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/cm³）**

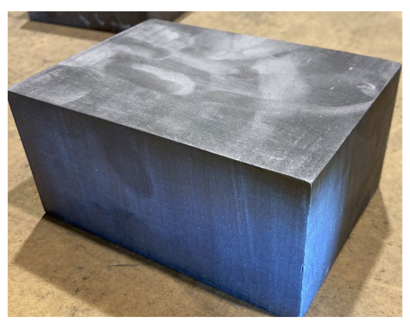
・**High stiffness**：Higher than Steel, **Thin design possible** by High strength

・**High heat resistance**：**C/C, C/SiC：800℃≦、phenolic CFRP：300℃≦**

・**High flame retardance**：phenolic CFRP（shot CF） **EN45545-2　R1/R6 HL3 passed**

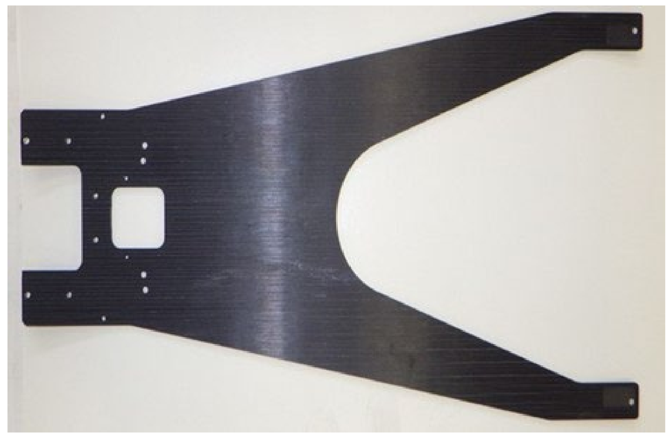
【Product example】

C/C brake ＆ Molding（short CF）

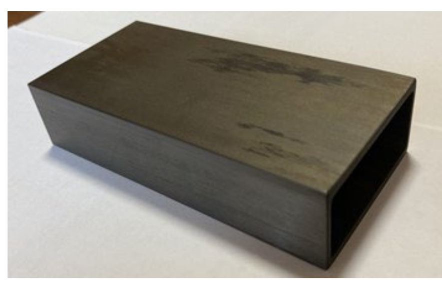


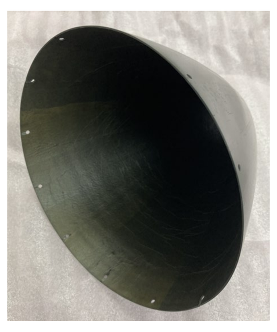
C/SiC brake（development）

C/C, C/SiC hand（long CF／development）



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



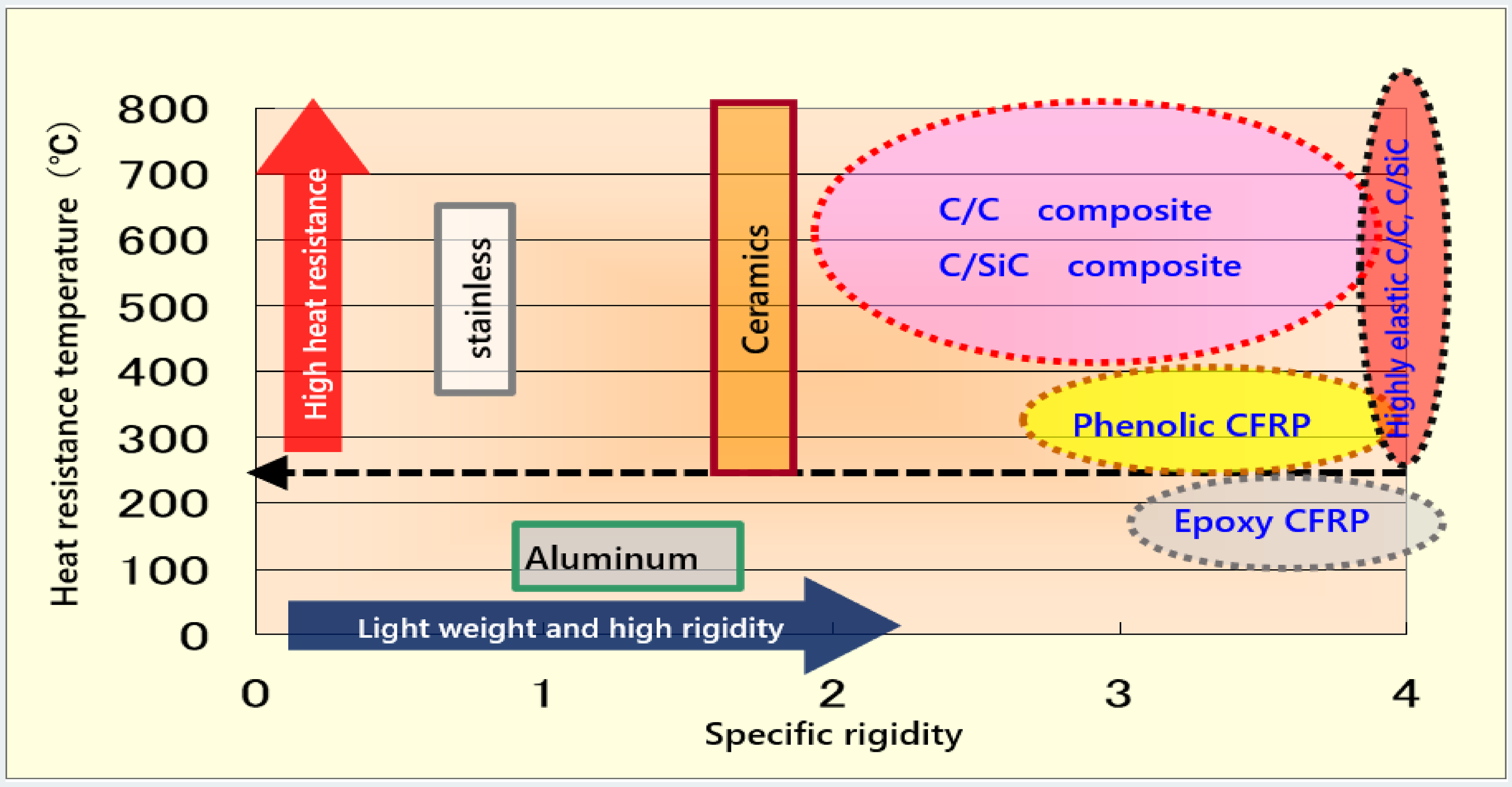


【Typical properties】

Materials	Direction	Bulk density g/cm³	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】



MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

High Thermal Conductivity C/C Composite

Application：Fusion rocket engine, Divertor of Fusion reactor

Thermal Conductivity

C/C Type		High Thermal Conductivity				Standard	Low
Carbon Fiber		Uni Direction		Felt		Felt	Felt
Product Name		MFC-1	MFC-1N (Development)	MCI-felt type2H	MFC-2 (Development)		
Bulk density［g/cm^3］		＞1.9	＞1.9	＞1.9	＞1.9	＞1.9	＞0.2
Thermal Conductivity［W/mK］	CF direction	550	520	340	370	70	10
	Transverse direction	40	30	60	60	12	0.7

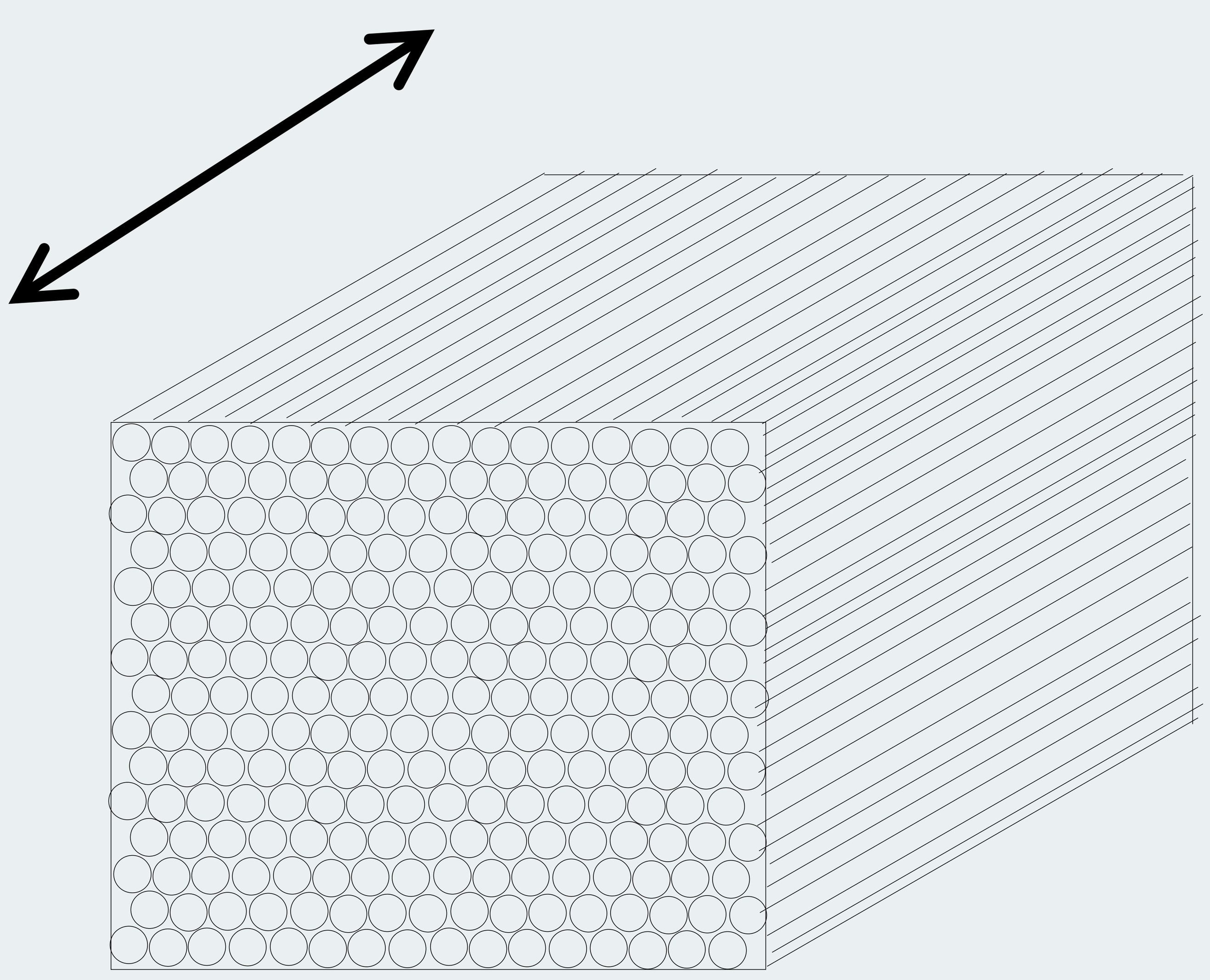
※The listed values are typical and can vary depending on the laminated structure and the amounts of substances contained.

※MCI-felt type2H has been used in Naka Research Institute's JT60U divertor.

※Past data in 1990-1994：https://jopss.jaea.go.jp/pdfdata/JAERI-M-90-119.pdf
https://jopss.jaea.go.jp/pdfdata/JAERI-M-93-149.pdf
https://jopss.jaea.go.jp/pdfdata/JAERI-M-94-046.pdf

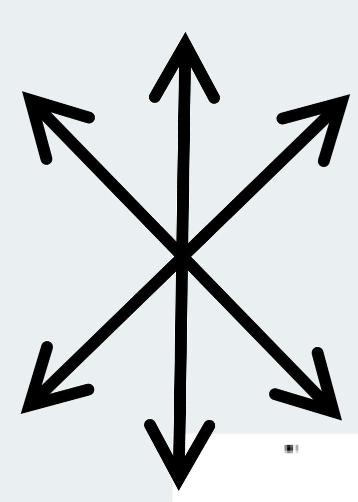
Uni Direction

CF direction



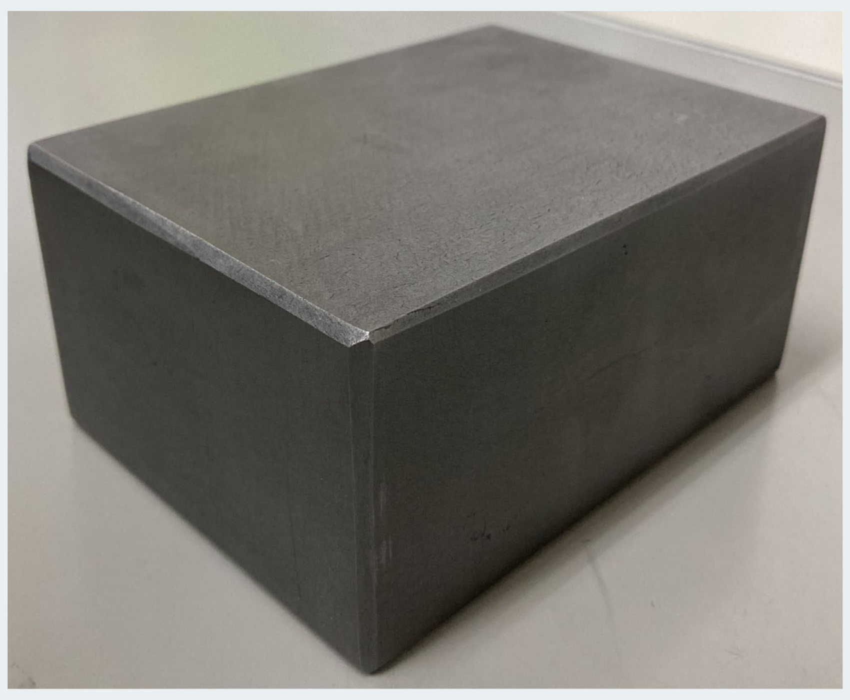
Felt

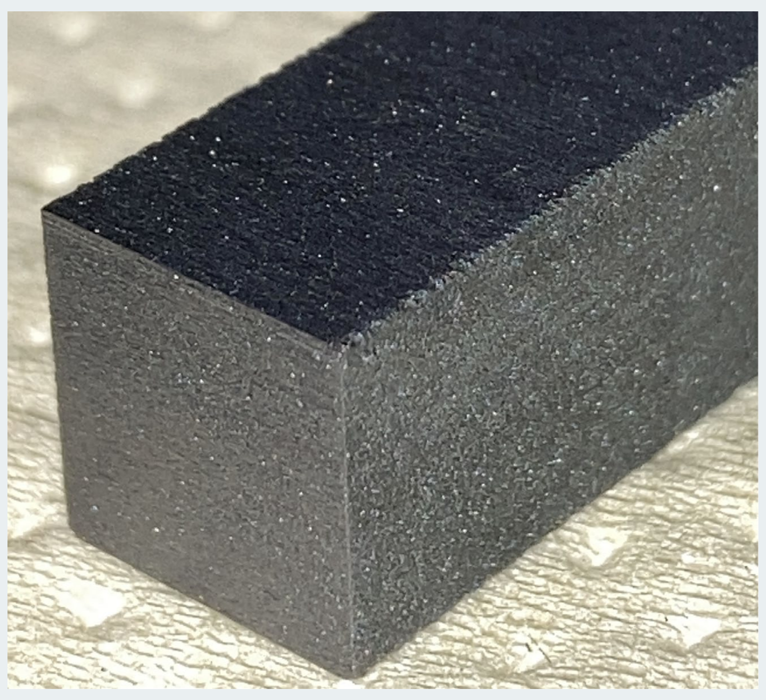
CF direction



MFC-1

MFC-1N（Development）

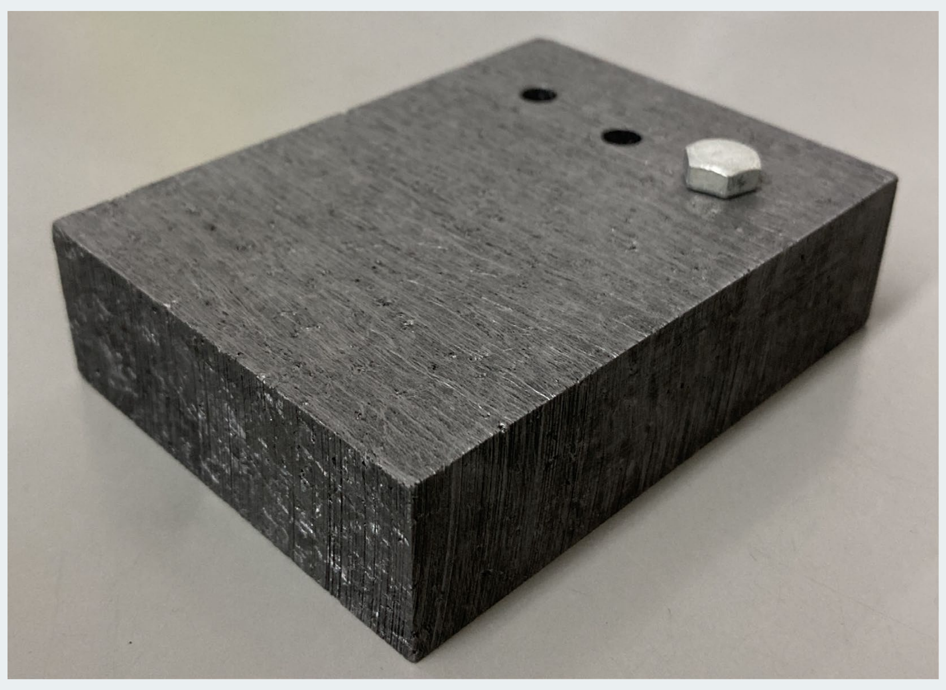


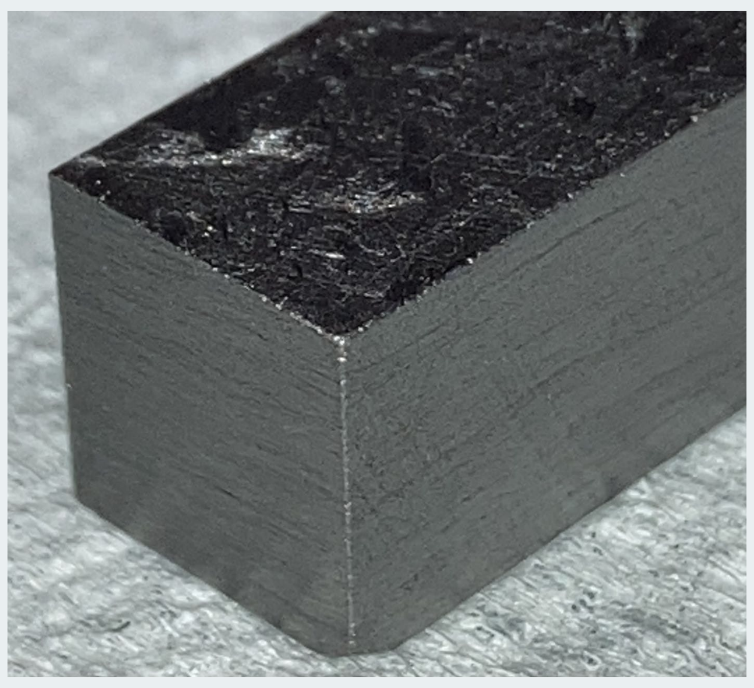


【Manufacturable size】Negotiable
210*×150×110mm *CF direction

MCI-felt type2H

MFC-2（Development）





【Manufacturable size】Negotiable
210*×150*×110mm *CF direction

MITSUBISHI CHEMICAL GROUP

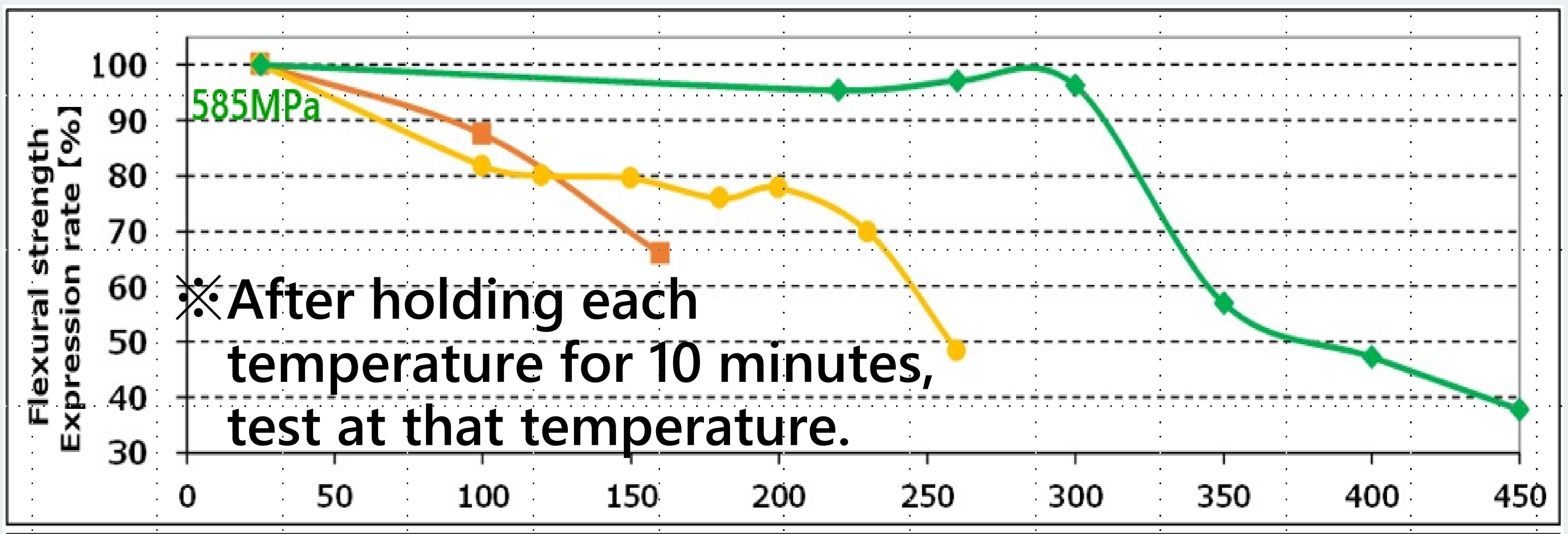
Mitsubishi Chemical Corporation

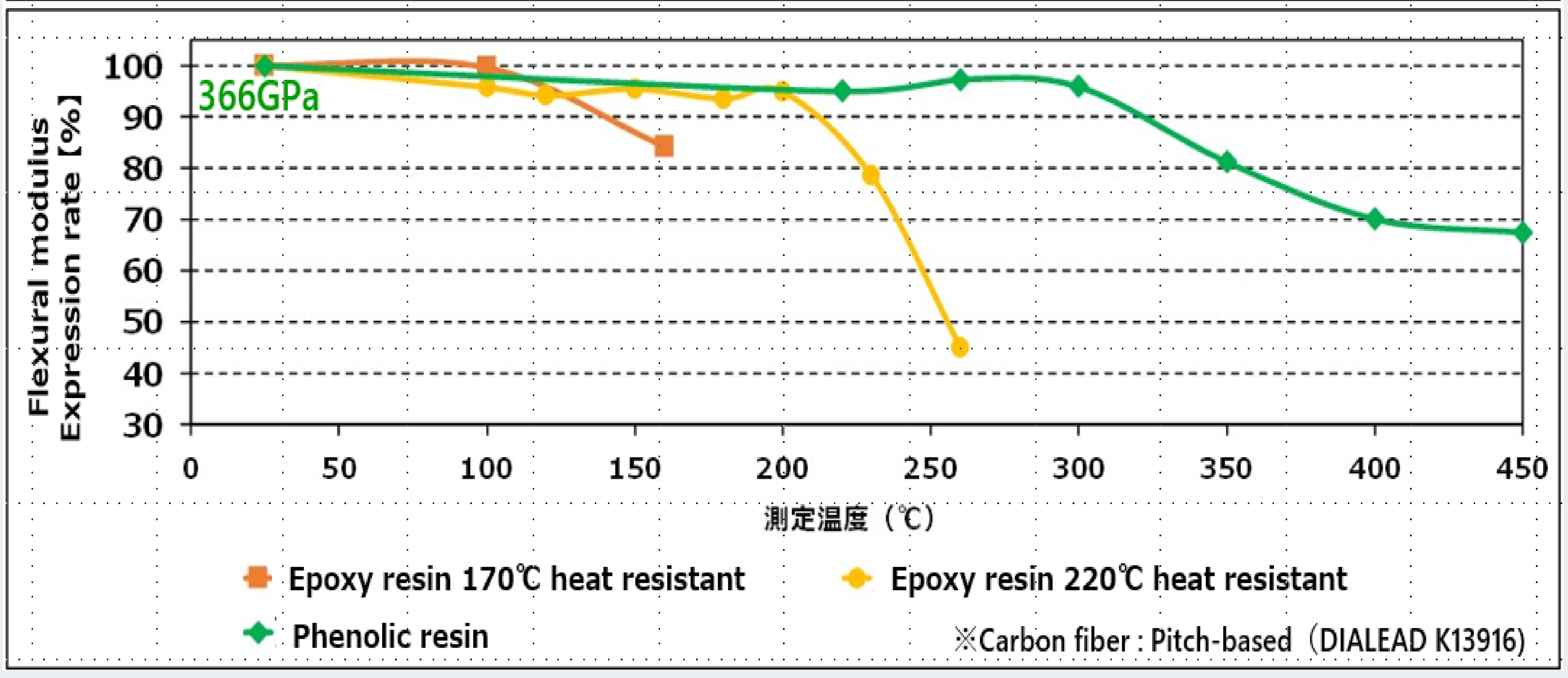
300℃ Heat Resistant Phenolic CFRP

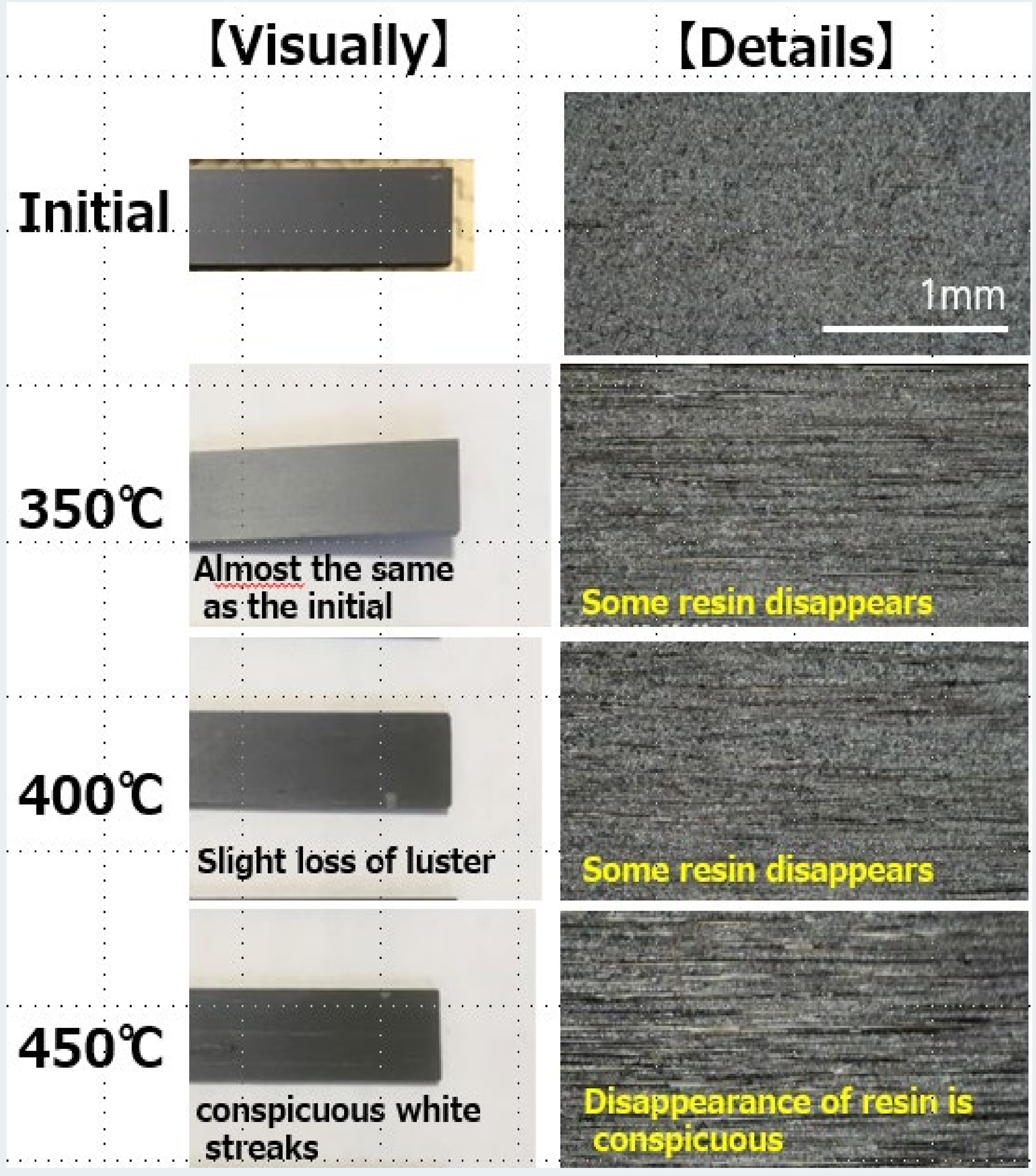
【 Characters 】

・**Light weight：1/4 or less density of steel（1.7 g/cm^3）**
・High stiffness：**Higher than Steel**, Thin design possible by High strength（long CF）
・**High heat resistance：300℃≦**
・Material type：Long CF, Short CF

