Heat Resistant Composite Materials
Carbon/Carbon Composite, CMC Composite

- C/C（Carbon/Carbon）：CF＋Carbon
- CMC（Ceramic Matrix Composite）：CF＋SiC
- Phenolic CFRP , SMC：CF＋phenolic resin

【Characters】

- Light weight：1/3-1/5 density of steel (7.9g/cm^3)
- High stiffness：Higher than Steel・Thin design possible by High strength
- High heat resistance：（C/C, C/SiC：800℃≦、phenolic CFRP：300℃≦）。
- High flame retardance：phenolic CFRP（shot CF）EN45545-2　R1/R6 HL3 passed

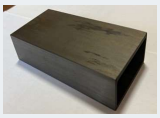
【Product example】

C/C brake（short CF）


C/SiC brake（development）

C/C, C/SiC hand（long CF ／development）


Phenolic CFRP hand & Molding（long CF・short CF／development）

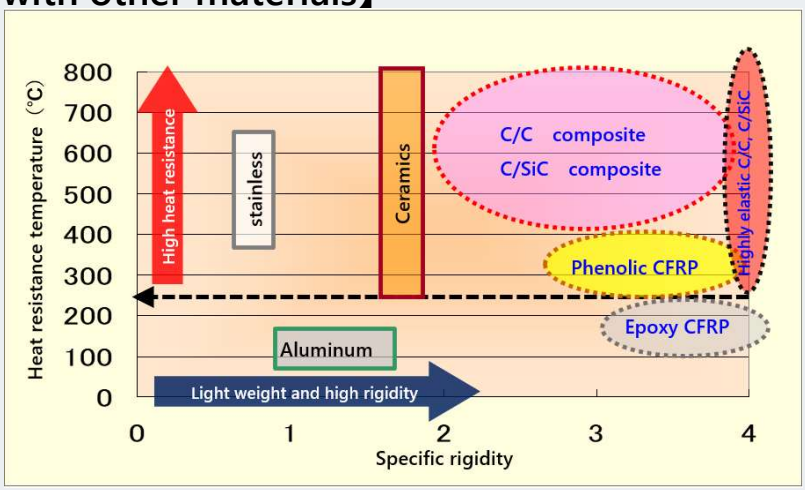




【Typical properties】

Materials	Direction	Bulk density g/cm^3	Bending strength (⊥) MPa	Bending modulus (⊥) GPa	Tensile strength (⊥) MPa	Compressive strength (⊥) MPa
C/C	Isotropic	1.9	180	70	110	170
	Unidirectional	1.7	440	290	300	300
C/SiC	Isotropic	2.4	150	100	100	500
	Unidirectional	2.1	410	310	300	450
Phenolic CFRP	Isotropic	1.6	100	20	50	170
	Unidirectional	1.7	630	390	1,710	300

The listed values are typical and can vary depending on the laminated structure　and the amounts of substances contained.

【Comparison with other materials】



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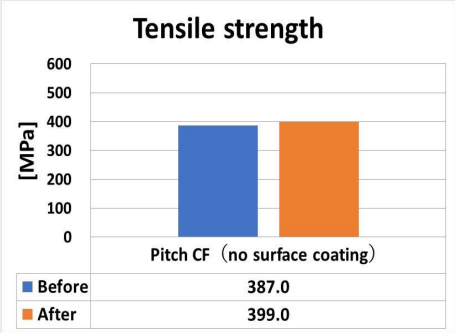
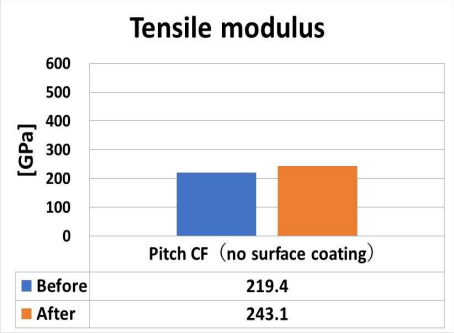
Mitsubishi Chemical Corporation

