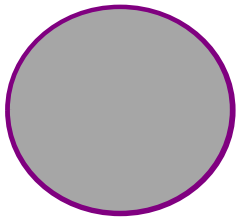
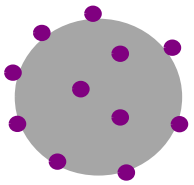
Application of support material





Uniform distribution

1) https://www.global.toshiba/jp/technology/corporate/rdc/rd/topics/22/2210-01.html

2) Hui-Yun Jeong et.al.High-performance water electrolyzer with minimum platinum group metal usage: Iron nitride-iridium oxide core-shell nanostructures for stable and efficient oxygen evolution reaction.Applied Catalystsis B:Environmental 330(2023), 122596,

TKK will continue to contribute to the precious metals business by recycling precious metals and proposing the best products for our customers.

Thank you for your attention!