【Temperature dependence of flexural properties and appearances】※long CF

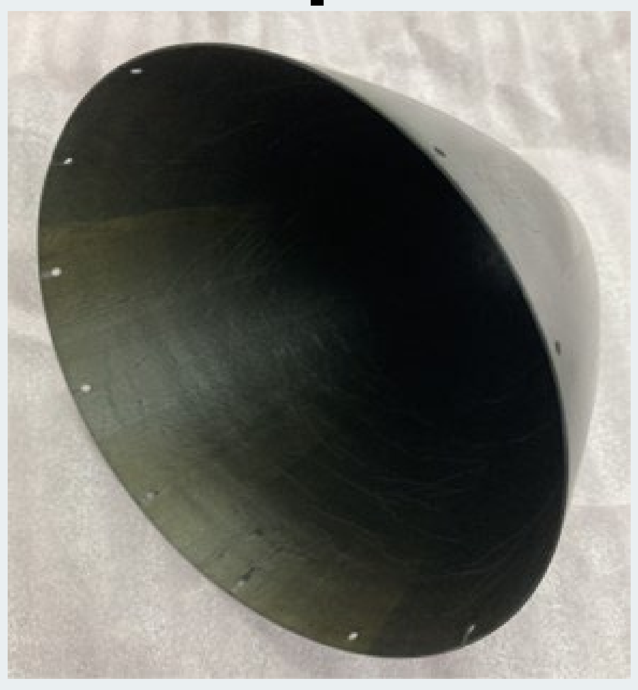






【 Product example 】

Cone shape（back side）



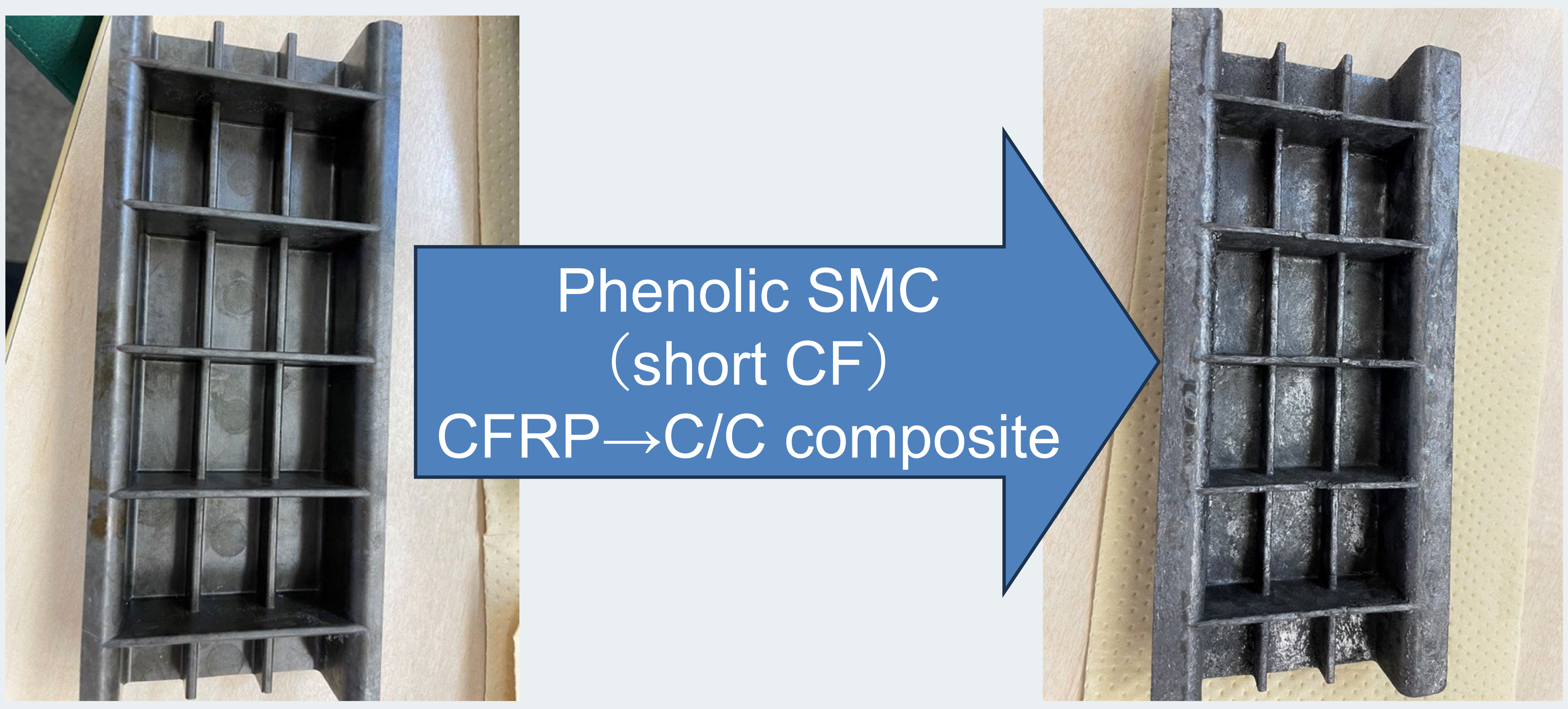
Pipe shape

【Other mechanical properties (Ref. epoxy CFRP)】

Carbon fiber type			Pitch-based K13916 (760GPa)	Pitch-based K63712 (640GPa)	PAN-based TR50S (230GPa)	Pitch-based K13916 (760GPa)
Rsin type			Phenol	Phenol	Phenol	Heat resistant epoxy
Density		g/cm^3	1.7	1.7	1.5	1.75
Void ratio		vol%	8	8	8	≦3
Tensile	Strength	MPa	1470	1400	1470	1700
	Modulus	GPa	430	340	150	460
Bending	Strength	MPa	590	610	1640	630
	Modulus	GPa	370	270	120	380
Compression	Strength	MPa	350	410	1420	360
	Modulus	GPa	520	340	130	460
ILSS（Shear）	Strength	MPa	32	47	59	60
IZOD（Impact）	Strength	kg･cm/cm	33	40	120	–

【 Application（carbonization）】

・**Almost the same after carbonization**



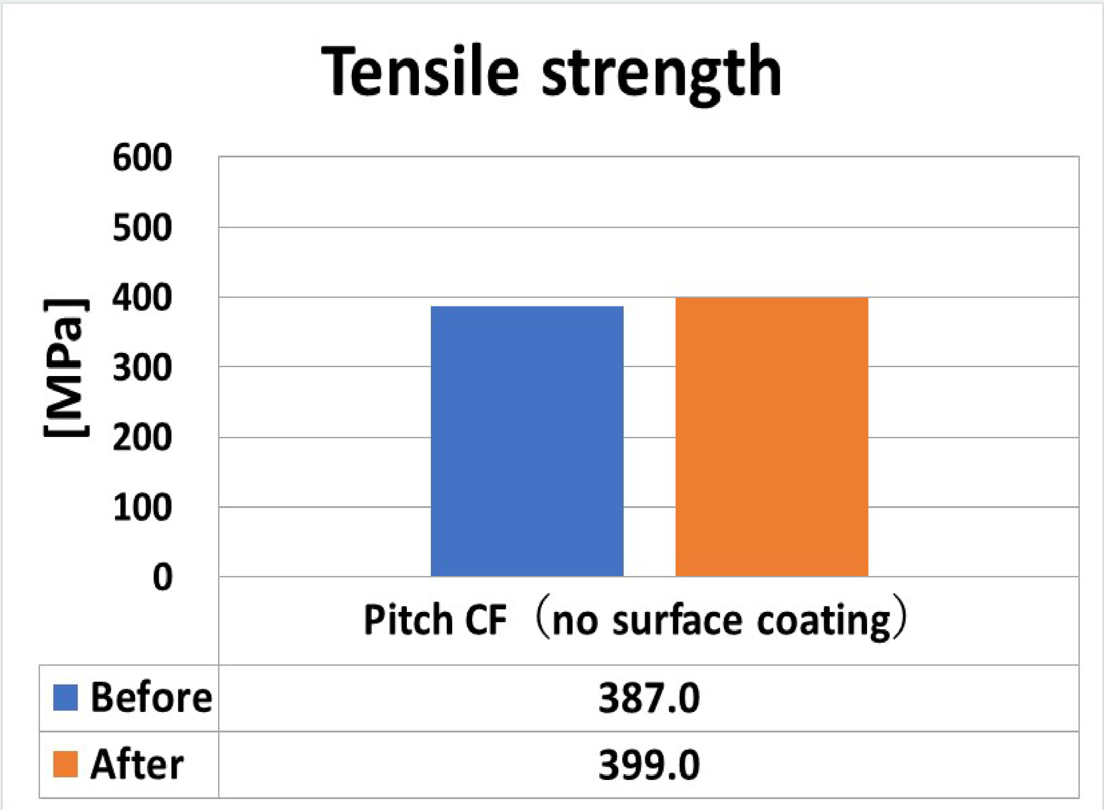
MITSUBISHI CHEMICAL GROUP

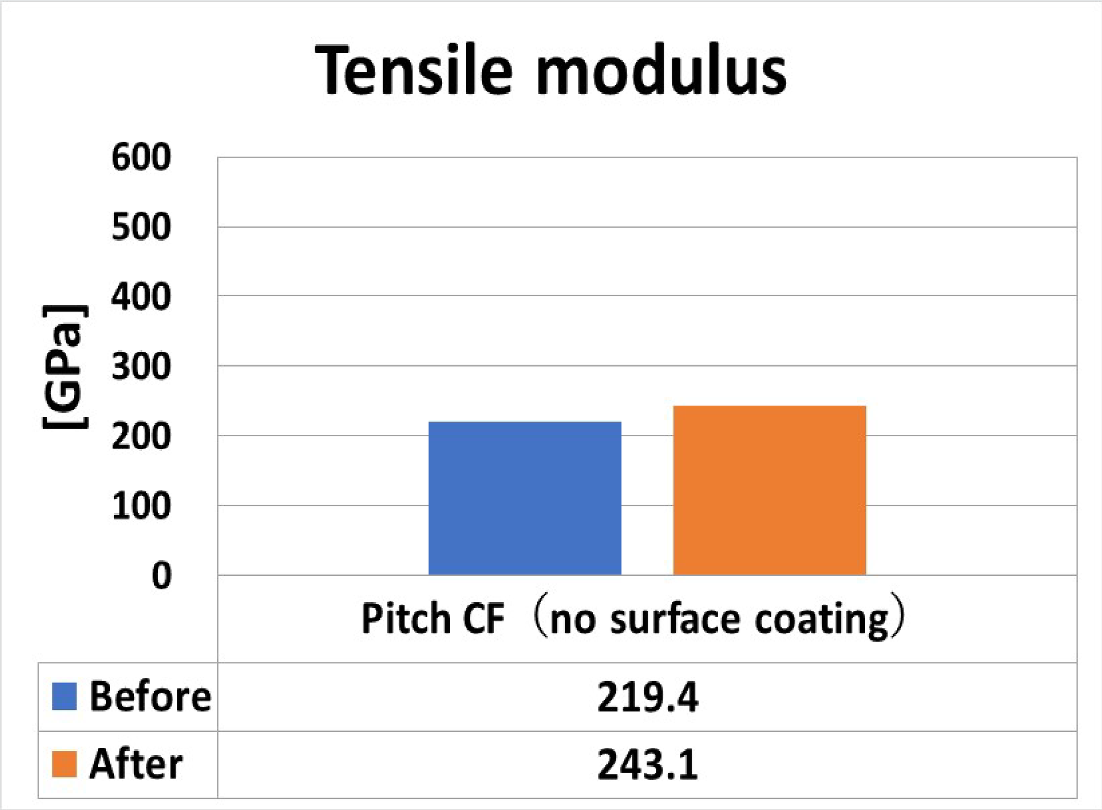
Mitsubishi Chemical Corporation

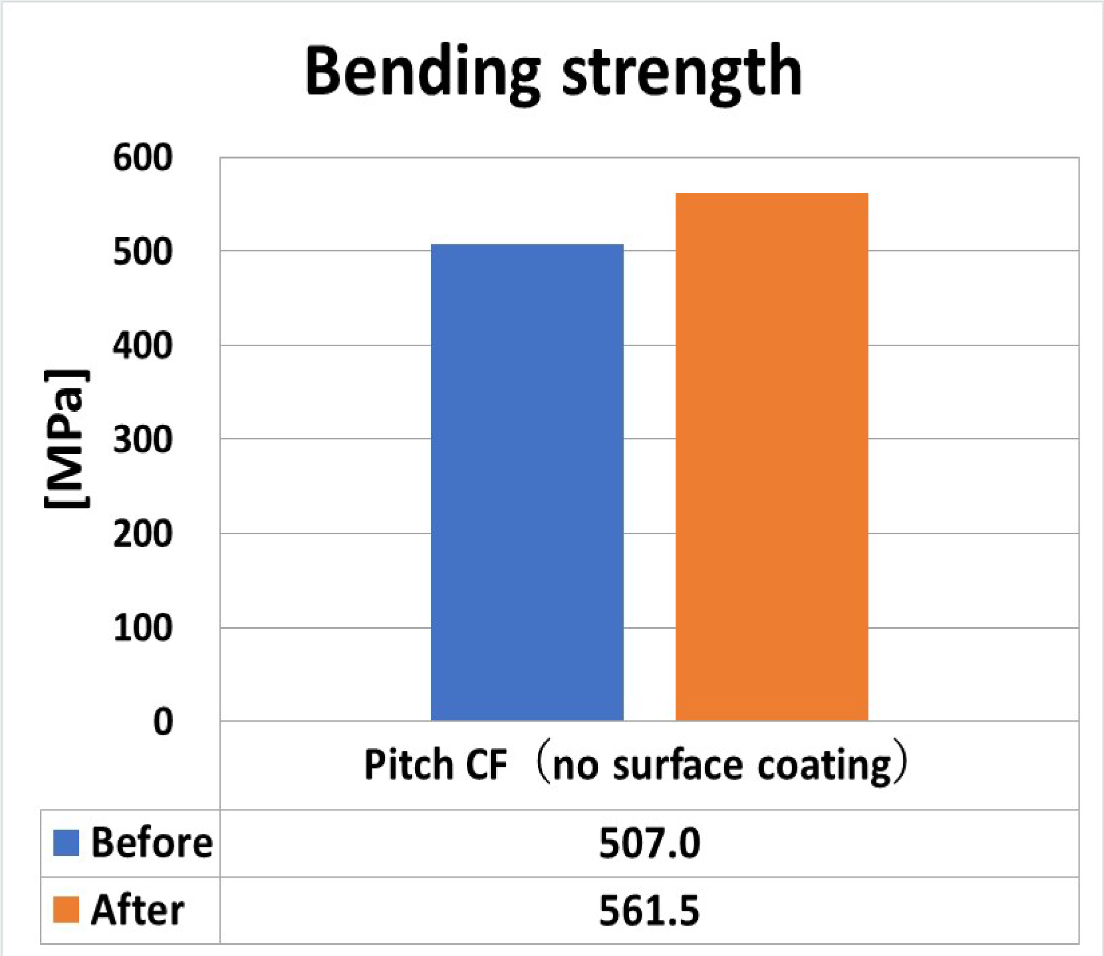
1500℃ Heat Resistant CMC (Pitch-based C/SiC Composite)

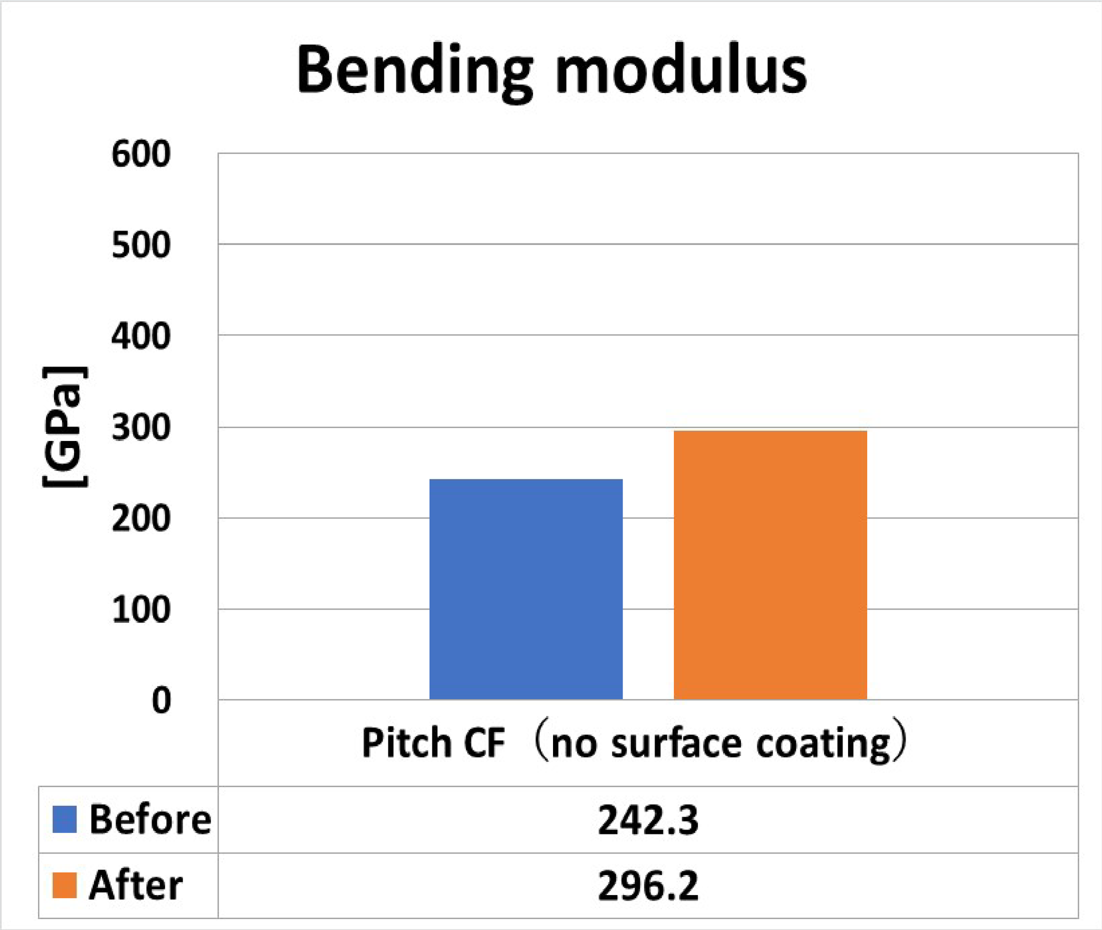
Application: Heat-resistant material for spacecraft heat shield tiles

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

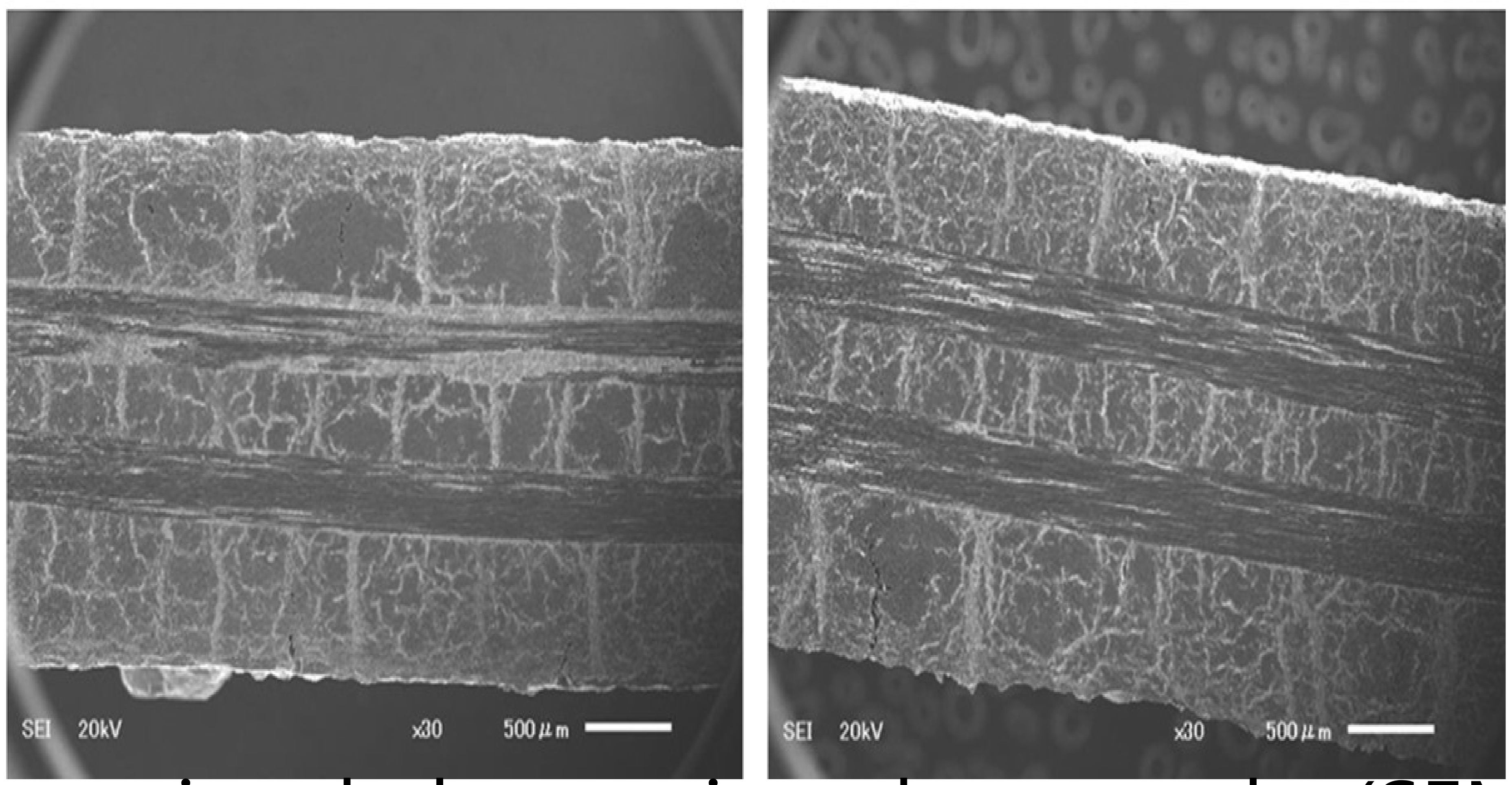








- No degradation of strength and modulus before and after heat treatment in air at 1,500°C for 1 hour,375MPa after exposure to 1500℃ for 1 hour
- JAXA innovative future space transportation system target: 1600℃-800 seconds resistance