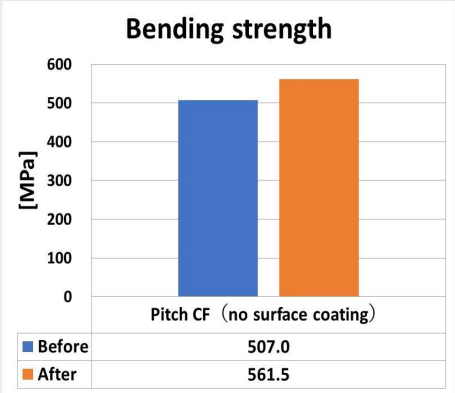
1500℃ Heat Resistant CMC (Pitch-based C/SiC Composite)

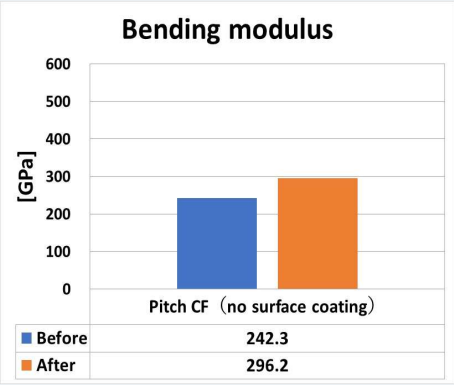
Application: Heat-resistant material for spacecraft heat shield tiles

Before vs after at 1,500℃×1 hour（in Air）

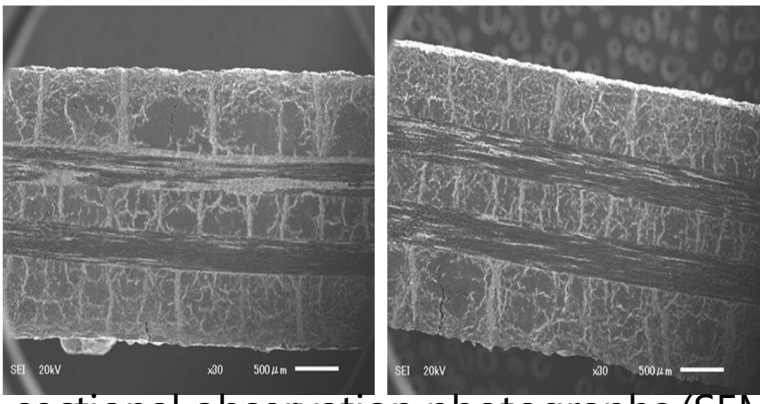








- No degradation of strength and modulus before and after heat treatment in air at 1,500°C for 1 hour,375MPa after exposure to 1500°C for 1 hour
- JAXA innovative future space transportation system target: 1600°C-800 seconds resistance



- The cross-sectional observation photographs (SEM images) before and after heat treatment are shown below (left: before, right: after). No major changes in appearance (deterioration) were observed.
- **Plan to perform ～ 2000℃ heating test in future**

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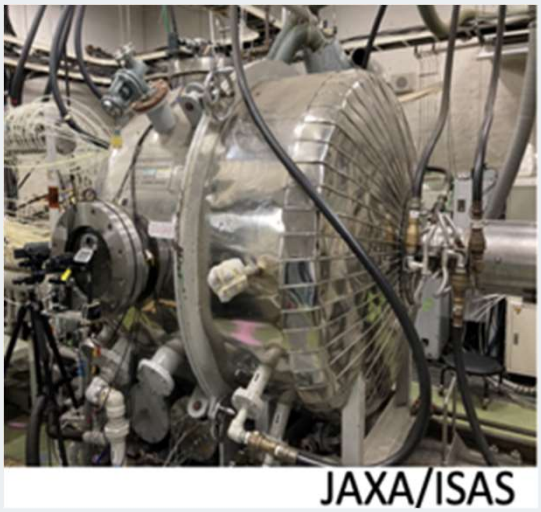
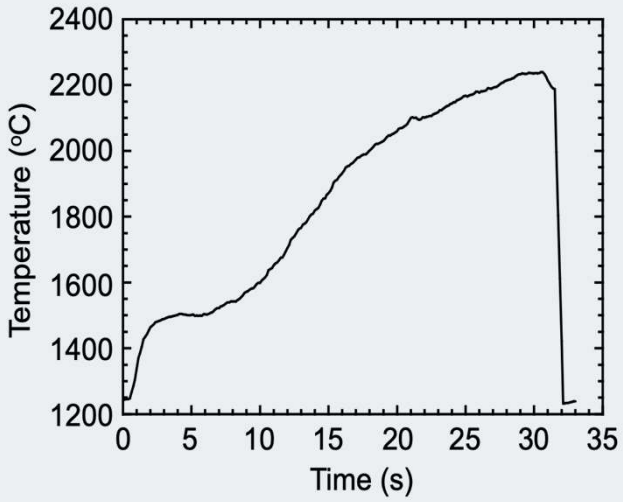
2200℃ Heat Resistant Pitch-based C/C Composite