- 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**

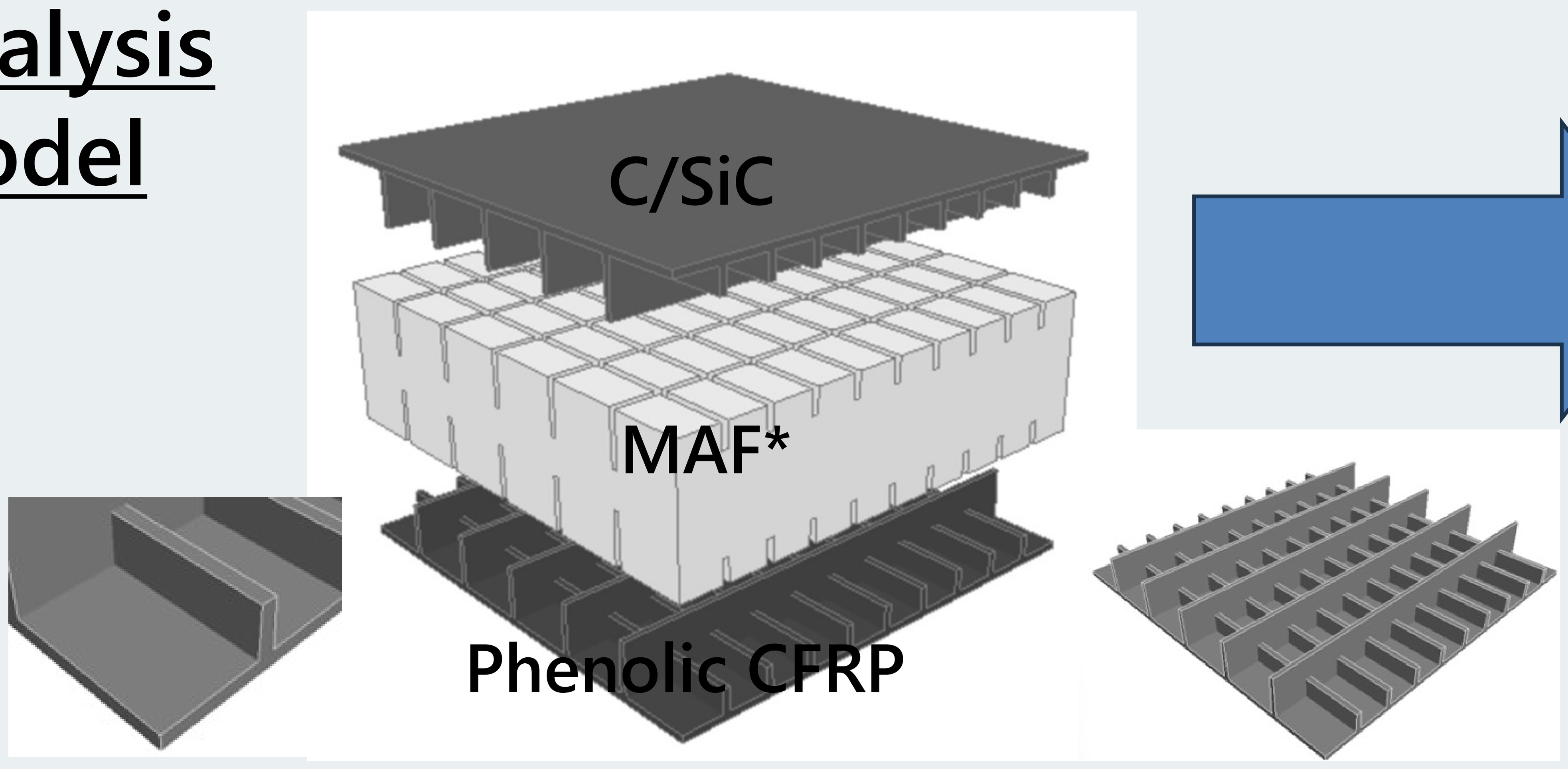
MITSUBISHI CHEMICAL GROUP

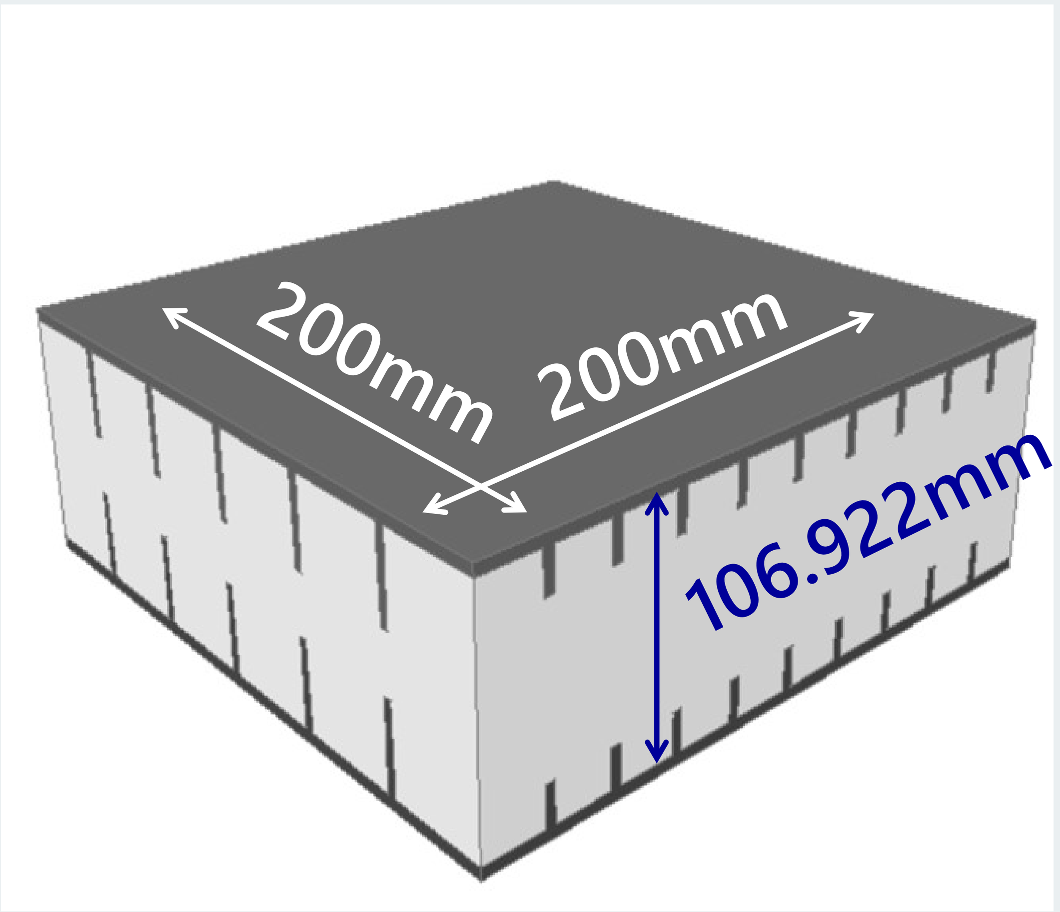
Mitsubishi Chemical Corporation

Thermal Protection System（Analysis）

Application：Heat-resistant material for spacecraft heat shield tiles

Analysis Model



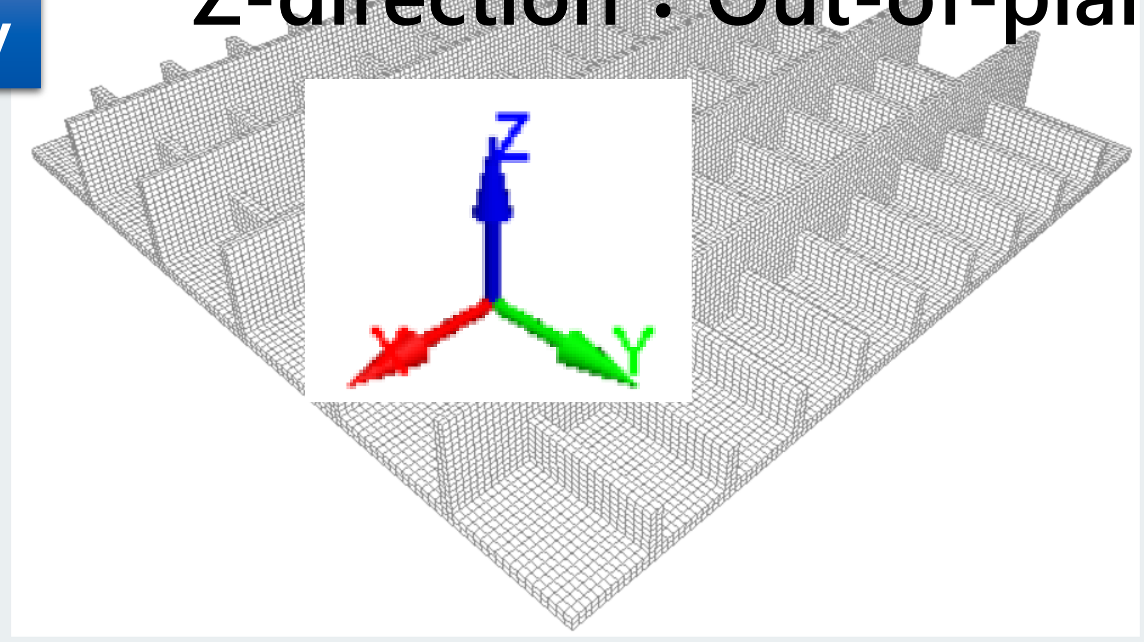


*https://www.maftec.co.jp/

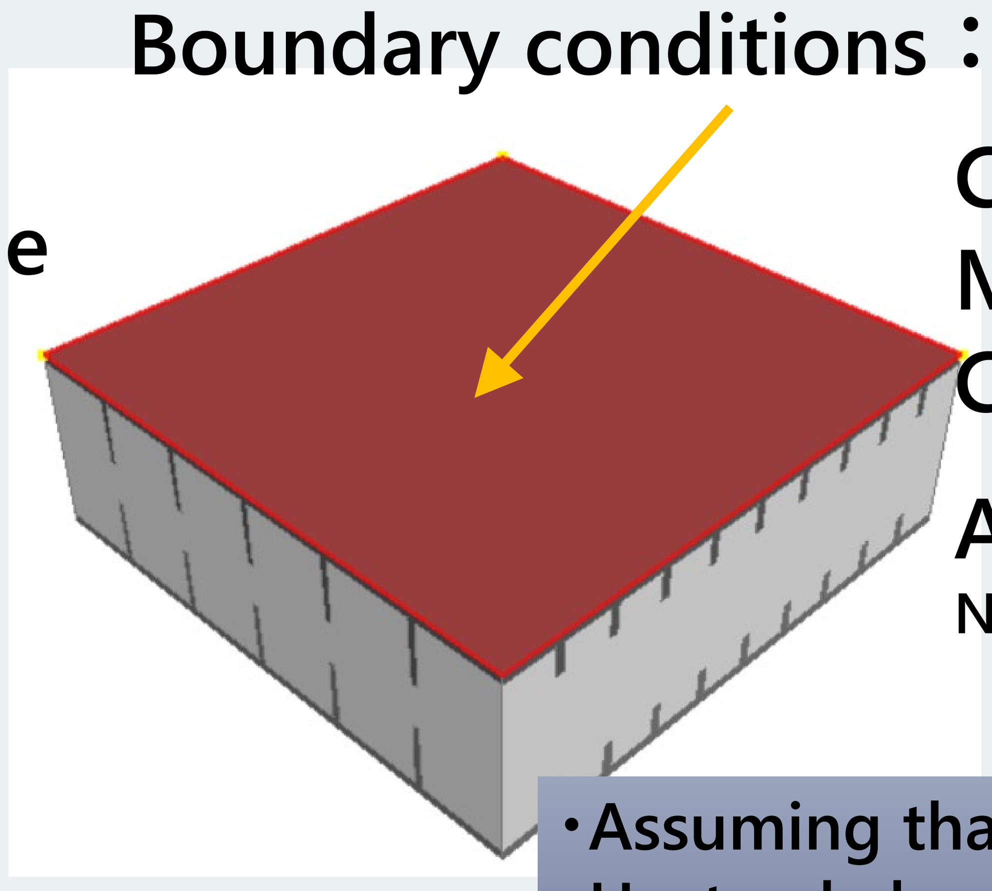
Analysis Conditions

Anisotropy

XY-direction：In-plane
Z-direction：Out-of-plane



Boundary conditions：Upper surface 1,650℃



C/Sic Initial temp.： 0 ℃
MAF Initial temp. ：23℃
CFRP Initial temp.：23℃

Around parts：Insulation
No heat exchange with surroundings

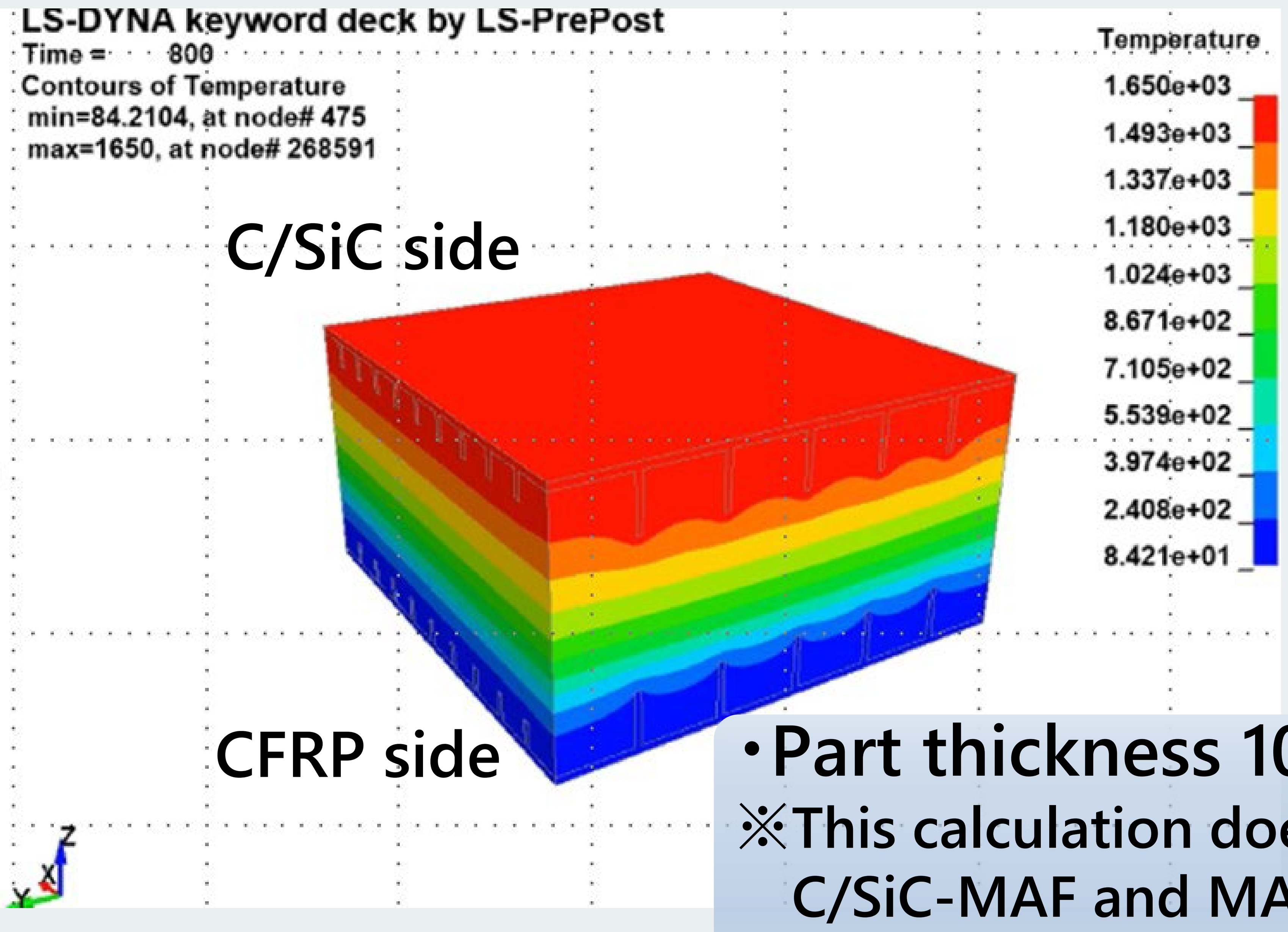
・Assuming that each part is in close contact
・Unsteady heat conduction analysis

Physical property

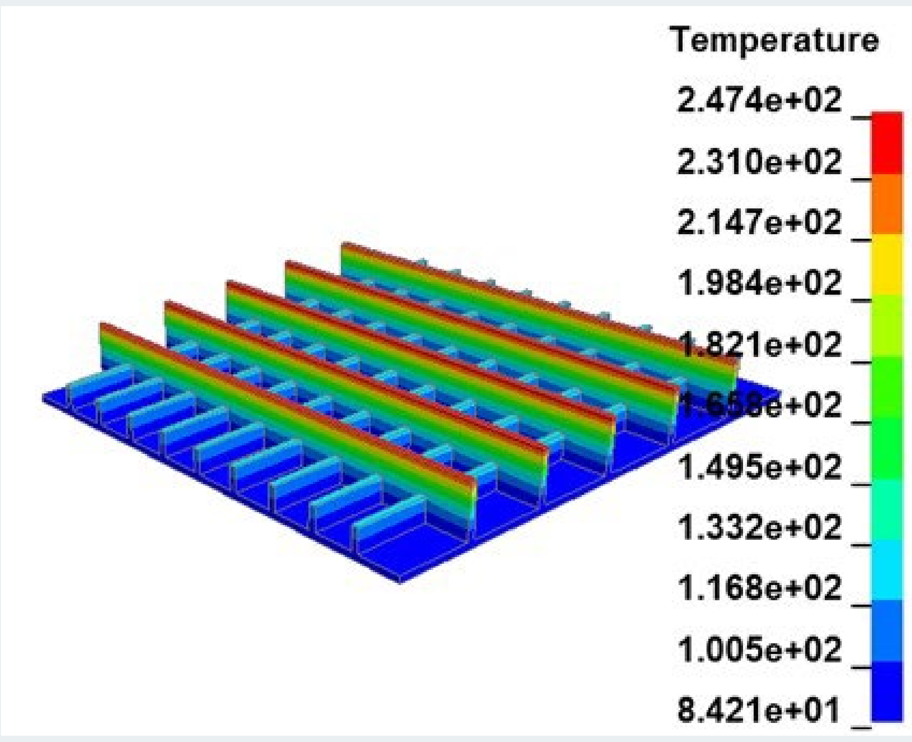
Properties	Unit	Phenolic CFRP	C/SiC	MAF
Thermal Conductivity（In-plane）	W/mK	55	Depends on temp.（Right table）	Depends on temp.（Right table）
Thermal Conductivity（Out-of-plane）	W/mK	1.5	Depends on temp.（Right table）	Depends on temp.（Right table）
Density	kg/m^3	1,600	2,400	130(Bulk)
specific heat	J/kgK	900	700	1200

	Temp.	C/Sic	Temp.	MAF
Thermal Conductivity（In-plane） W/mk	25℃	78	25℃	0.15
	500℃	65	600℃	0.15
	1,000℃	55	1000℃	0.32
	1,200℃	55	1200℃	0.46
	2,000℃	55	2000℃	0.46
Thermal Conductivity（Out-of-plane） W/mk	25℃	32	25℃	0.15
	500℃	28	600℃	0.15
	1,000℃	23	1000℃	0.32
	1,200℃	23	1200℃	0.46
	2,000℃	23	2000℃	0.46

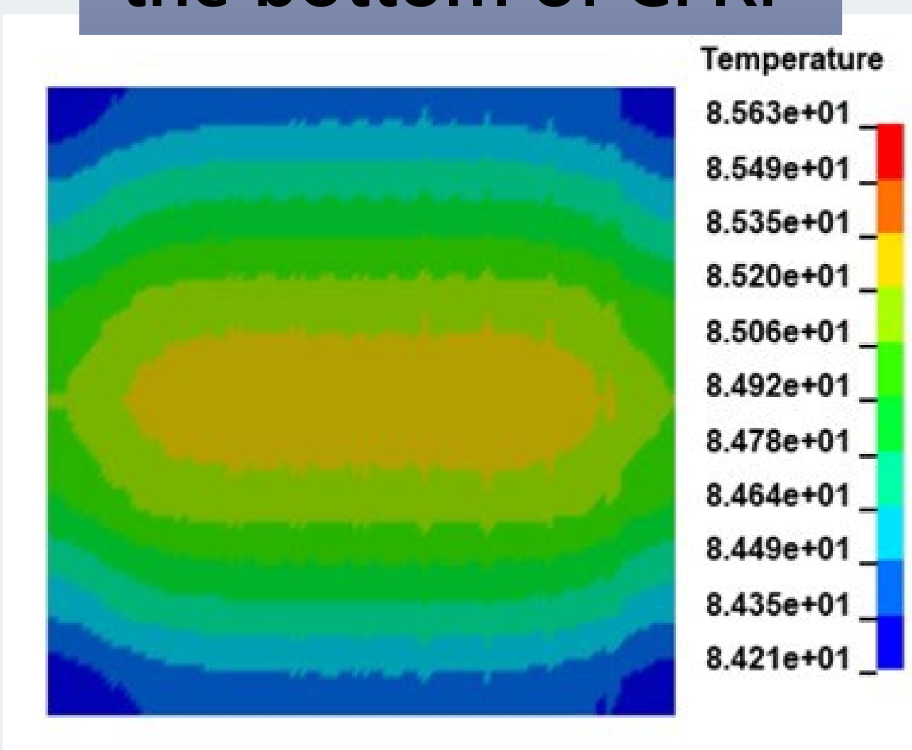
Analysis Results



Temperature distribution of CFRP



Temperature distribution on the contact surface with the bottom of CFRP



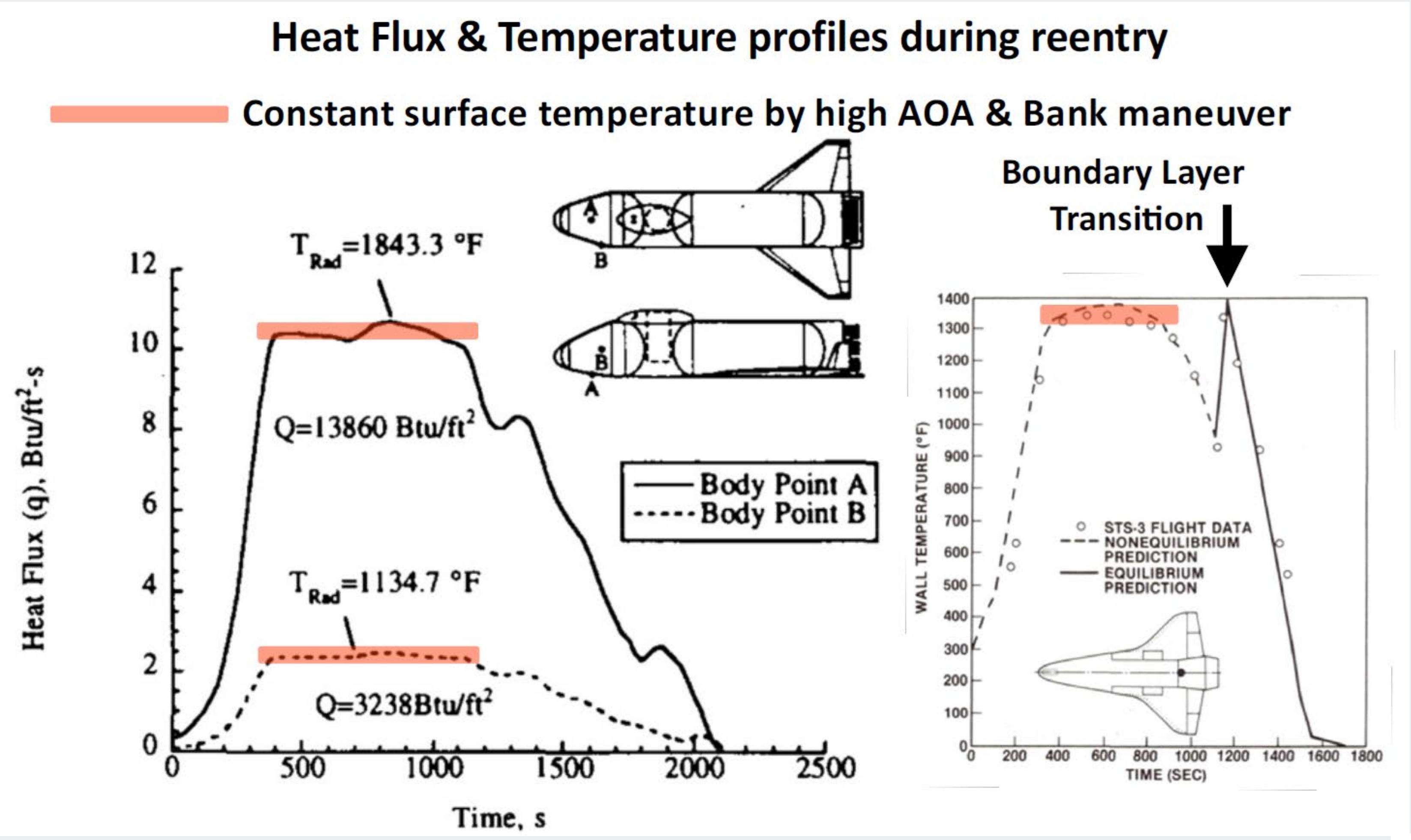
・Part thickness 107㎜：Contact surface 86℃ after 800 sec.
※This calculation does not take into account the contact resistance of C/SiC-MAF and MAF-CFRP, so we guess that the temperature in the actual will be lower than the predicted temperature.

MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

Thermal analysis applying Space Shuttle heating energy

Space Shuttle Heating Energy



Reference

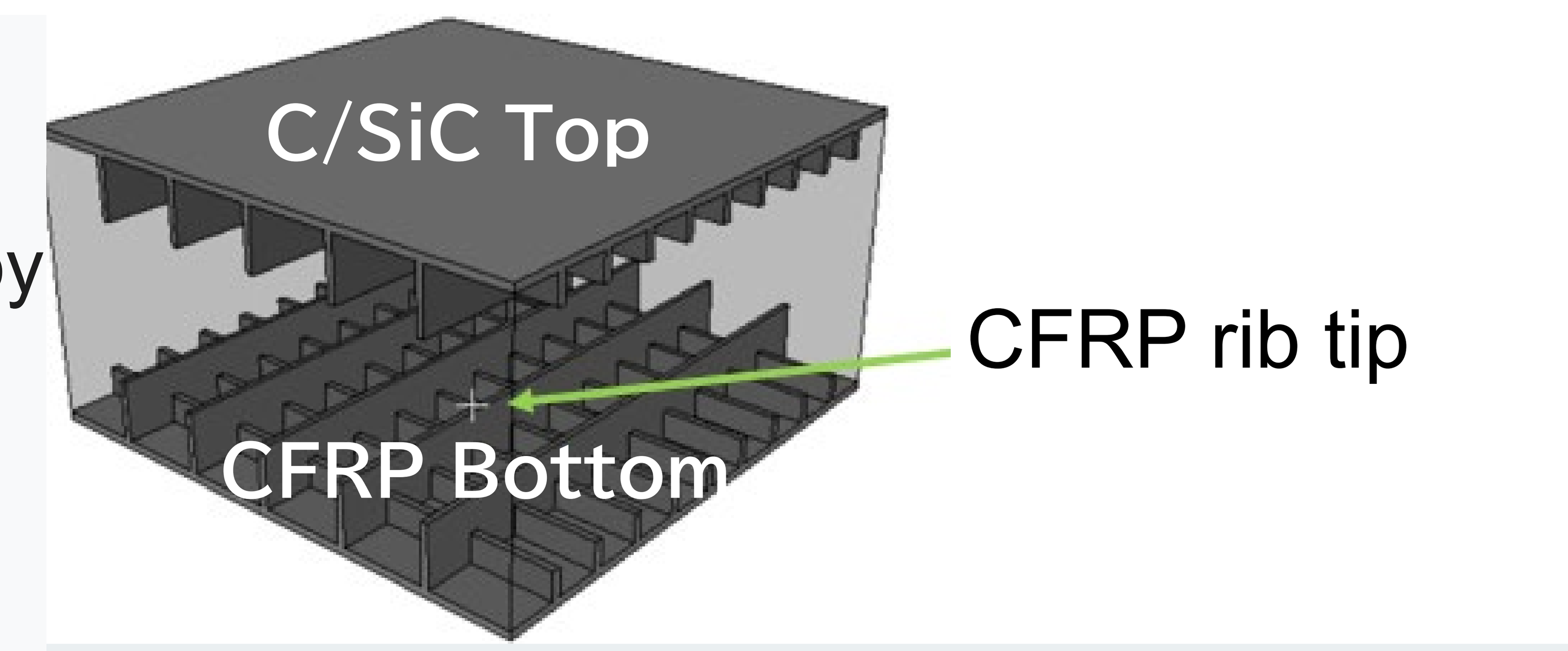
・AIAA-99-3459 Parametric Weight Comparison of Current and Proposed Thermal Protection System (TPS) Concepts David E. Myers, Carl J. Martin, Max L. Blosser NASA Langley Research Center Hampton, VA 23681-2199 33rd Thermo physics Conference 28 June - 1 July, 1999 / Norfolk, VA

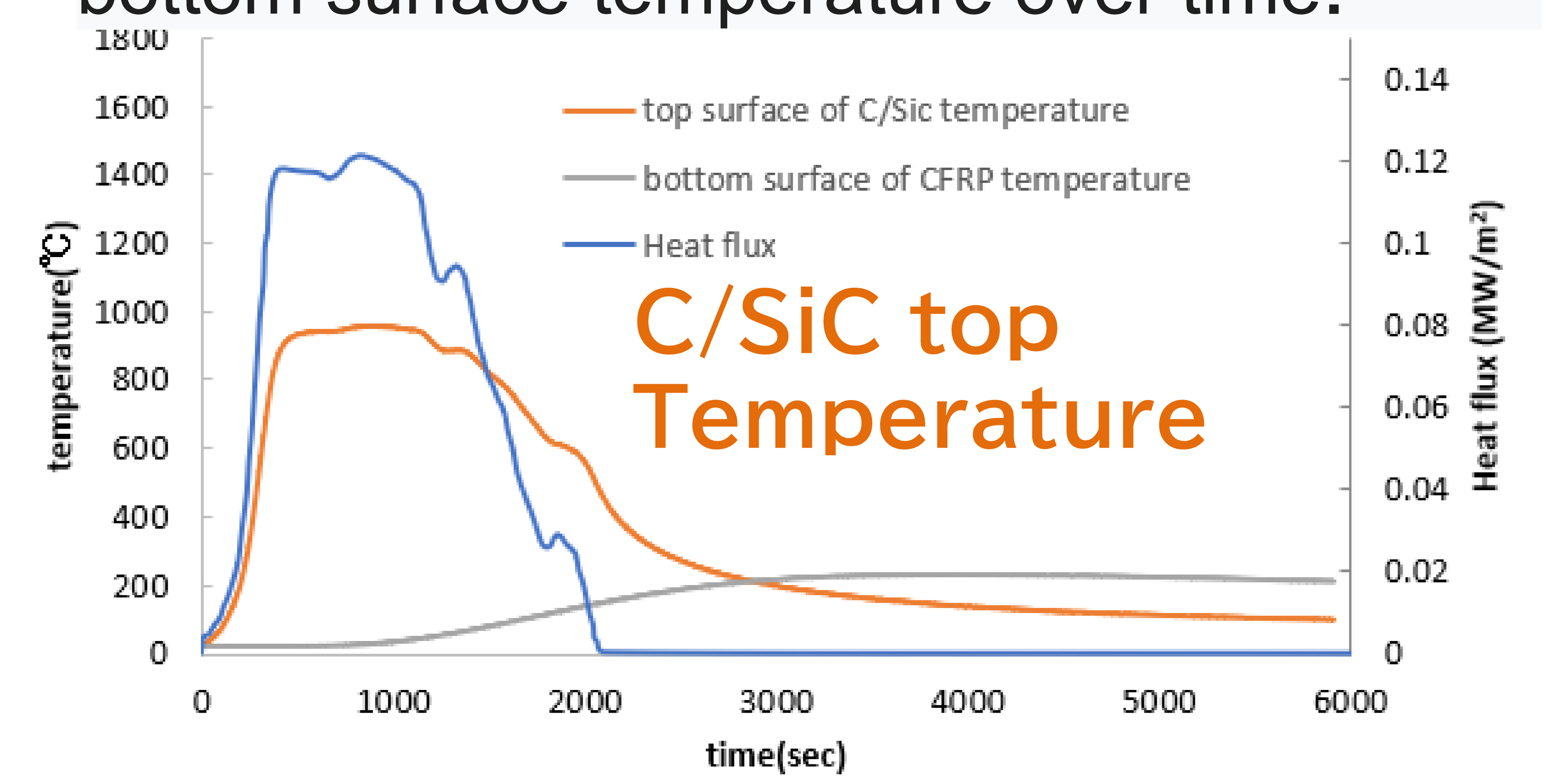
・NASA CP2283 "Shuttle performance Lessons Learned", part 2, 1983 Aerothermal Environment, Thermal Protection

from Dr. Yoshifumi Inatani

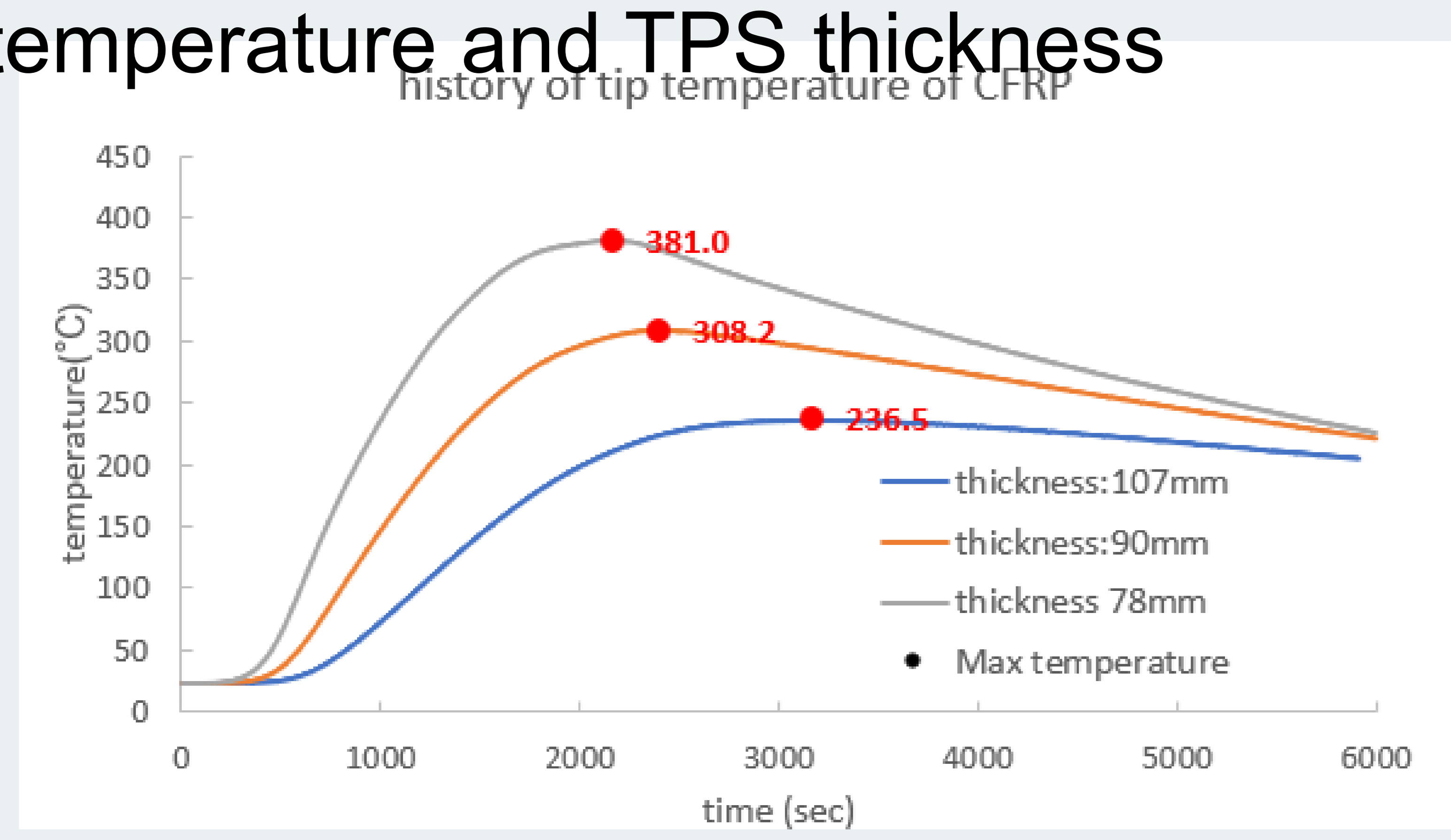
TPS thermal analysis results

Analyzing the conditions under which the CFRP rib tip temperature is 300℃ or less by changing the thickness of the Thermal Protection System For a case with a thickness of 107 mm, plot the change in C/SiC top surface temperature and CFRP bottom surface temperature over time.

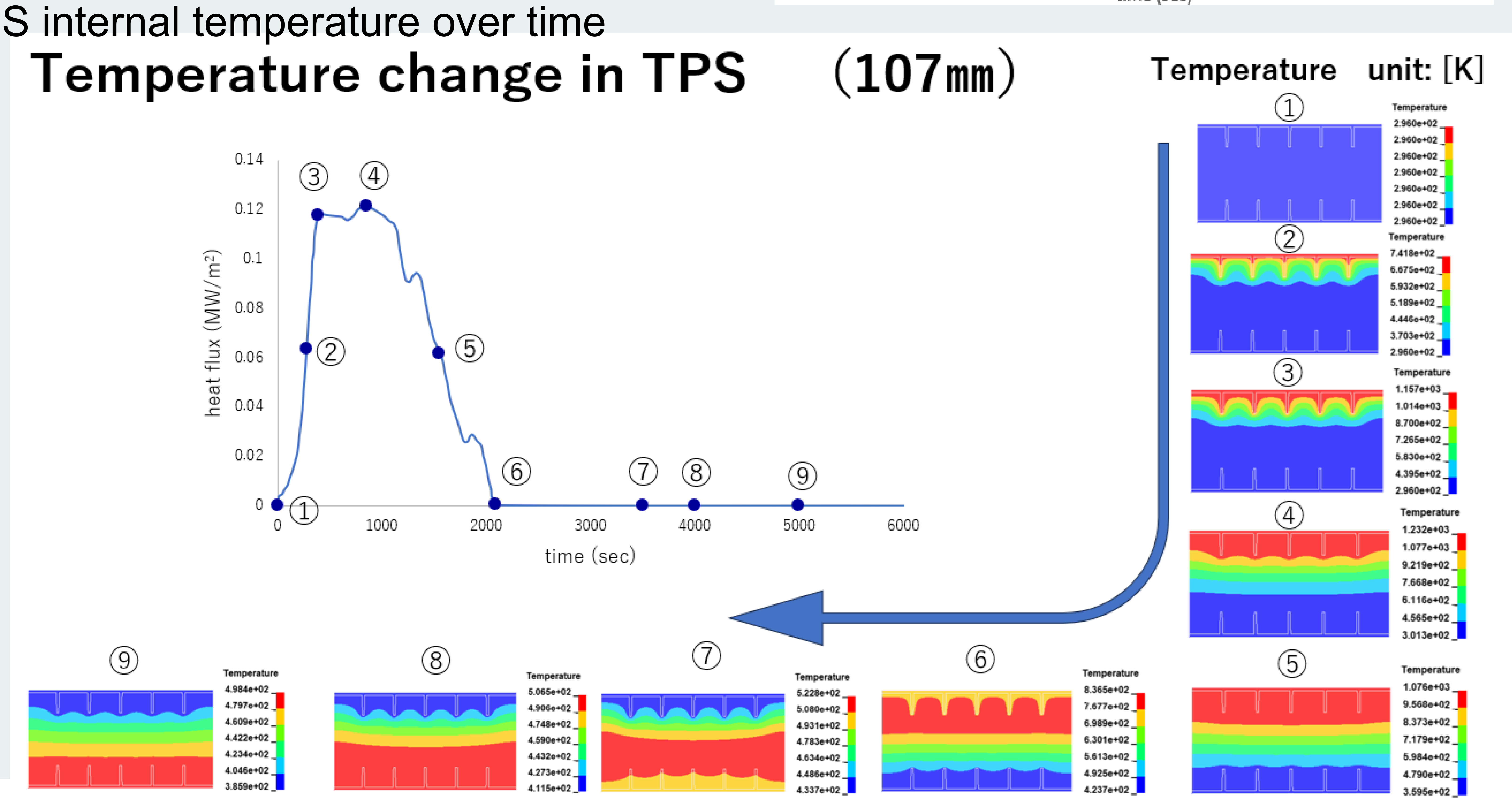




Relationship between CFRP rib tip temperature and TPS thickness



TPS internal temperature over time

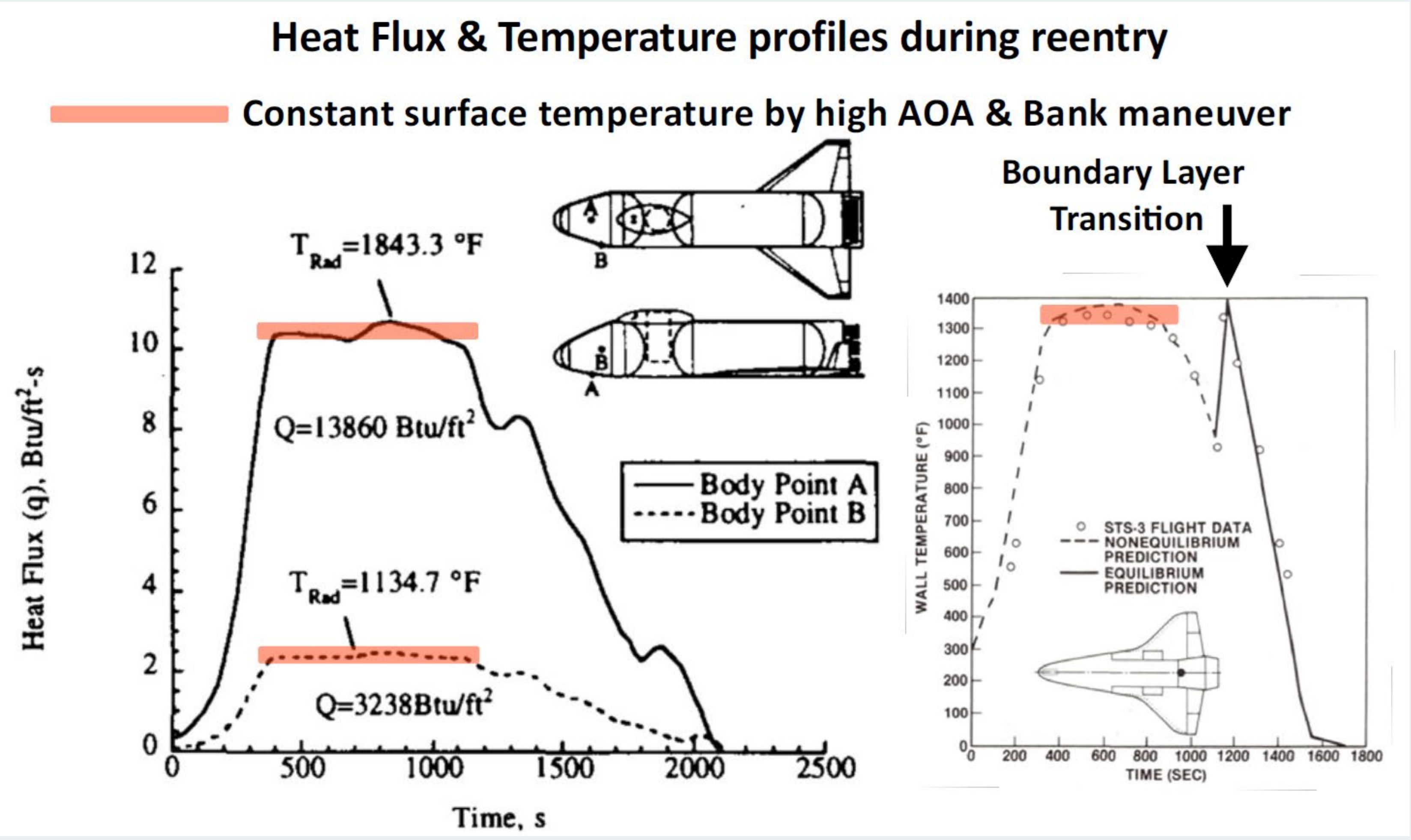


MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

Thermal analysis applying Space Shuttle heating energy

Space Shuttle Heating Energy

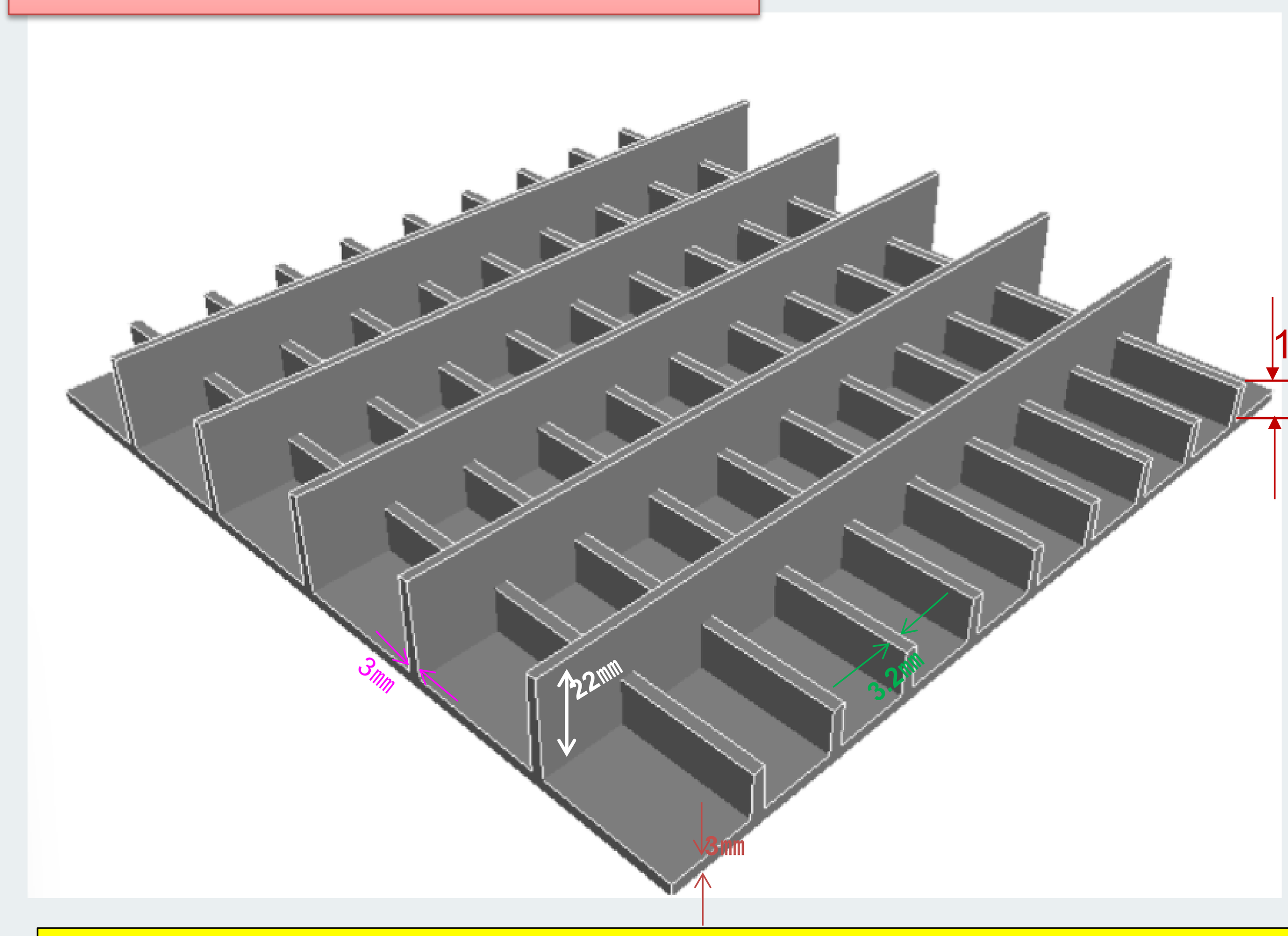


Reference

・AIAA-99-3459 Parametric Weight Comparison of Current and Proposed Thermal Protection System (TPS) Concepts David E. Myers, Carl J. Martin, Max L. Blosser NASA Langley Research Center Hampton, VA 23681-2199
33rd Thermo physics Conference 28 June - 1 July, 1999 / Norfolk, VA
・NASA CP2283 "Shuttle performance Lessons Learned", part 2, 1983
Aerothermal Environment, Thermal Protection

from Dr. Yoshifumi Inatani

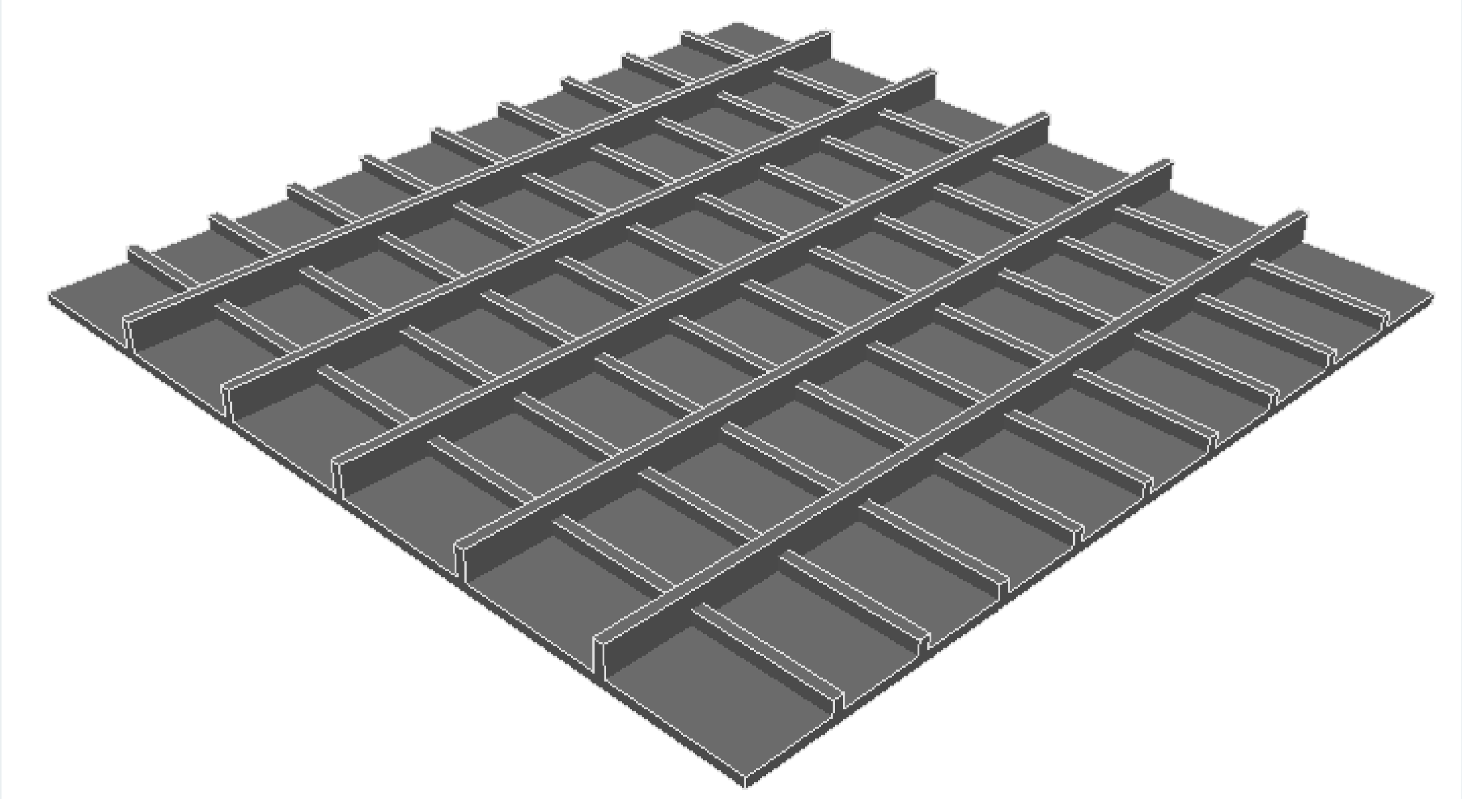
STD model



C/SiC density:2.2 Wt 12.5Kg/m²
MAF density:0. 13 Wt 10.2kg/²
CFRP density:1.6 Wt 9.1Kg/m²
TPS90mm Weight 32kg/m²