Application: Heat-resistant material for rocket nozzles and satellite attitude control thruster nozzles

JAXA arc heating wind tunnel test facility



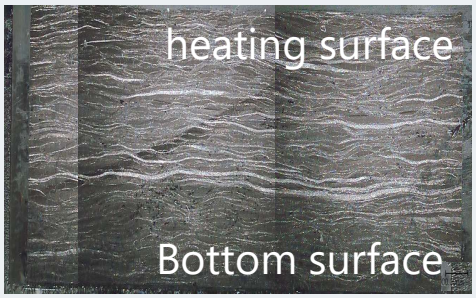
Heating condition
Heating rate: 4.83 MW/m2
Dynamic pressure: 13~14 kPa



Surface after heating test

Thickness reduction rate: 10%

Cross section after heating test



Surface during heating at 2200℃

- Joint development of CMC heat-resistant materials is underway with Tokyo University of Science.
- As a result of arc heating wind tunnel testing of the base material, the amount of wear was approximately 10% (0.8mm) for pitch-based C/C composite with a thickness of 8mm, .Plans for impregnating with alloys such as Zr-Ti to improve the heat resistance performance.

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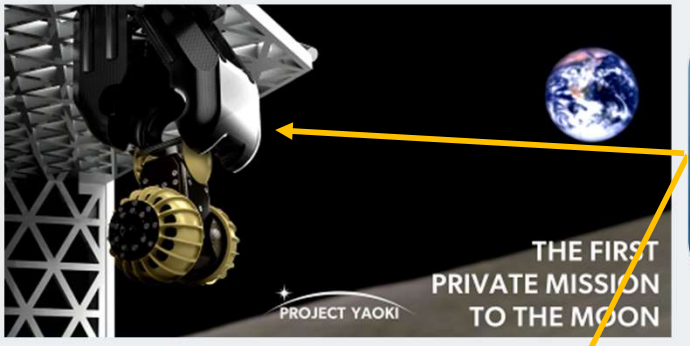
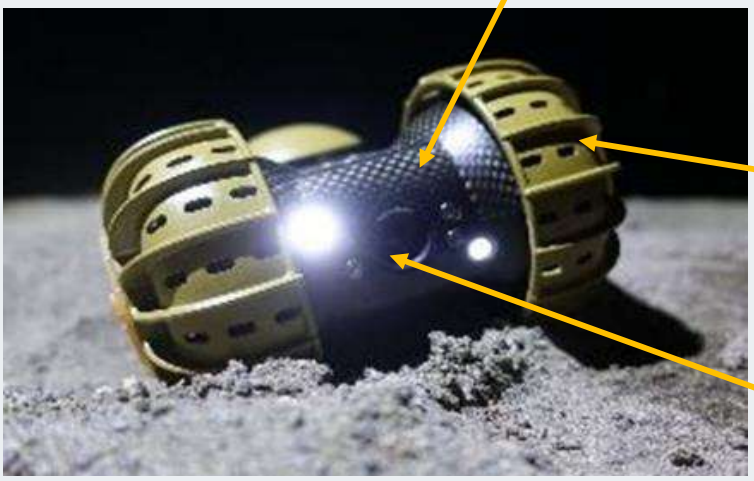
Moon robot YAOKI and cyanate resin PP



「YAOKI" body, deployer (case)Cyanate ester resin CFRP(Carbon fiber reinforced plastic) applied