CFRP rib Tip temp:297℃

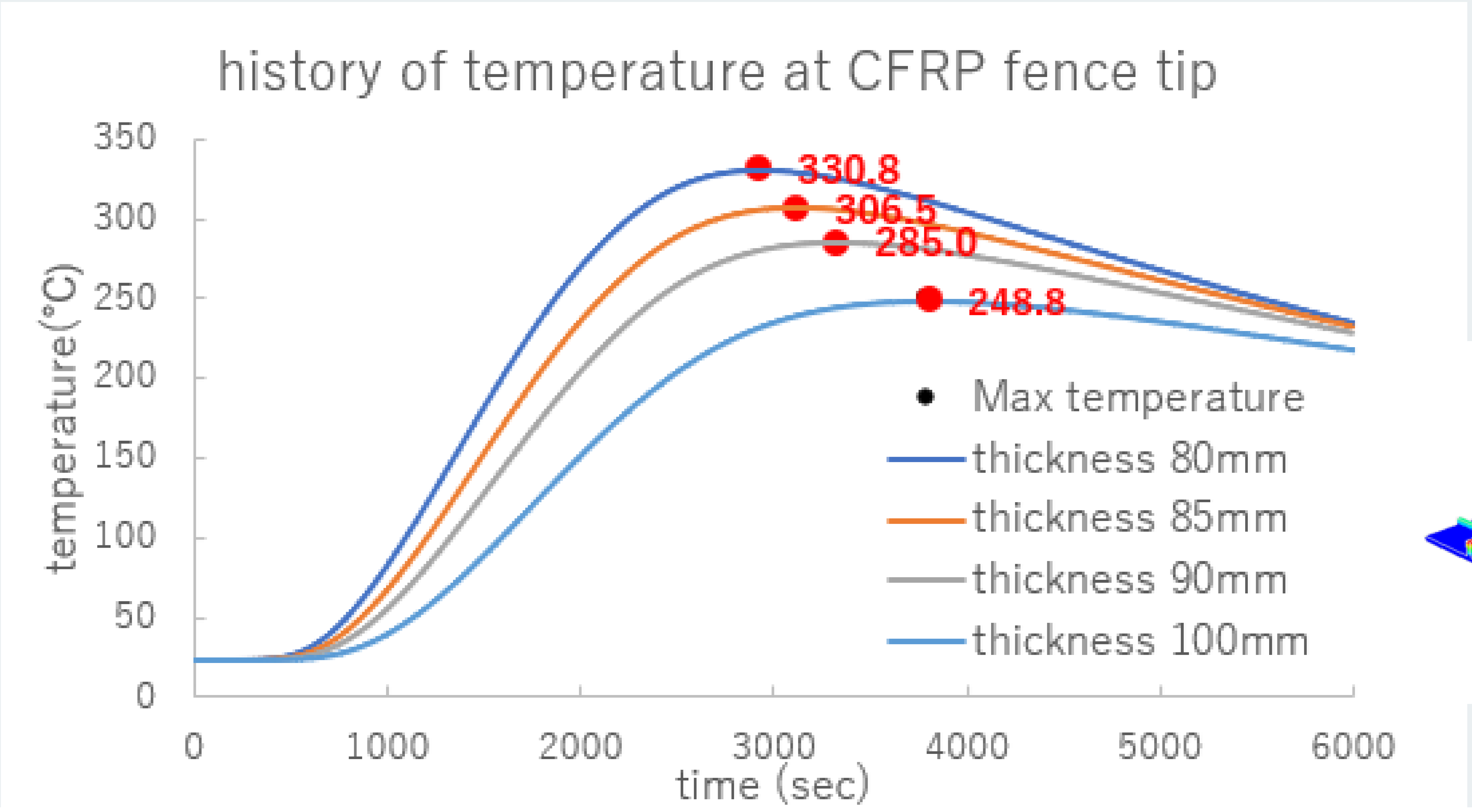
Light Weight model



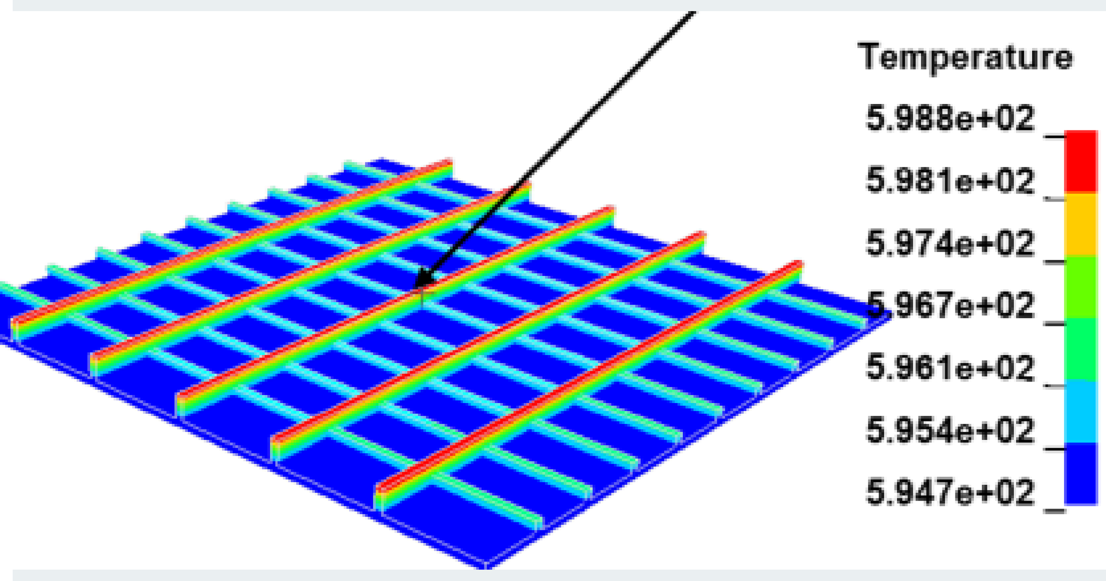
C/SiC density: 2.2 Wt 7.2Kg/m²
MAF density:0. 13 Wt 10.8kg/m²
CFRP density:1.6 Wt 5.2Kg/m²
TPS90mm Weight 23kg/m²

CFRP rib Tip temo:285℃

CFRP rib Tip temperature



CFRP rib Tip Temp



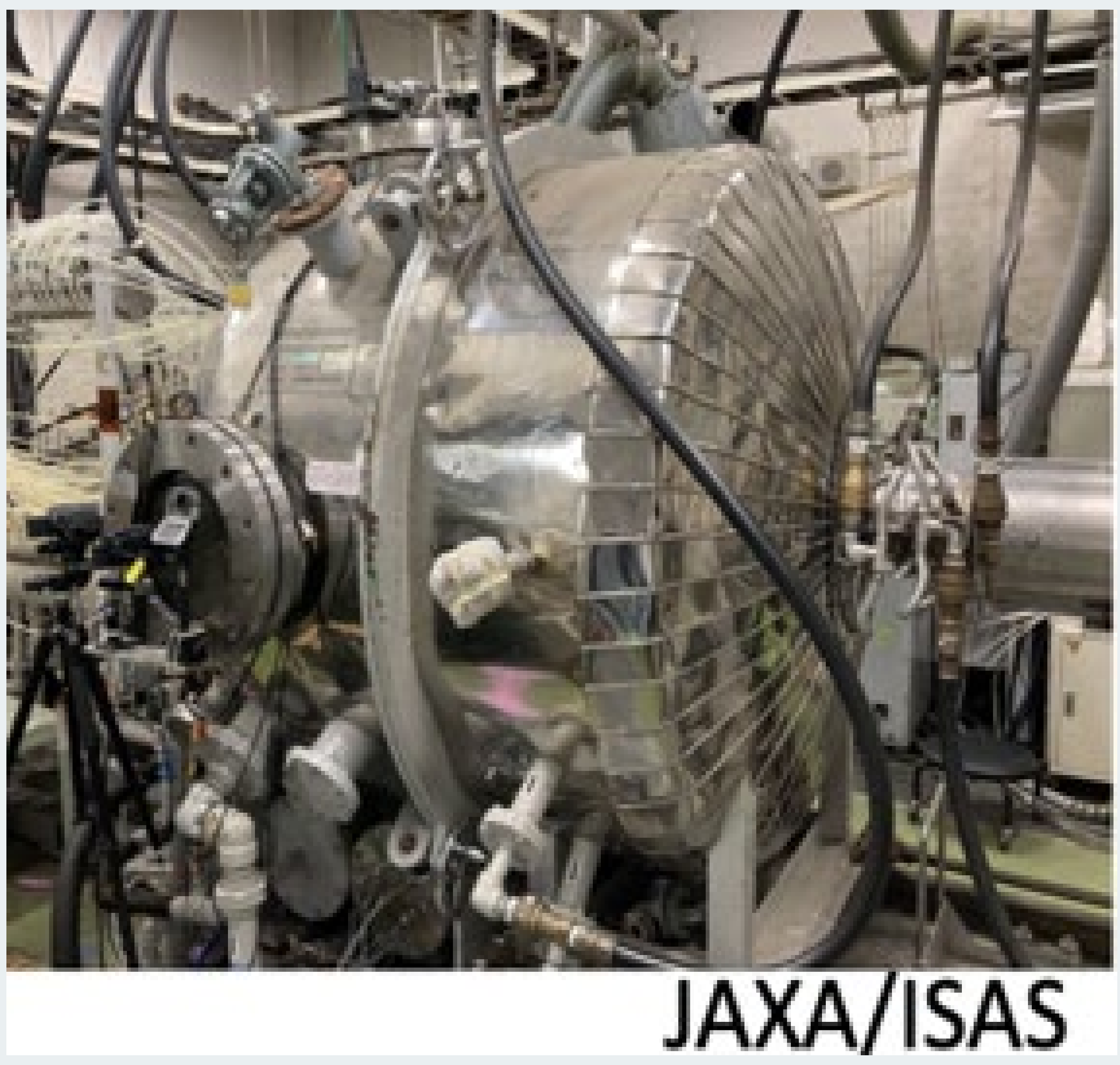
MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

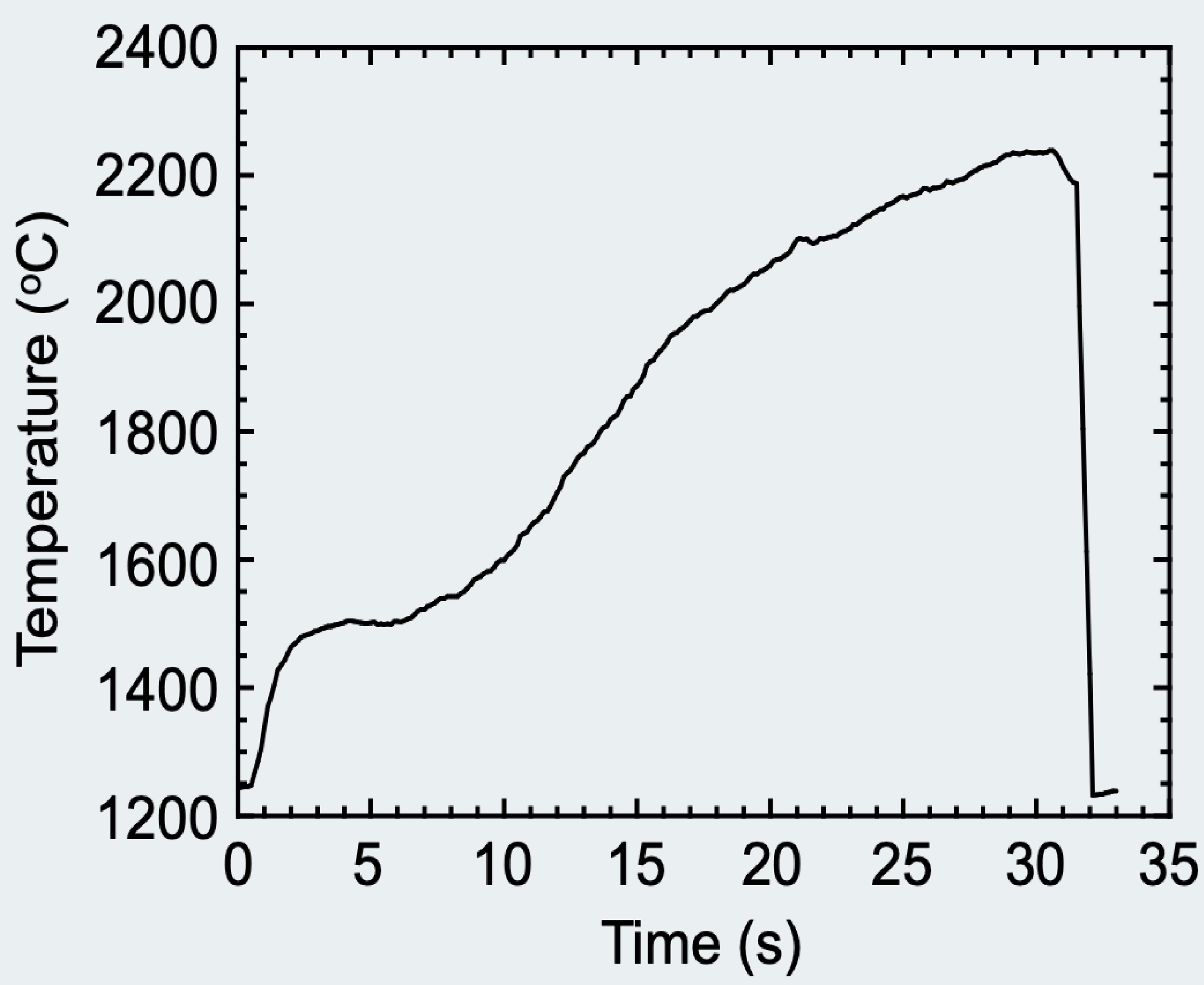
2200℃ Heat Resistant Pitch-based C/C Composite

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

JAXA arc heating wind tunnel test facility



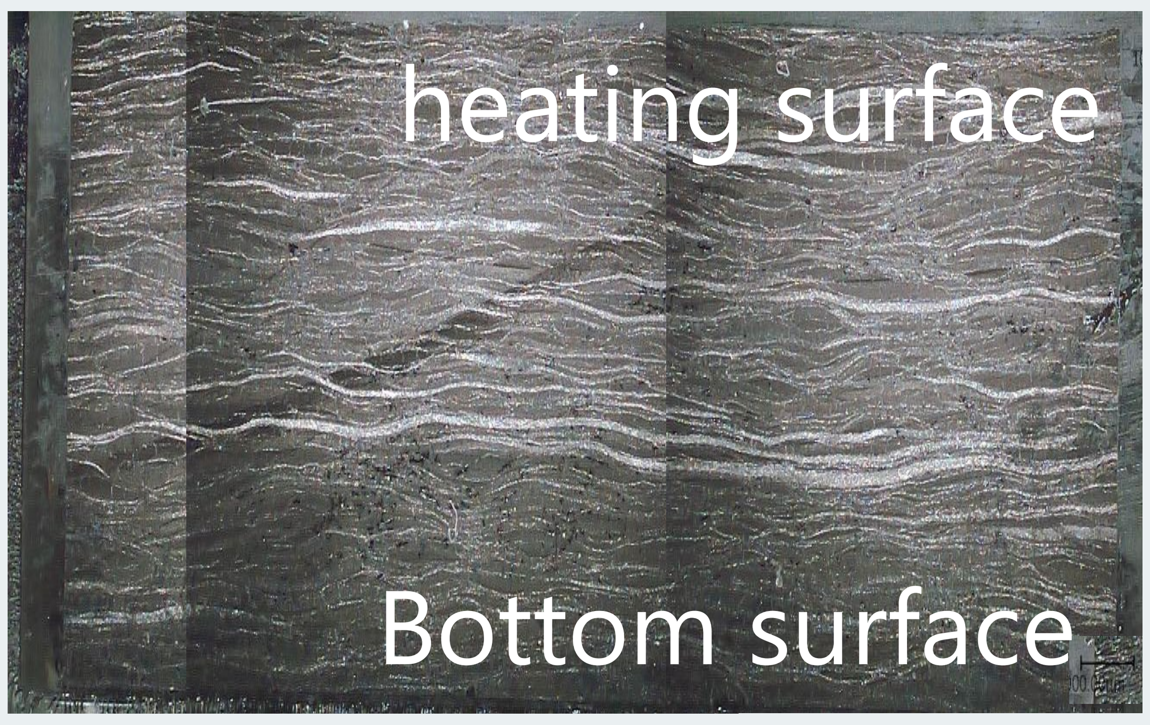
Heating condition
Heating rate: 4.83 MW/m2
Dynamic pressure: 13~14 kPa



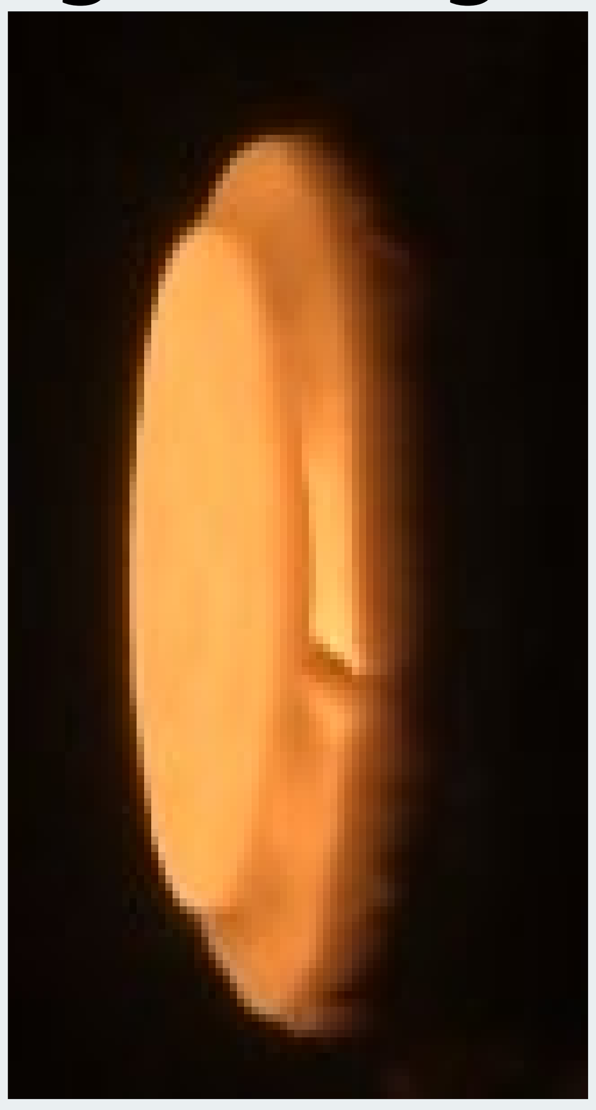
Surface after heating test

Thickness reduction rate: 10%

Cross section after heating test



Surface during heating at 2200℃

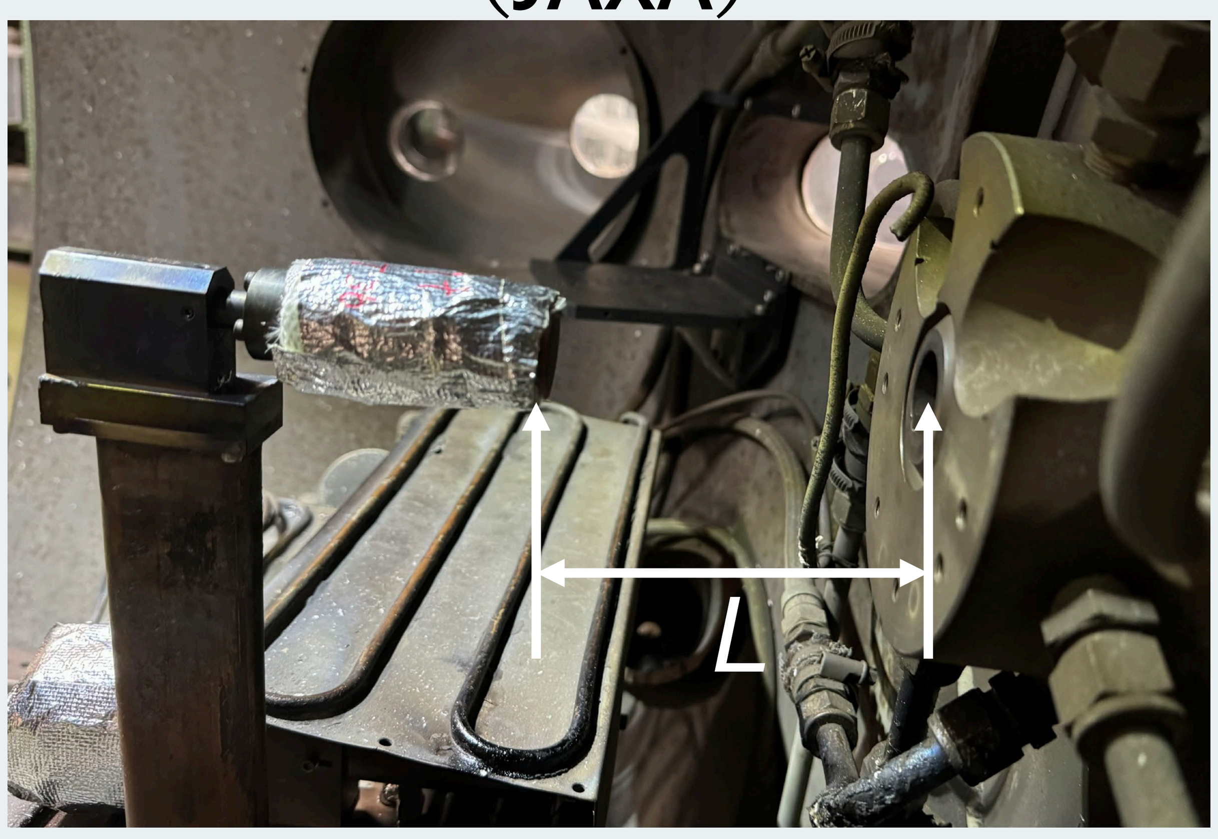


- Joint development of CMC heat-resistant materials is underway with Tokyo University of Science.
- As a result of arc heating wind tunnel testing of the base material, the amount of wear was approximately 10% (0.8mm) for pitch-based C/C composite with a thickness of 8mm, .Plans for impregnating with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

2,500℃ Heat Resistant Pitch-based CMC composite

Application：Rocket nozzle, Heat-resistant materials for fusion reactors

Arc heating wind tunnel test machine (JAXA)