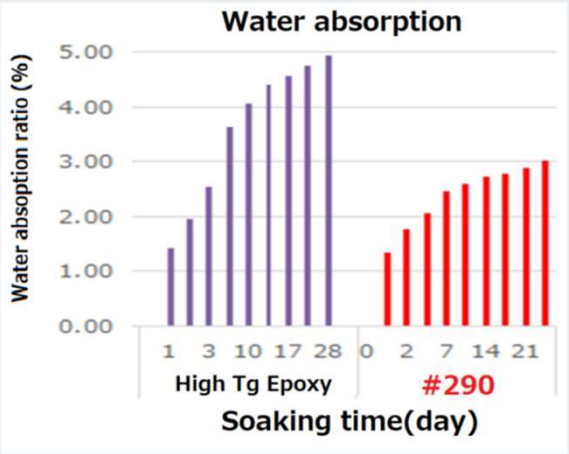


"YAOKI" tires
PAI material (super engineering plastic/polyamideimide) applied

"YAOKI" lens
Suppression of regolith adhesion
Apply coating agent

【Characteristic of Cyanate ester resin "#290"】

Resin type	Tg	toughness	Moldability	Life
#290 Cyanate ester	270℃	◎	◎	◎
High Tg epoxy	180 ~ 220℃	○	○	○
BMI	300℃	×	×	○



Composite Mechanical properties of Cyanate ester resin "#290"

Type	Carbon Fiber	0° Ts [MPa]	0° Tm [GPa]	0° Cs [MPa]	0° Cm [GPa]	ILSS [MPa]	G'-Tg [℃]
UD	TR50S	2920	140	1690	126	107	271
UD	K13916	1560	430	400	340	63	257
Woven	TR3110	719	57	625	52	69	272

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Compliant Mechanism Design

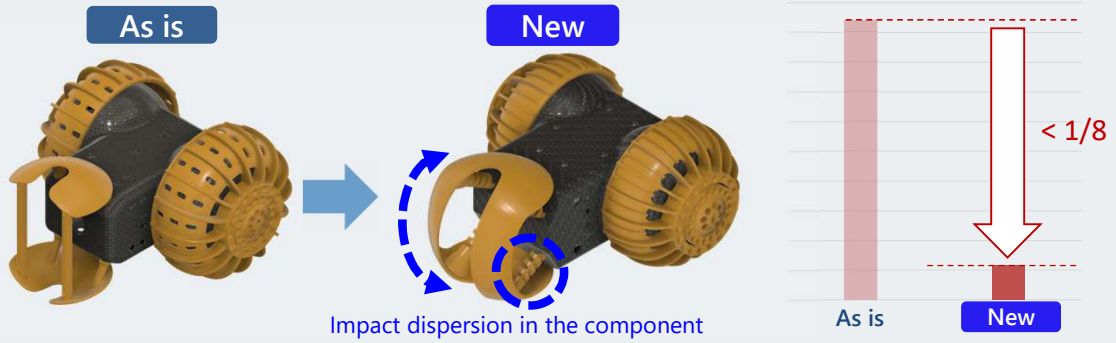
Mitsubishi Chemical is helping to create new products by incorporating design technology into our strengths in materials and molding expertise.

A compliant mechanism is a design concept in which movement is achieved through the suppleness of materials. By replacing conventionally assembled and fabricated products with supple one-piece plastic products, various advantages such as improved performance and weight reduction can be created.

Example for space application

Improvement of "YAOKI" slider

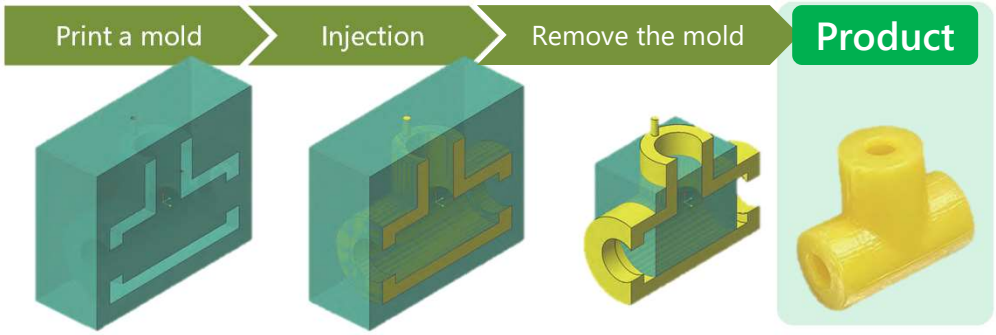
Usually, to improve impact resistance, designs that increase wall thickness to make them sturdier or that use high-strength metals are used. However, in space applications, where strict weight reduction is required in terms of transportation costs, supple design techniques using resins may be effective.



In an example of application to a small lunar rover under development, we succeeded in reducing the maximum stress applied to a component to less than 1/8 of its original value at the time of impact, while minimizing the weight increase.

Free-form Injection Molding

Free-form injection molding is a new injection molding technic using a special 3D printer. Complex shapes that cannot be removed from a mold can be produced from a single piece with the same strength as injection molding.



FIM Example

YAOKI slider

Our group company* possesses this technology, which enables us to develop products from compliant mechanism design to modeling in a single integrated process.

* MCC Advanced Moldings Co., Ltd.

MCC ADVANCED MOLDINGS

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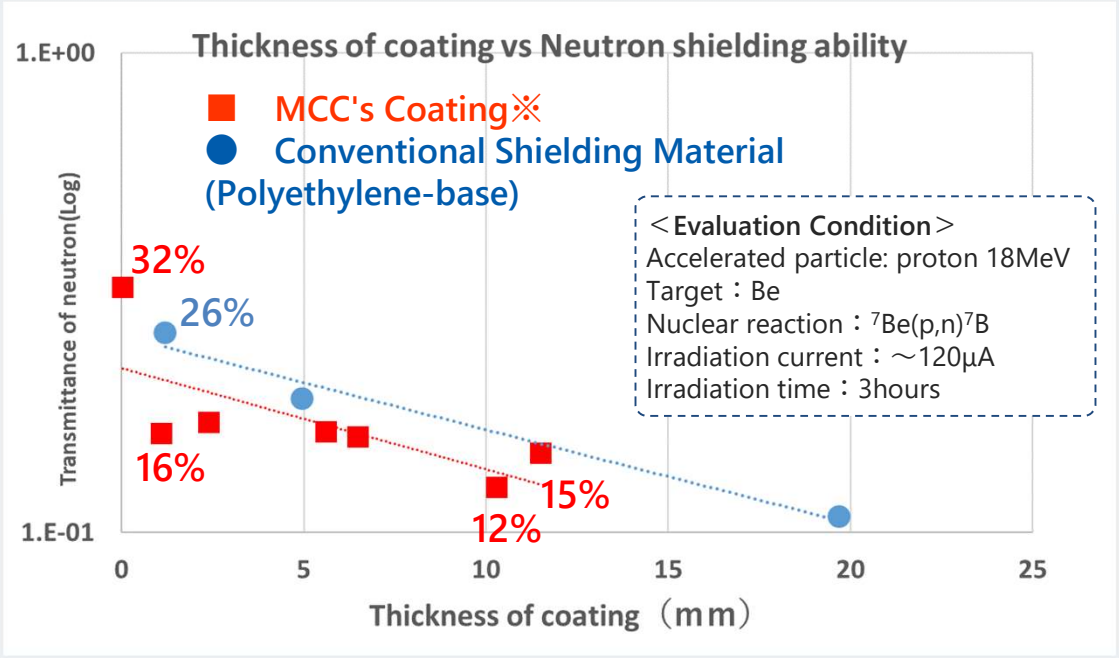
Neutron Shielding Coating
（Development Product）

【Characters】

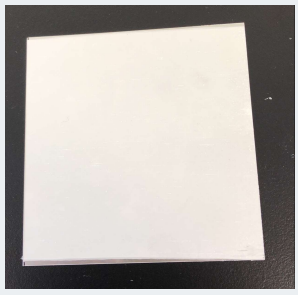
- Combination of inorganic filler and polymer designed by MCC leads to neutron shilding character and good dispersion of the coating.
- 1mm (thickness) coating can shiled almost all thermal neutron in the evaluation.
- 40μm coating can 80% of thermal neutron.
- The coating have higher shielding ability than conventional polyethylene-based materials.
- The coating shows good adhesion to aluminum substrate.

50μm coating sample on PET film
Flexible and no crack



※Water-based coating including inorganic filler and polymer designed by MCC

The coating can keep the dispersion after leaving for 24 hours.



The coating shows good adhesion to aluminum substrate.
(50μm coating samle)

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Kyron™ULTRA (UD CF-Thermoplastic Composite Prepreg -Development Product-)

What is Kyron™ULTRA ?