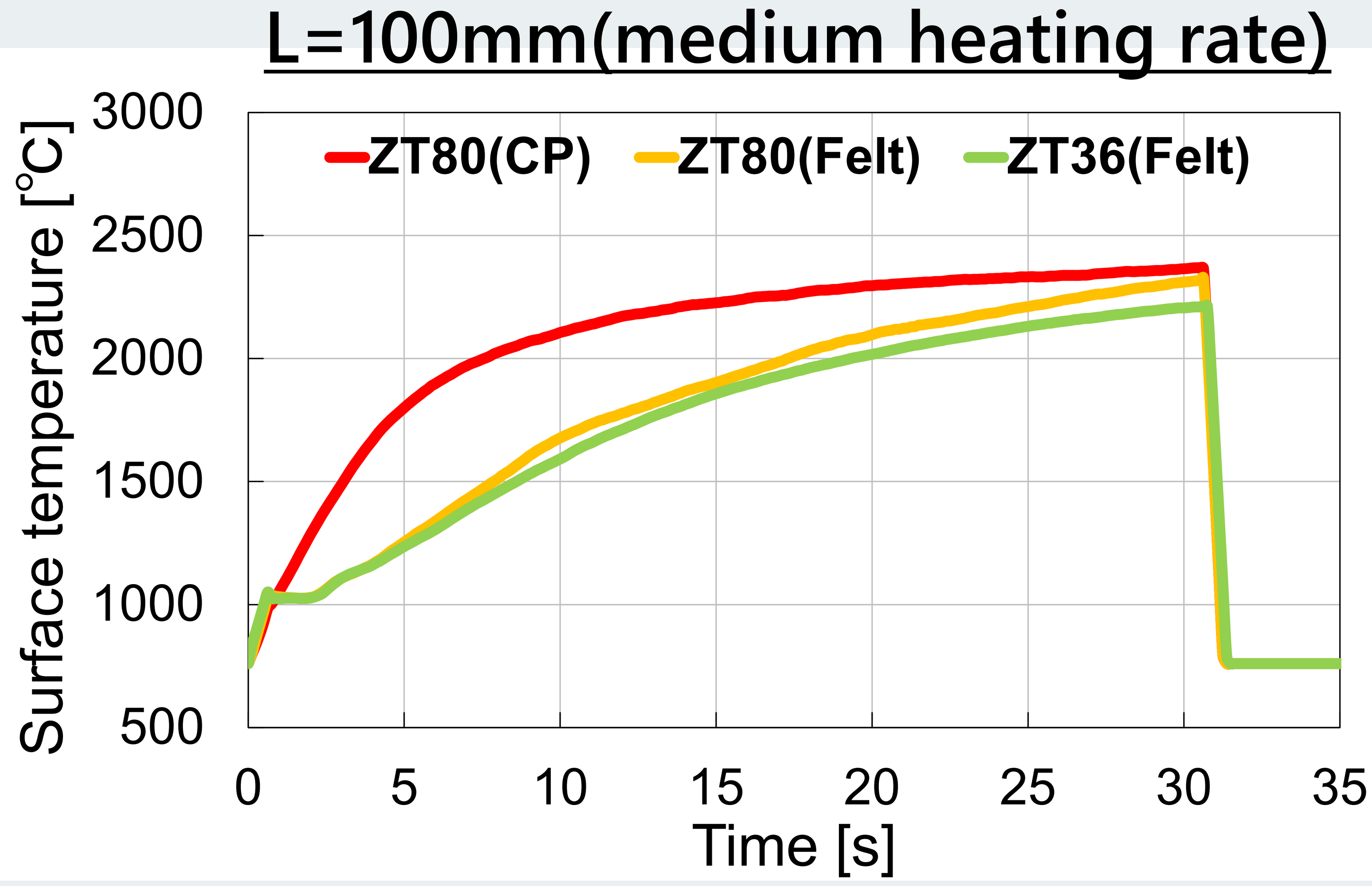
L: Distance between an arc nozzle and the specimen

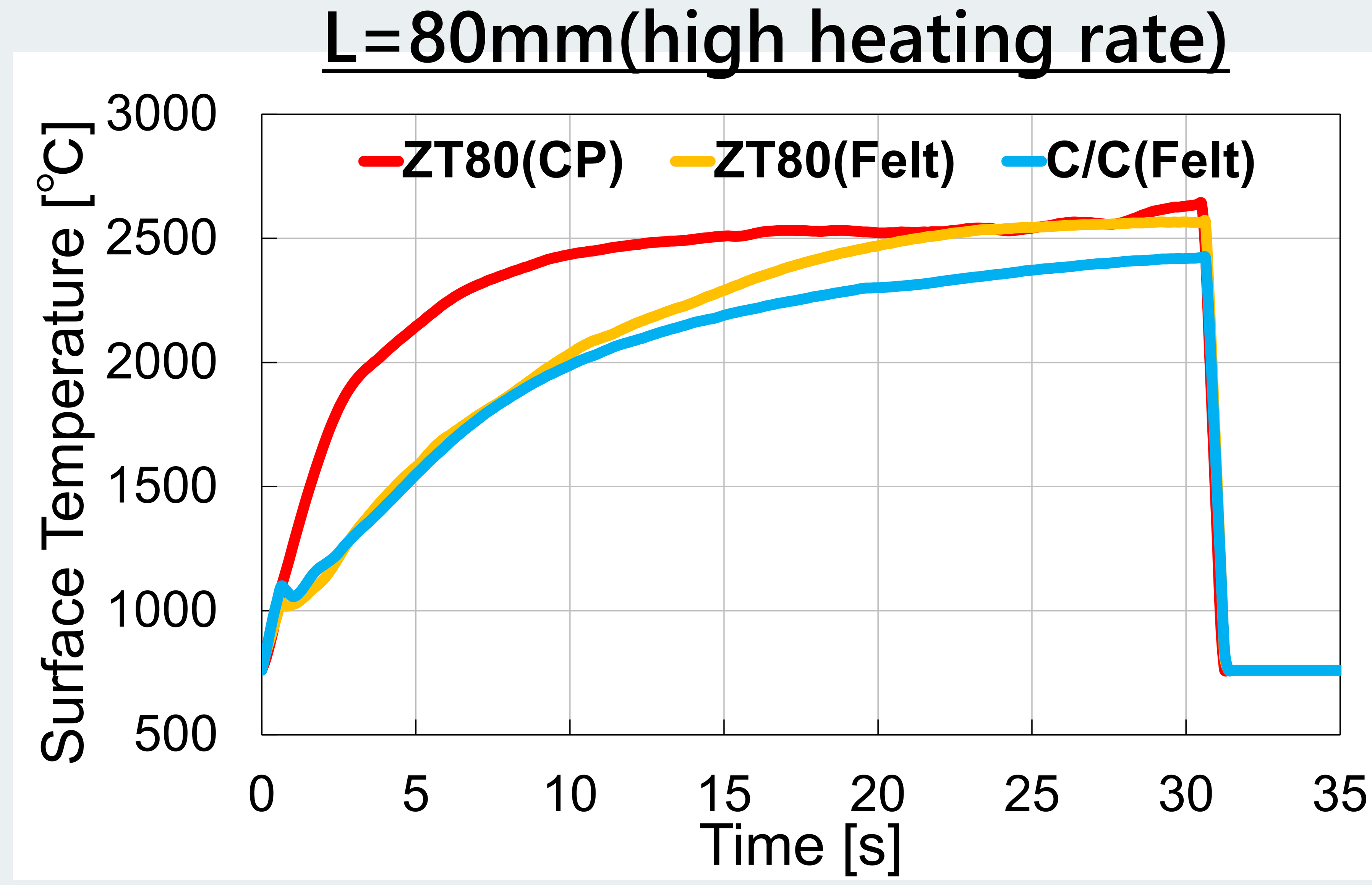
Sample／Test condition

Sample	Details	*L* [mm]	Heating time [s]	Heating rate [MW/m2]	Dynamic pressure [kPa]
A	ZT80 (CP)	100	30	4.8	13.5
B	ZT80 (Felt)				
C	ZT36 (Felt)				
D	ZT80 (CP)	80	30	7.3	21.4
E	ZT80 (Felt)				
F	C/C (Felt)				

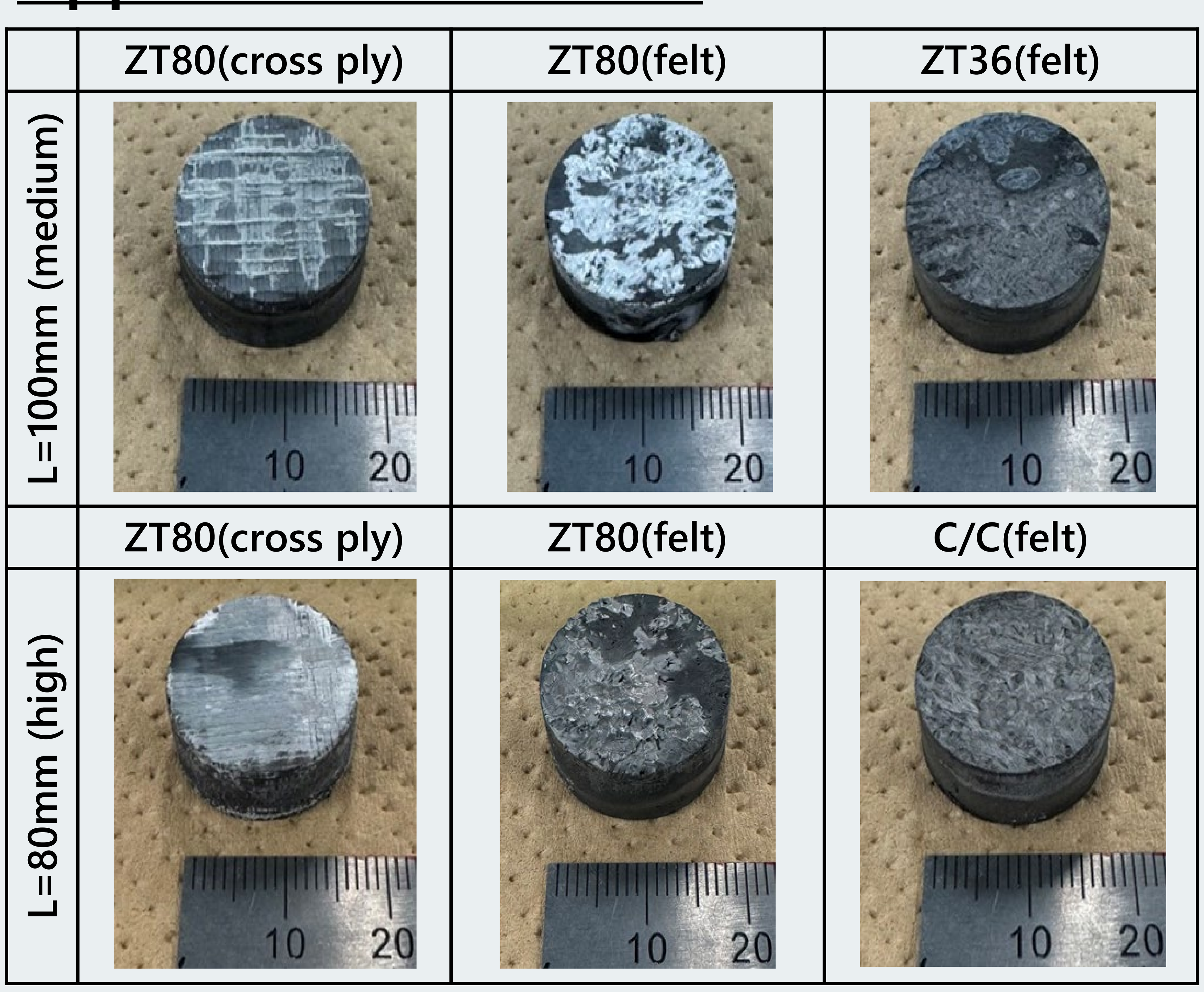
CP: Cross Ply (0/90°)、ZT80: Zr/Ti=80/20、ZT36: Zr/Ti=36/64

Surface temperature change during test





Appearance after test



- Under joint development with Tokyo University of Science.
- As a result of arc heating wind tunnel tests on a pitch-based C/C composite as a base material and a material impregnated with Zr-Ti alloy, There were no cases of detachment.

- We plan to measure thermal and mechanical properties.

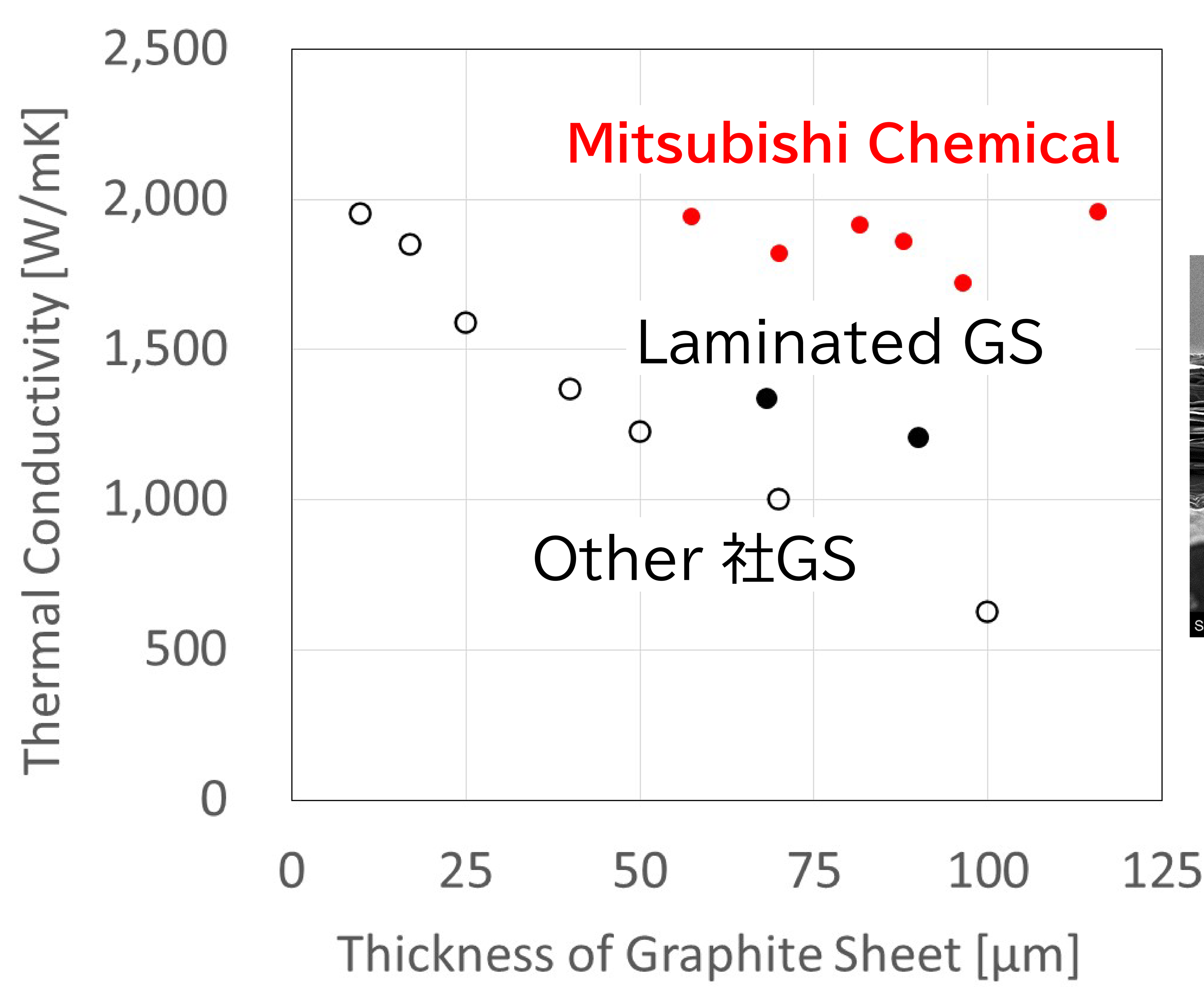
MITSUBISHI CHEMICAL GROUP

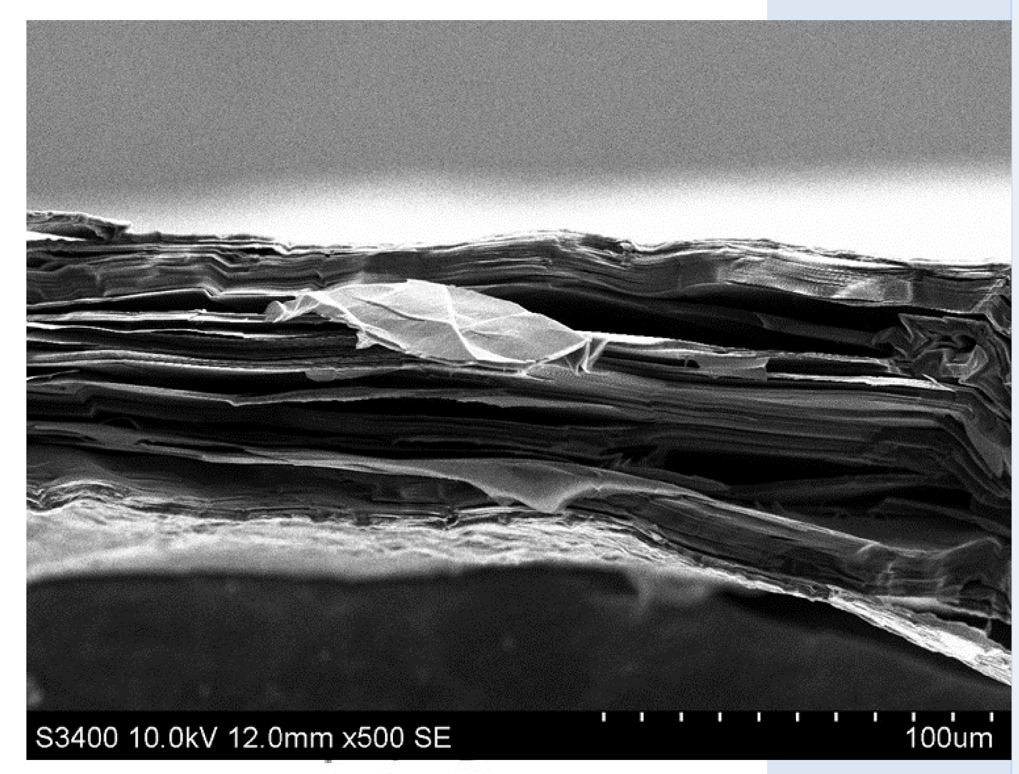
Mitsubishi Chemical Corporation

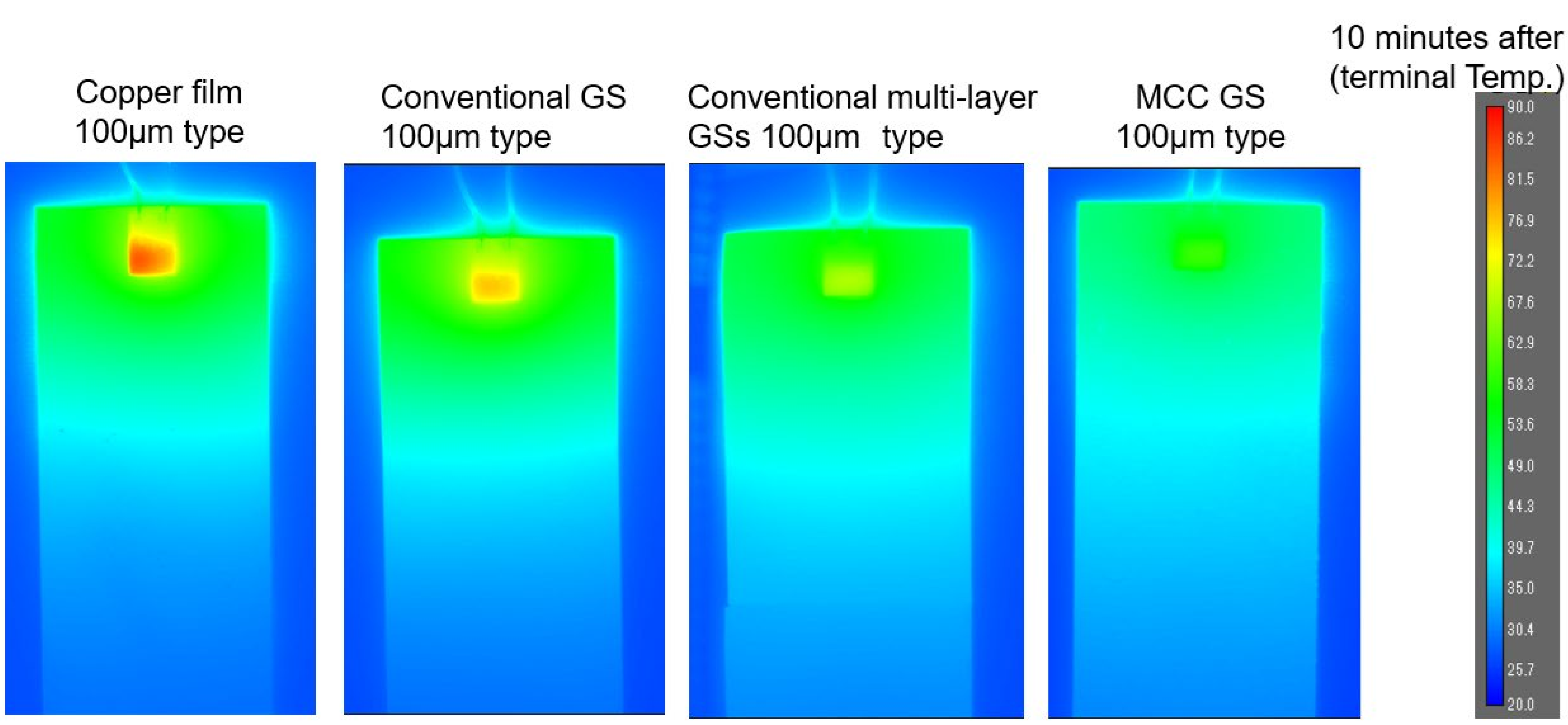
Innovative graphite sheet business development project

Space communication antenna, Optical laser, High TC C/C

Tickner than 100μm with High Thermal conductivity







MCC GS shows the best performance to lower the temp.

MITSUBISHI
CHEMICAL
GROUP

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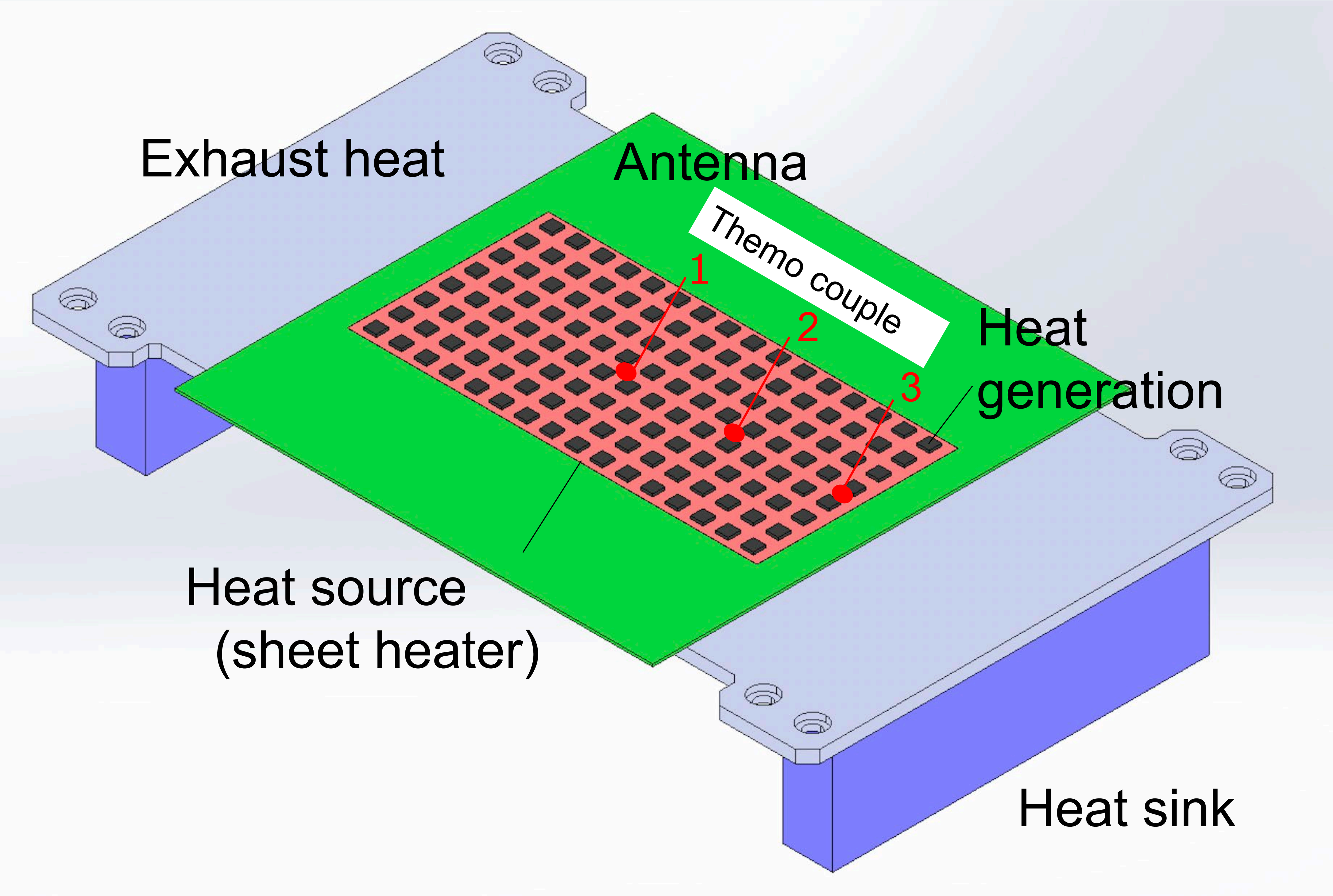
Innovative graphite sheet (GS) business development project