Thermoplastic resin matrix unidirectional carbon fiber composite prepreg with high mechanical properties, low outgassing, heat resistance and flame retardancy.

【Application Example for Space Equipment】

Kyron™ULTRA

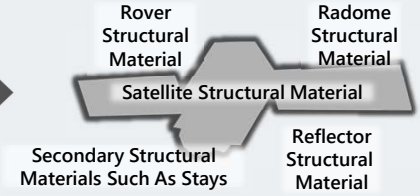
High-quality prepreg that takes advantage of the reinforcing effect of unidirectional carbon fiber and the features of thermoplastic resin.

Molding Proccess

Applying the most suitable molding method depending on part shape, dimensions, and quantity.

Application Example

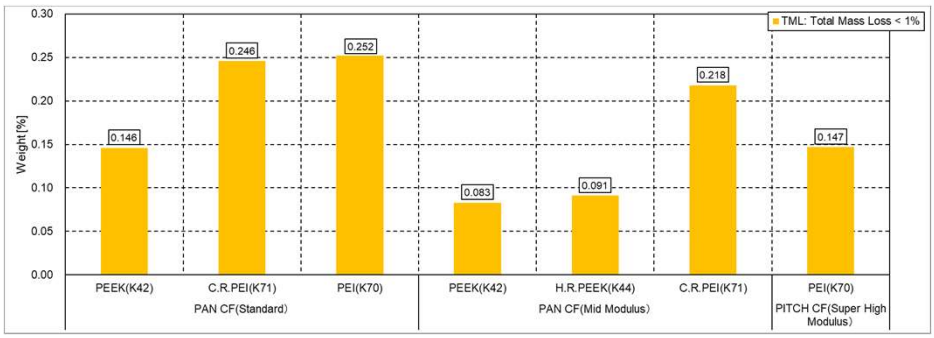
Providing high-performance, lightweight solutions to the space equipment industry.



【Prepreg Lineup】

Matrix Resin(Code)	PEI(K70)/Chemical Resistant PEI(K71)/PEEK(K42)/Heat Resistant PEEK(K44)
Fiber	PAN CF(Regular/Mid Modulus) / PITCH CF(Super High Modulus)

【Property Example: Outgass Measurment Data ASTM E595】



TML/CVCM/WVR were measured. All materials showed exllent outgass properties.

【Kyron™ULTRA Composite Lineup】

We also have a lineup of molded parts such as flat plates and brackets. L-shaped brackets that take advantage of the strengths of CFRTP, which has high strength and excellent mass productivity, have a thickness of 1.5/2.2 mm and a length of 350/500 mm as standard specifications.

L-shaped Brakets Made of Kyron™ULTRA

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PYROFIL™ GDL (Gas Diffusion Layer for PEFC)

What is GDL (Gas Diffusion Layer) ?

Pyrofil™ GDL is a multi-functional electrode material that has been optimized for Polymer Electrolyte Fuel Cell (PEFC) and Redox Flow Battery (RFB).

【Function and Advantage】

- Supplies hydrogen and air to the electrode
- Collects electrons produced by the electrode chemical
- reaction, and drains moisture and water on the electrolyte
- membrane generated by the process
- Superior surface smoothness
- Distinctive porous structure allows for improved water management
- Easily adapted to roll-to-roll process

【Packaging specification】

Product width ：300 mm
Roll length ：300 M
Inside diameter of core ：6 inch (152 mm)

【Product Line-up】

	Unit	MFK	MFX	MFL	MFK-A	MFX-A	MFL-A
Surface Treatment	-	Non	Non	Non	MPL	MPL	MPL
Thickness	[mm]	0.205	0.170	0.125	0.220	0.190	0.150
Area Weight	[g/m^2]	63	57	39	79	73	55
Bulk Density	[g/cm^3]	0.31	0.36	0.31	0.36	0.38	0.39
Gas Permeability	[mL/cm^2/hr/Pa]	200	950	700	10 *	40 *	30 *
Electrial Conductivity	[mΩ·cm^2]	5.7	5.7	4.5	7.6	7.0	6.5
Compression Thickness	[mm]	0.18	0.14	0.11	0.2	0.16	0.12
Compression Ratio	[%]	88	82	80	91	84	79
MD Bending Strength	[MPa]	39	33	34	35	31	31
TD Bending Strength	[MPa]	27	43	19	25	41	17
Porosity Rate	[%]	83	80	83	80	79	78

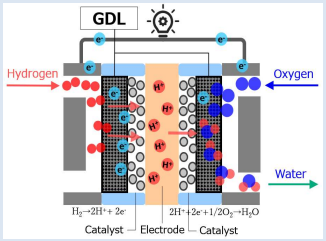
*Above values represent typical properties, not guaranteed values.
*The gas permeability of MPL products are just for the reference.

【Market and Application】

「Hydrogen」

Water Electrolyzer
Fuel Cell

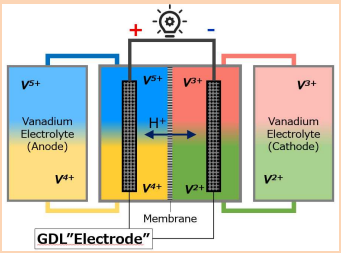
Ref：Mechanism of PEFC



「Storage Battery」

Redox Flow Battery
Other secondary batteries

Ref：Mechanism of RFB



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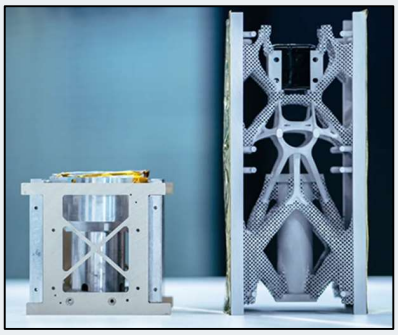
Utilization of plastics in artificial satellites

[MCC initiatives]

Mitsubishi Chemical Corporation is collaborating with Miyashita Laboratory, Department of Modern Mechanical Engineering, School of Creative Science and Engineering, Waseda University to utilize plastics in artificial satellites.

This is also part of a project by the Polymers & Compounds / MMA business group to create new business.



" WASEDA-SAT-ZERO " image

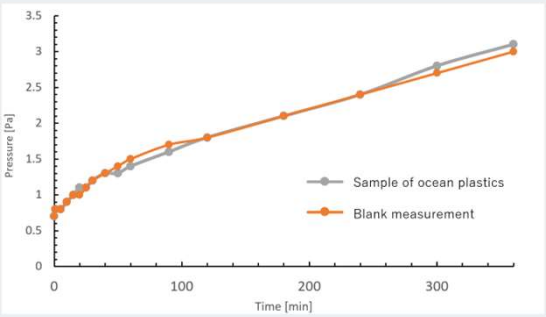
[Miyashita Laboratory]

The CubeSat `` WASEDA-SAT-ZERO '', which utilizes metal 3D printer lamination technology and has ``zero screws in the main structure'', was installed on Epsilon Launch Vehicle No. 6 . We are proceeding with research and development for the next launch. Our company will continue to collaborate on technologies for utilizing recycled plastics in space.

[Utilization idea]

1) Recycle ocean plastics found from space into satellite

We aim to improve the efficiency of collection by monitoring ocean plastics by analyzing satellite images, and we are also proposing that recycled plastics be installed on satellites as one way to utilize it. (Analysis partner: Tenchijin Co., Ltd.)



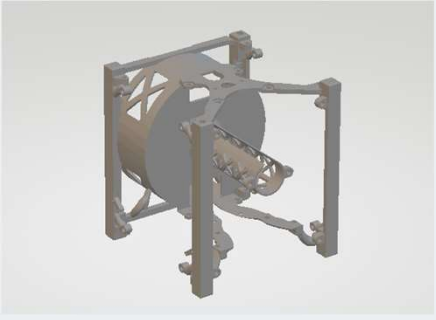
Ocean plastics through vacuum testing
Sample outgas reference data

At Waseda University, we are evaluating the various performances of recovered ocean plastics instrumentation parts in an environment that simulates outer space.

2) **Plastics replacement for metal parts such as satellite casings**

By molding the satellite housing using 3DP, it is expected to be lighter and reduce the number of screw fixing points.

It is expected that the In addition to using plastics for the housing, we will also propose the possibility of applying our products and developed products to satellite components.



3 DP output housing model

Through our expansion into the space field, we will continue to supply products to the world and contribute to the realization of a sustainable society.

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