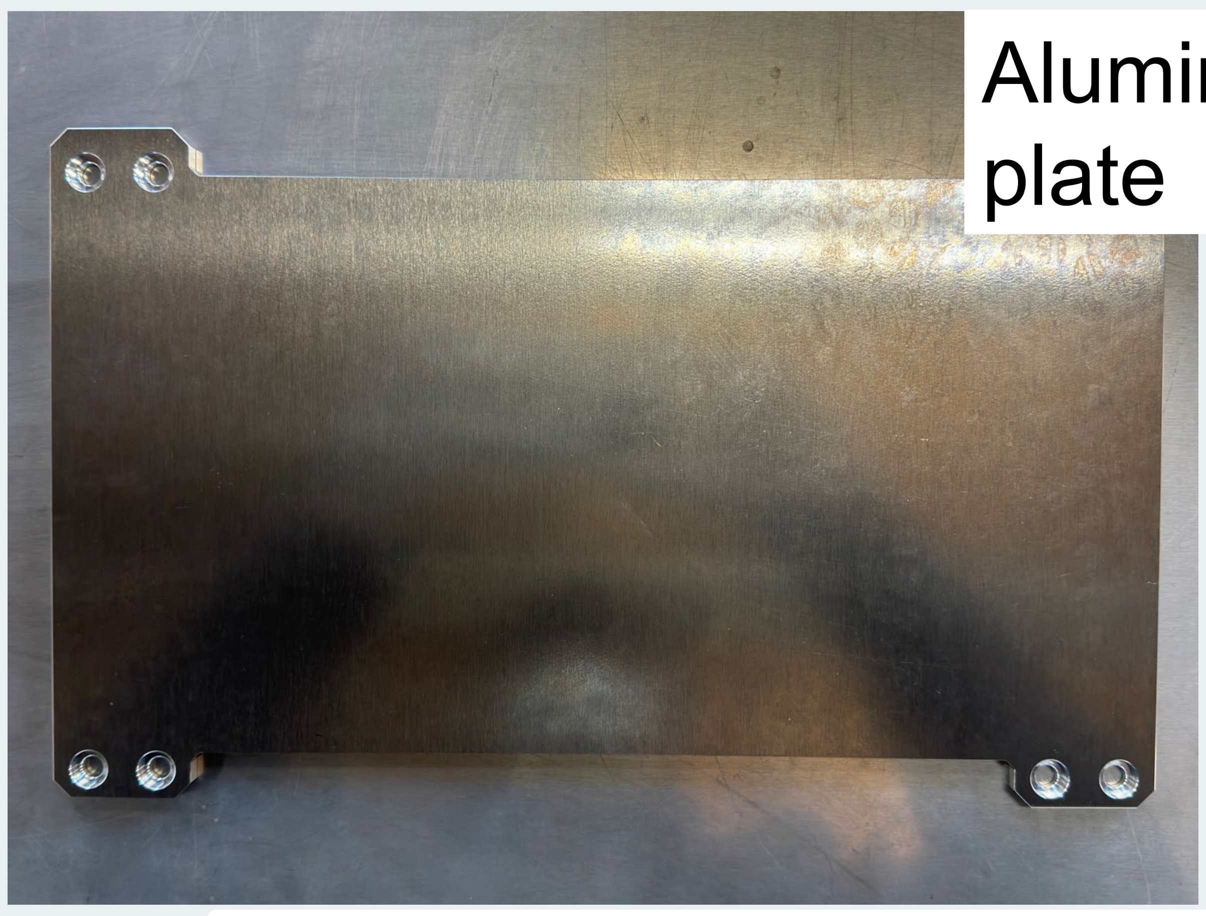
Heat exhaust plate of flat antenna for space communication: NICT/Tech Lab

Exhibit and space communication demo at NICT event

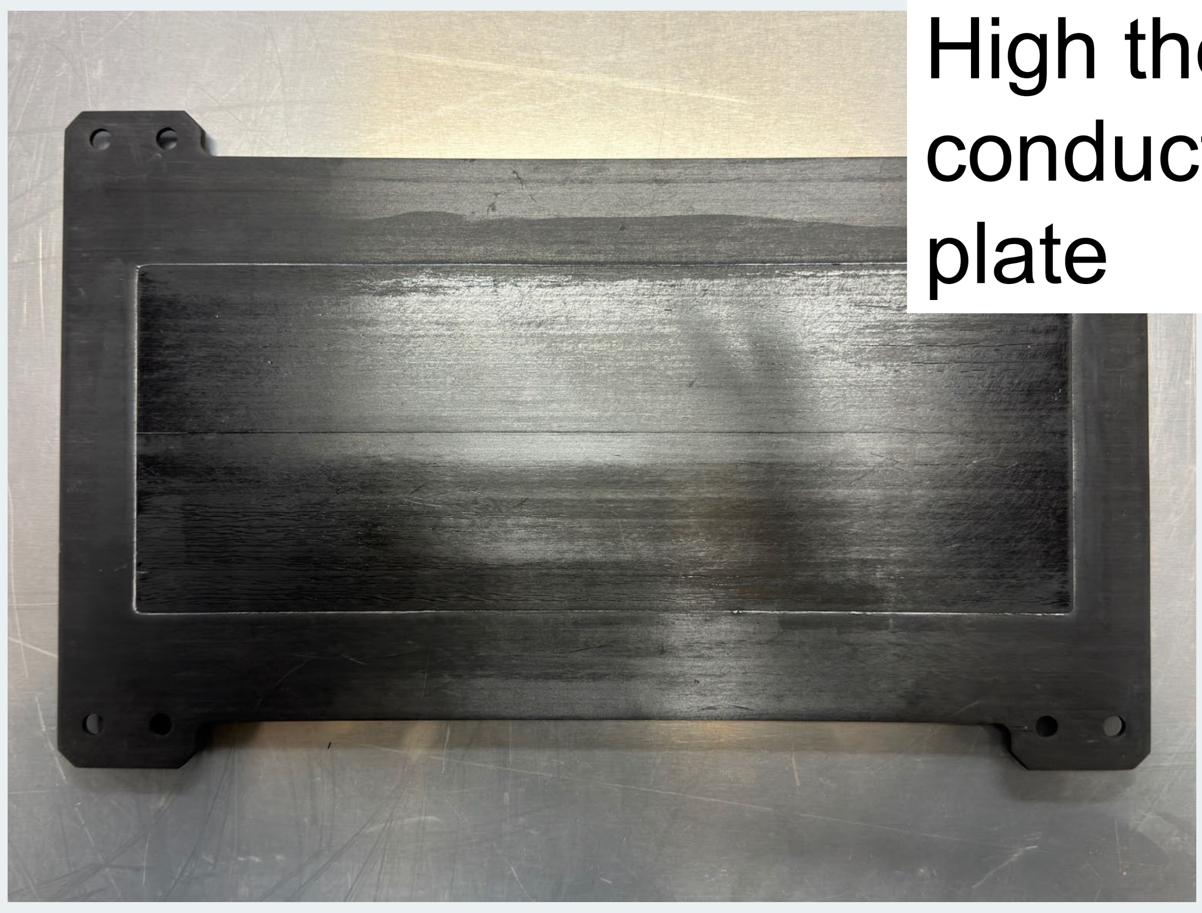
Verification of high thermal conductivity performance through heat generation/exhaust heat model experiments of flat antennas



The effectiveness of suppressing heat generation in antenna elements using a heat exhaust plate that takes advantage of the high thermal conductivity of graphite sheets has been experimentally verified.



Aluminum plate



Graphite sheet/ High thermal conductivity CFRP plate

		Material of plate		
		Aluminum	CFRP	GS/CFRP
Density		2.7	1.7	1.8
Themo couple	1	61.4°C	57.9°C	39.4°C
	2	60.1°C	55.6°C	36.5°C
	3	50.5°C	48.4°C	26.5°C

Aluminum heat exhaust plate weighing over 20 kg can be reduced to less than 4 kg. (Thinner due to lighter material x high heat transfer performance)

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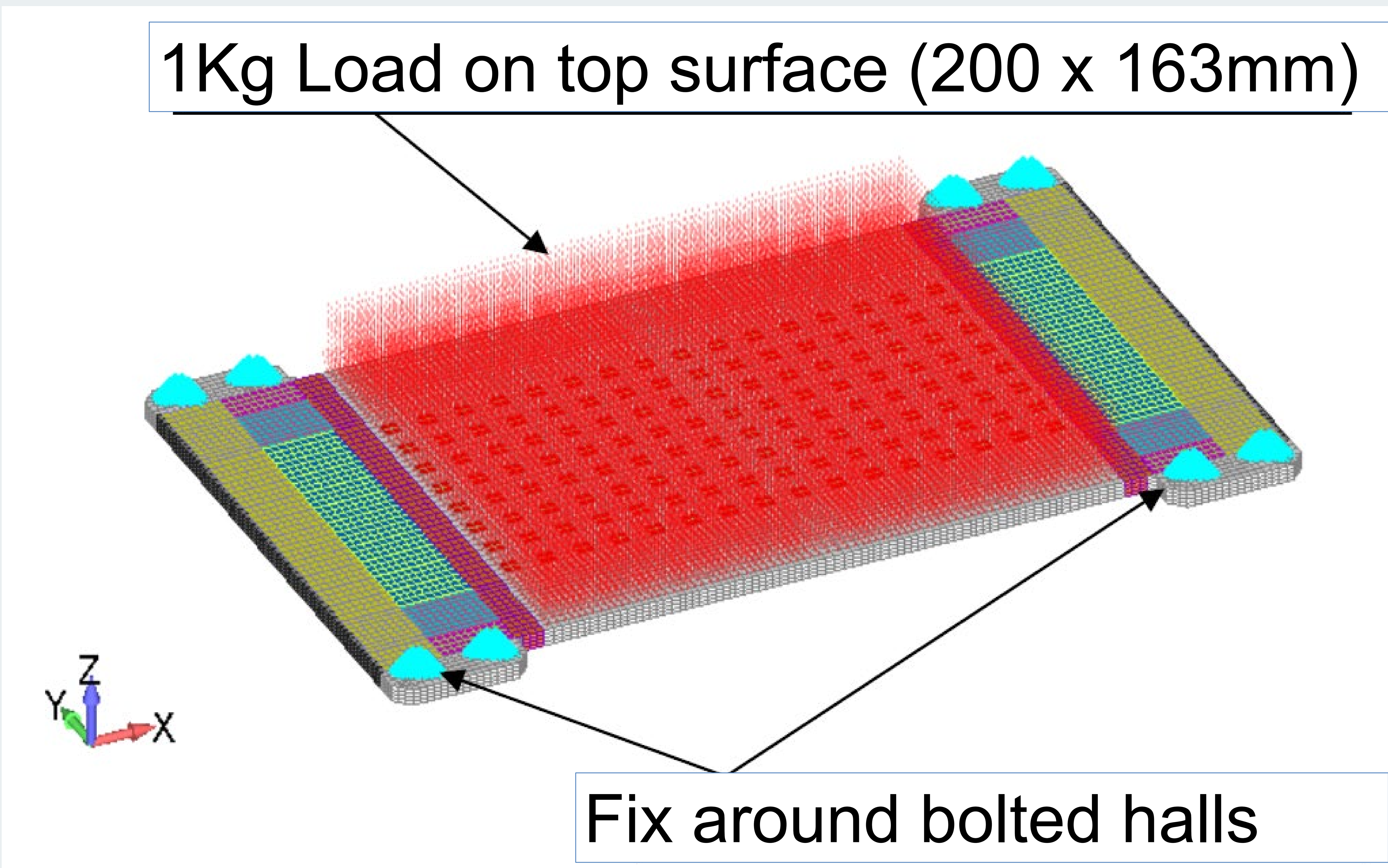
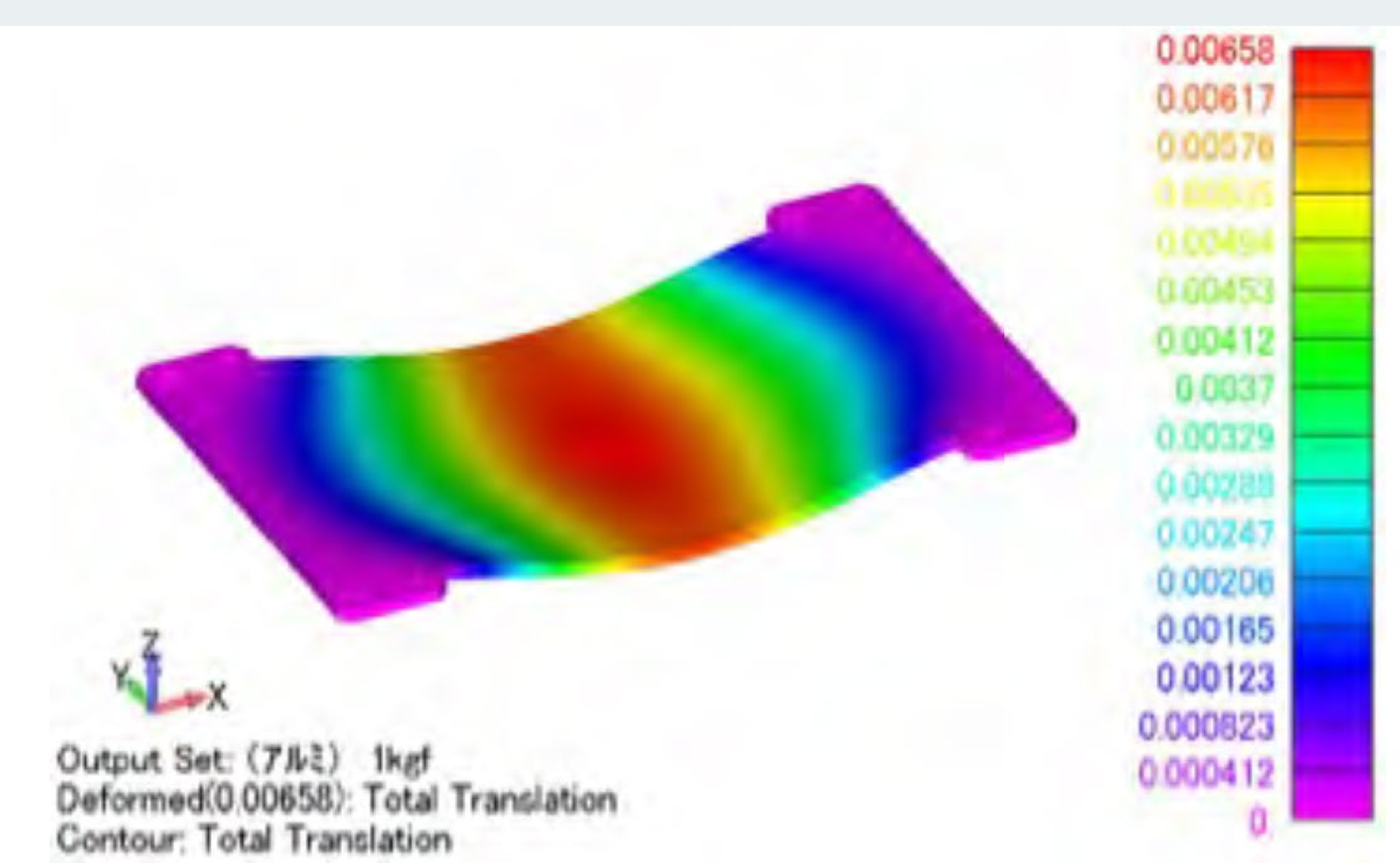
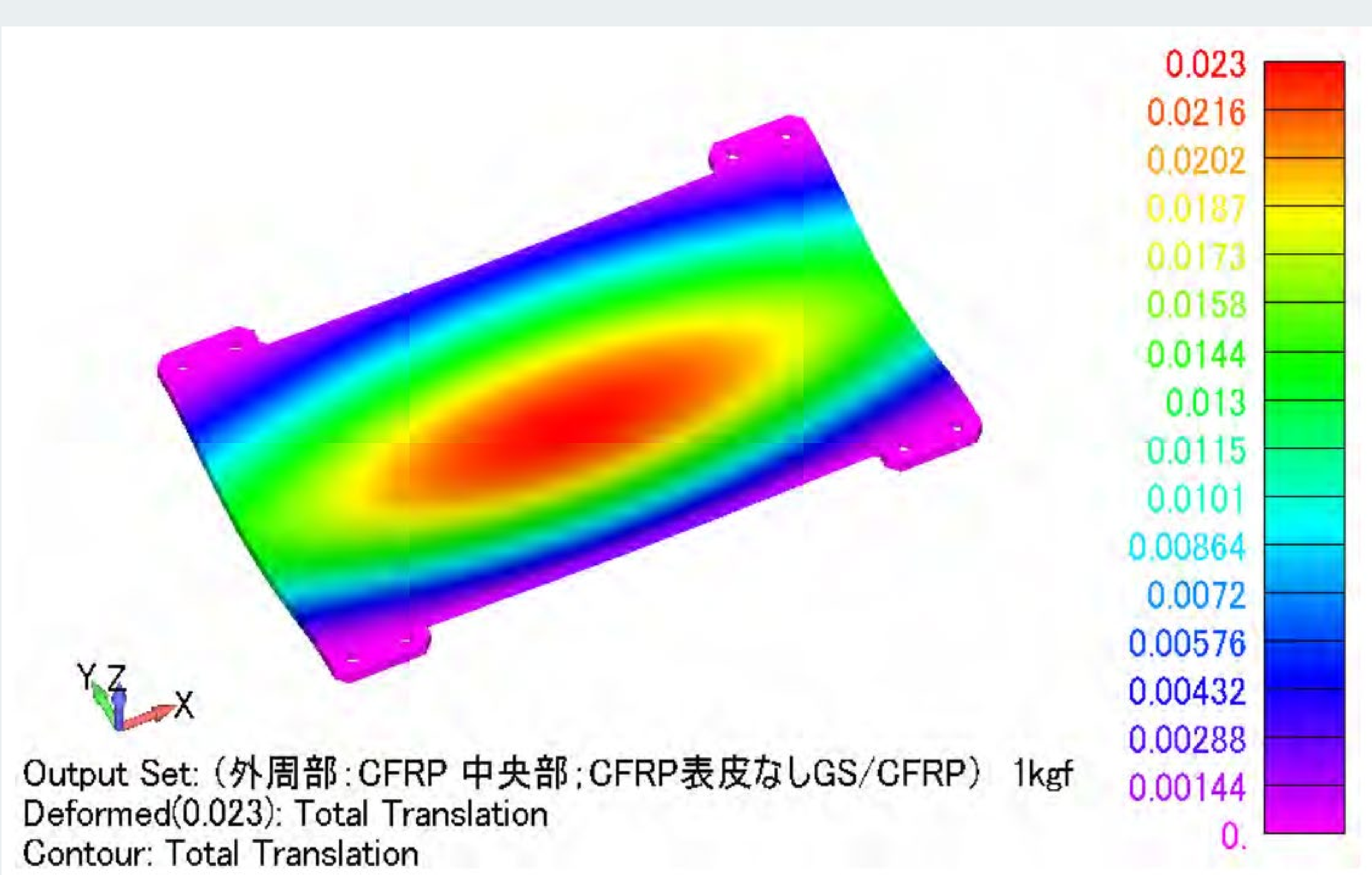
Innovative graphite sheet (GS) business development project

Heat exhaust plate of flat antenna for space communication: NICT/Tech Lab

Deformation amount when loaded with 9.8N (1kg equivalent weight)







Aluminum heat exhaust plate Weight: 7.2kg
Maximum displacement: 7μm

Graphite sheet/high thermal conductivity CFRP heat exhaust plate Weight: 4.5kg
Maximum displacement: 23μm

Moon Robot YAOKI

Mitsubishi Chemical Group Corporate strategy meeting **Vision & Strategy**

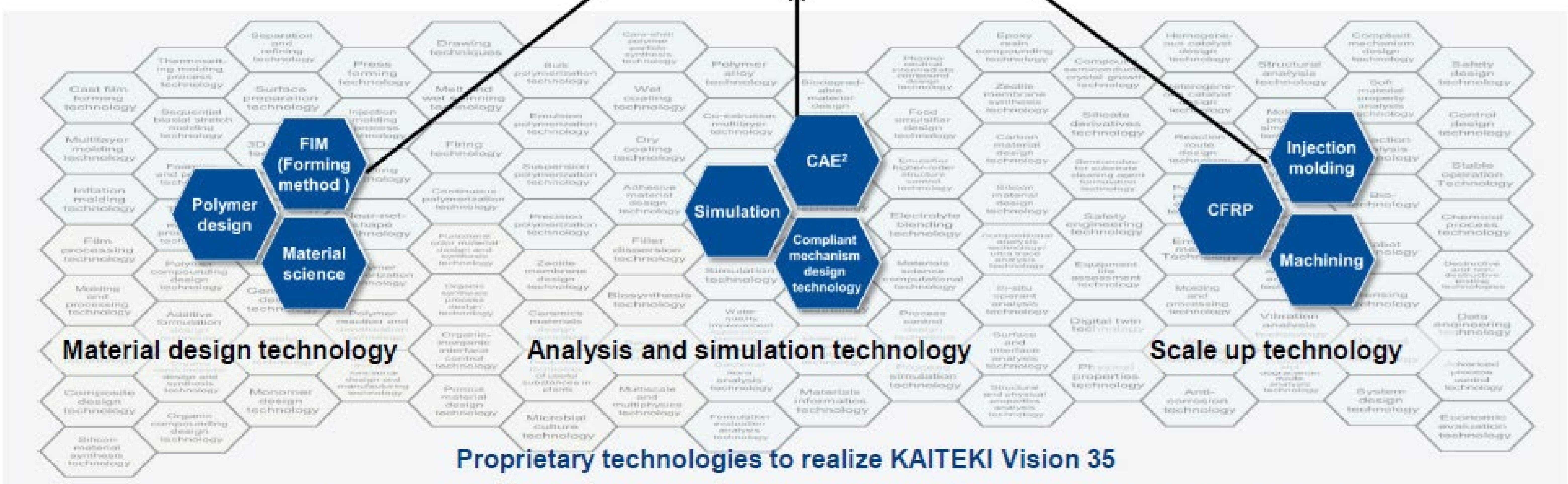
Successful examples of solutions: connecting our technologies

MITSUBISHI CHEMICAL GROUP

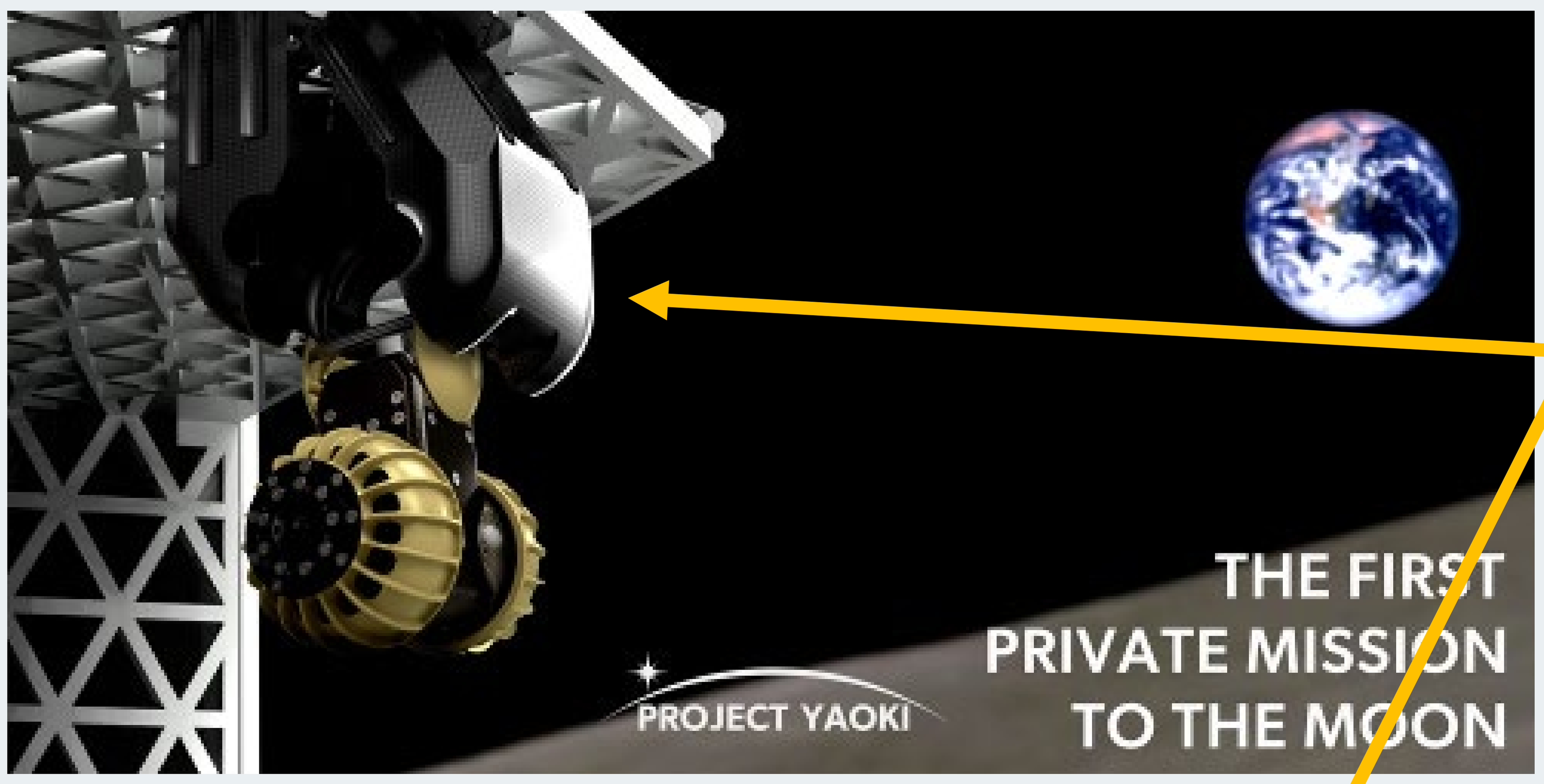
High-rigidity, lightweight materials for aerospace

- Lunar rover[1] "YAOKI" of Dymon Co., Ltd. combines various technologies and products in its structure, tires, sliders, and lens sections to achieve both lightweight and improved shock resistance

Lunar rover "YAOKI"



1. Missions can be carried out on the moon without deterioration in physical properties, even in environments with temperatures ranging from -170° C to 110° C and exposure to cosmic radiation
2. Computer Aided Engineering



「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

MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

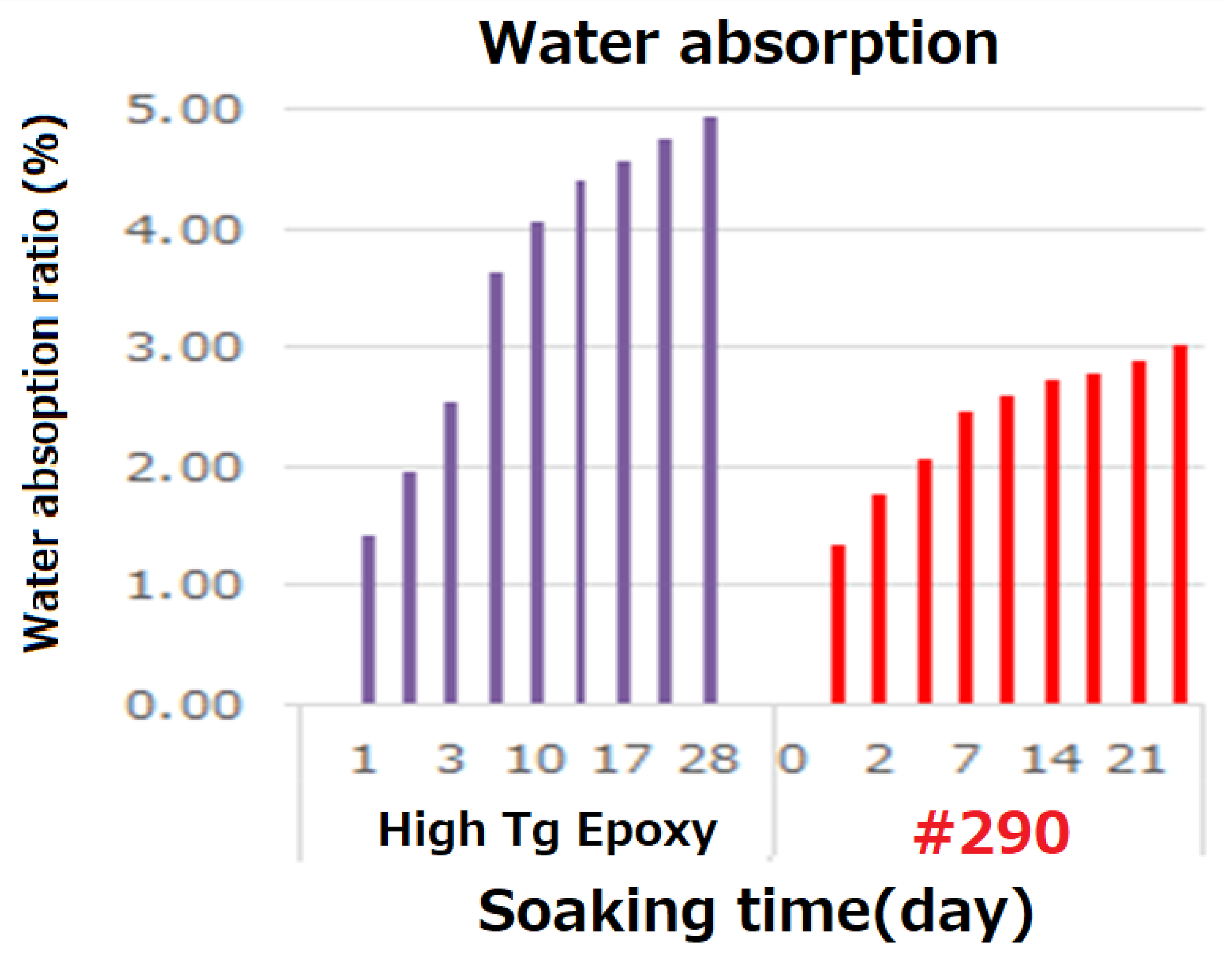
Cyanate ester resin CFRP

Characteristics of cyanate resin CFRP

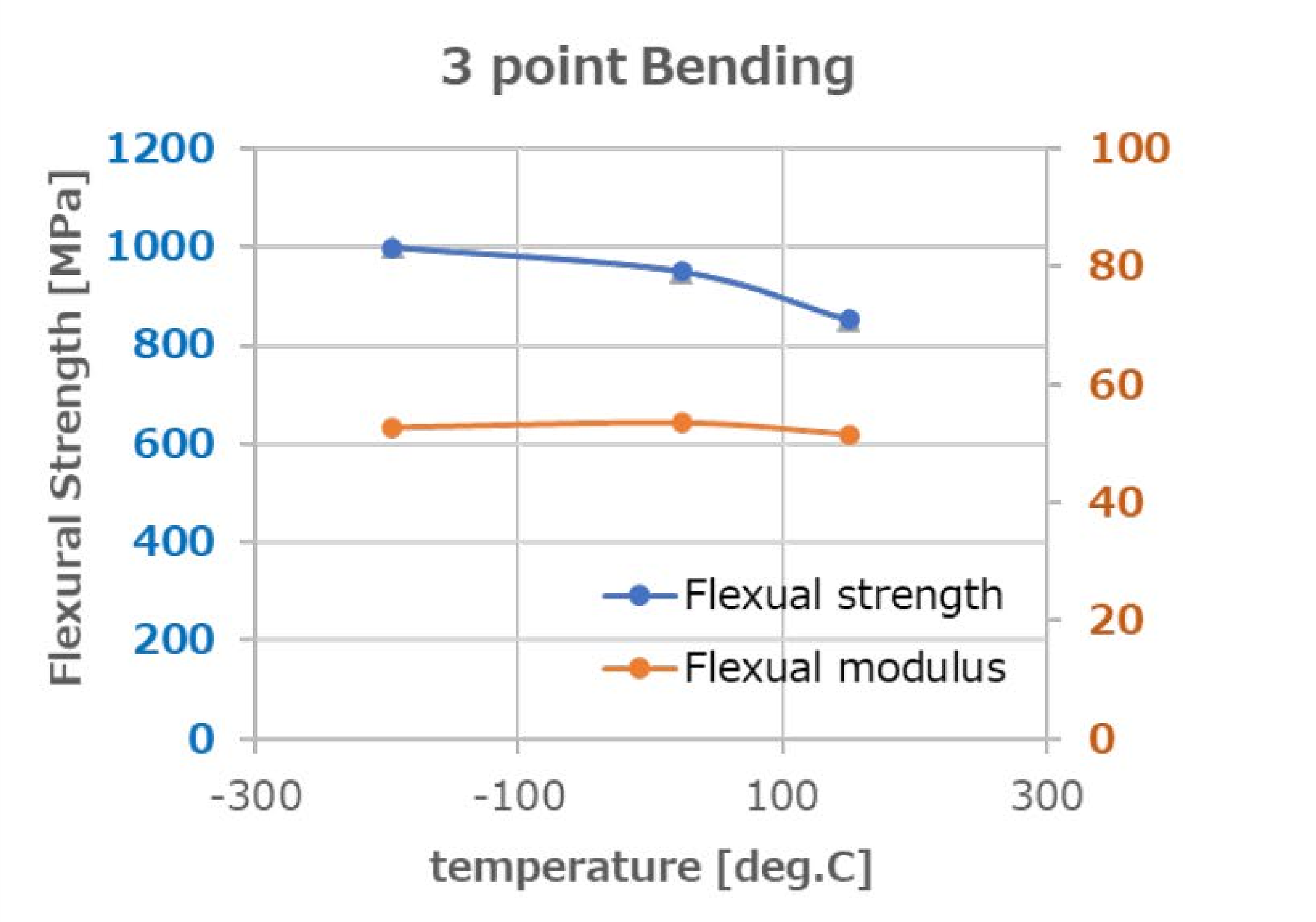
Low moisture absorption ➡ Small Coefficient of Moisture Expansion (CME)
Less cryogenic micro-cracks ➡ No loss of strength at cryogenic temperatures
Low dielectric constant ➡ Low electromagnetic wave loss

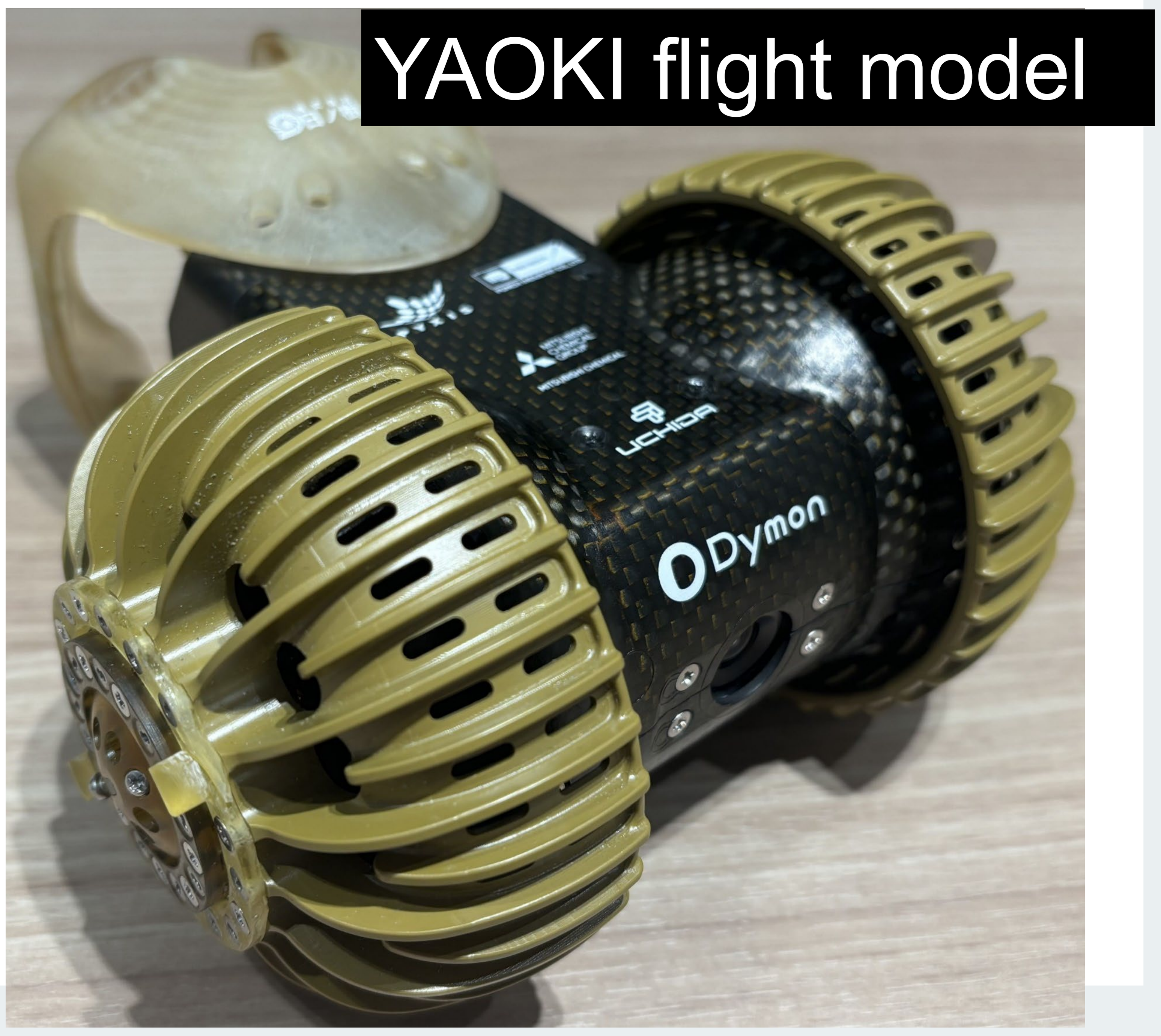
【Characteristic of Cyanate ester resin "#290"】

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



TR3110 290GMP （FAW 196g/m2, RC 40wt%）





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

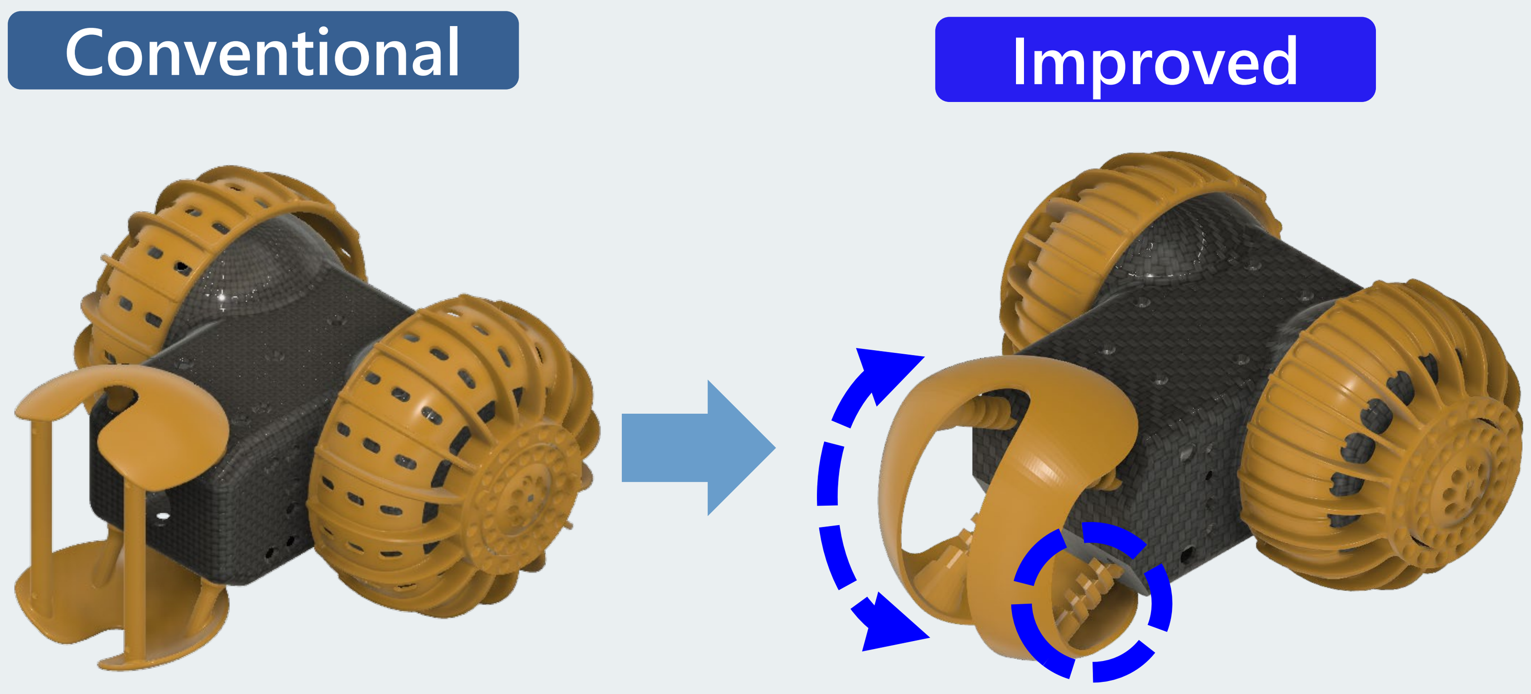
Compliant Mechanism Design

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

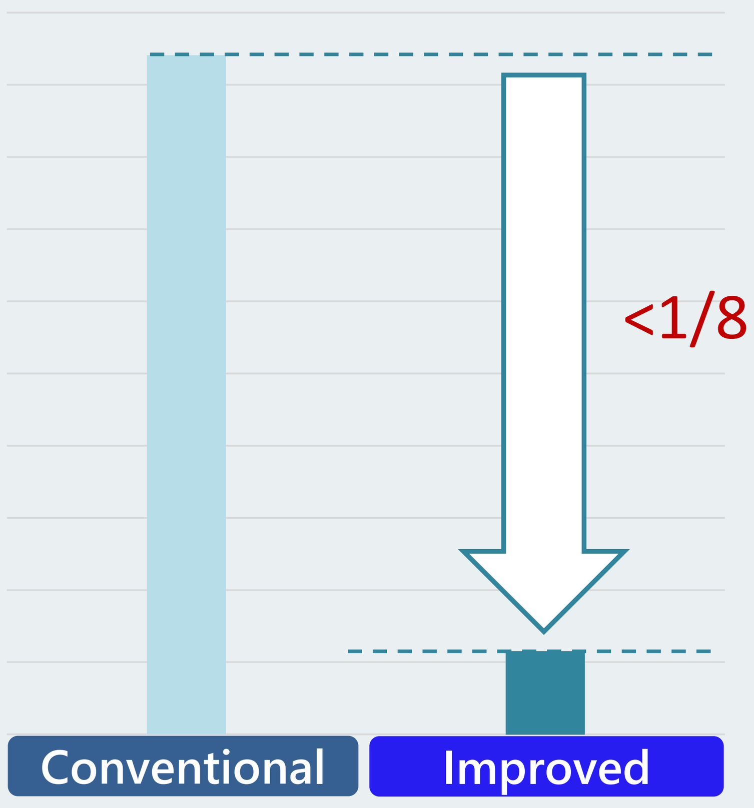
The compliant mechanism is a design concept in which movement is achieved by the suppleness of the material. By replacing conventionally assembled and fabricated products with supple one-piece resin products, various advantages such as improved performance and weight reduction can be created.

Example of space application: "YAOKI" slider improvement

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.



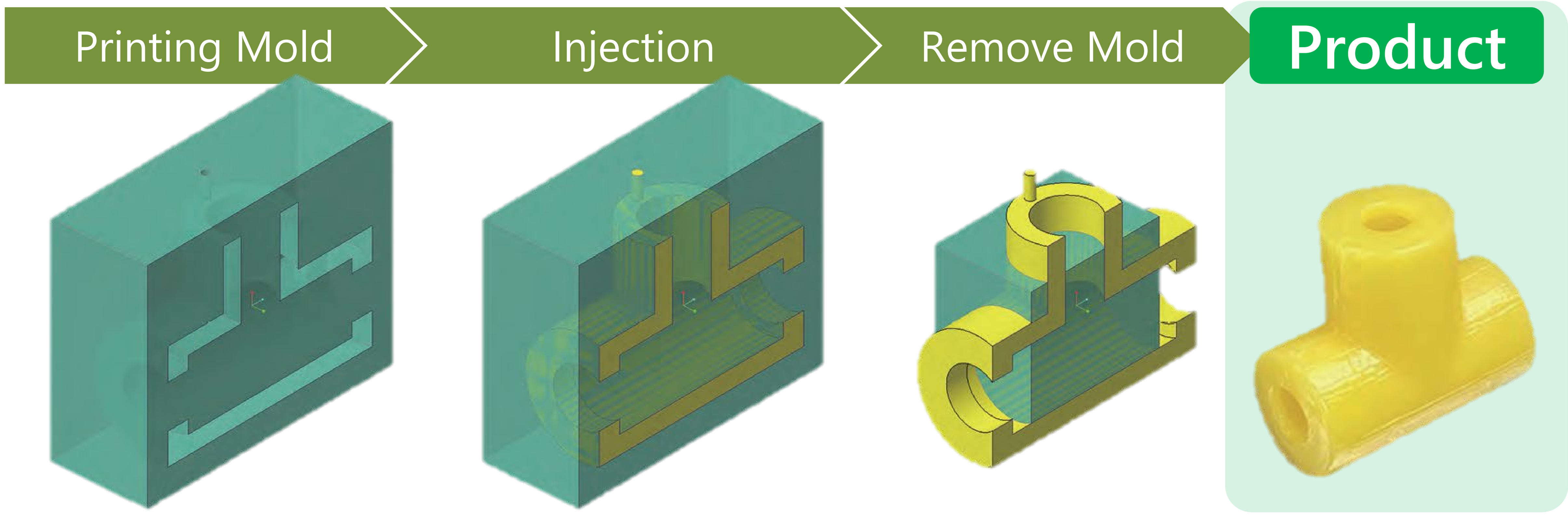
Impact dispersion in the component



In an example of application to a small lunar exploration vehicle under development, the maximum stress applied to a component in the event of a collision was successfully reduced to 1/8 or less, while minimizing the weight increase. The vehicle was adopted as a lunar surface transportation model.

Free-form Injection Molding

Free-form injection molding (FIM) is a novel injection molding technology that uses 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.



Improved "YAOKI" Slider Example

Our group companies (*) possess this technology, which enables us to develop products from compliant mechanism design to modeling in a single integrated process.

* MCC Advanced Moldings Co., Ltd.

MITSUBISHI CHEMICAL GROUP

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

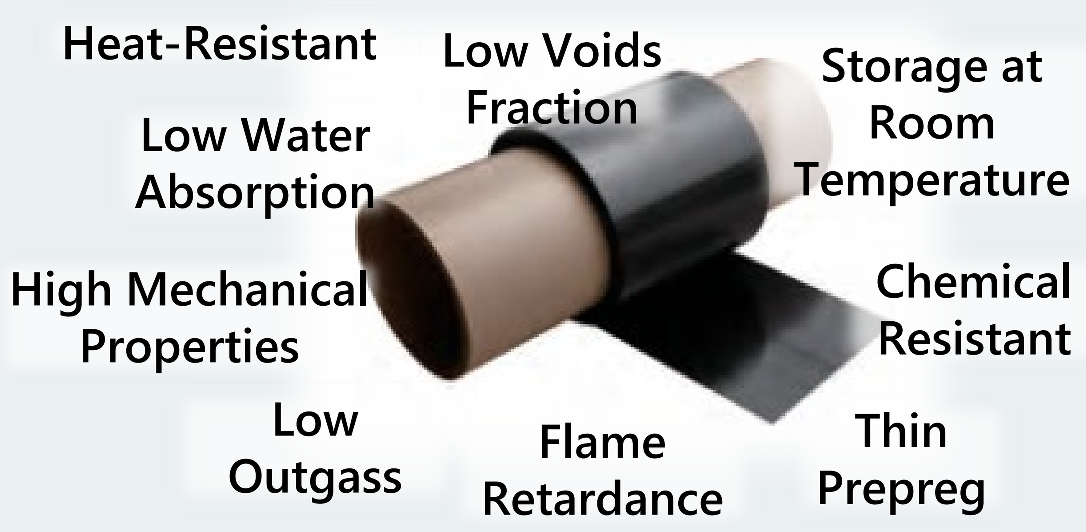
What is Kyron™ULTRA ?

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

【Potential Applications in Space Equipment】

Kyron™ULTRA

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

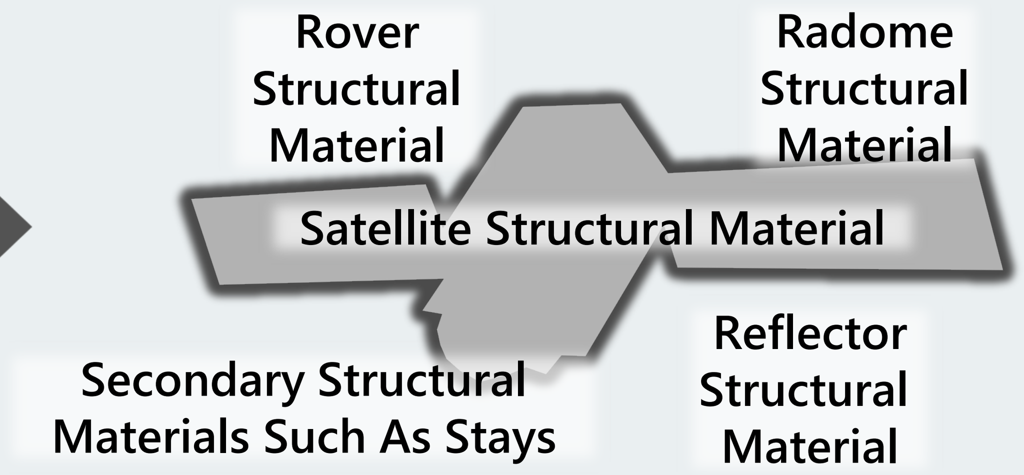


Molding Methods

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

Potential Applications

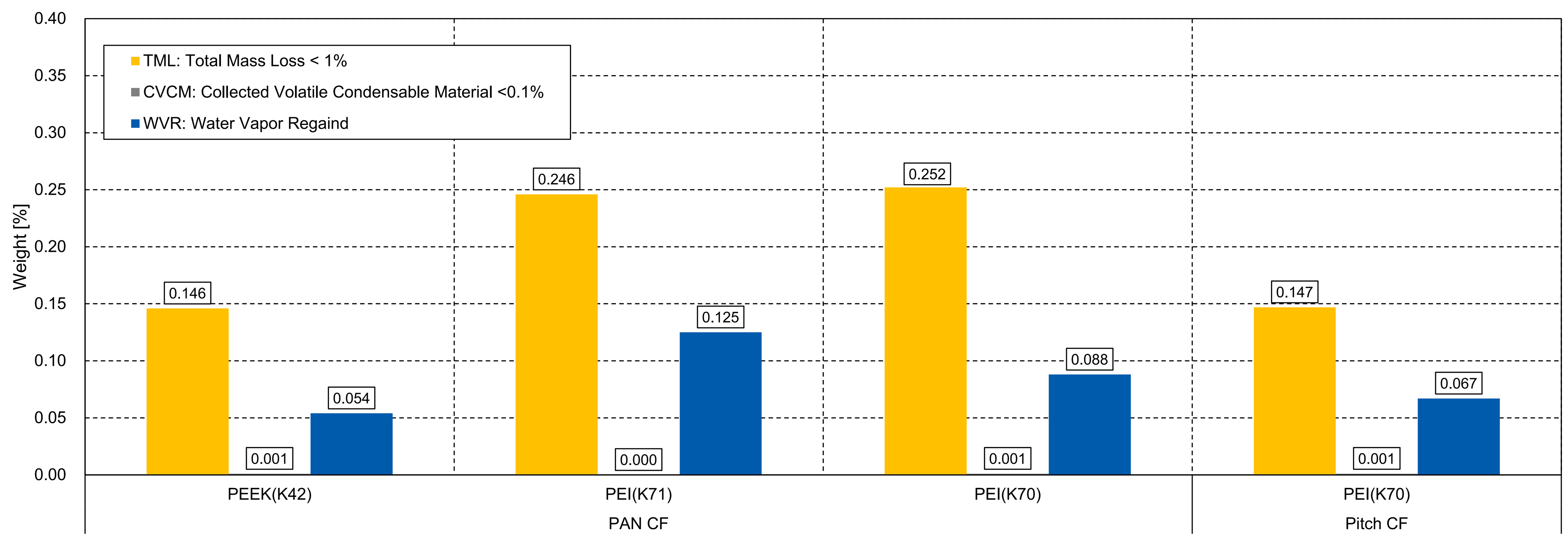
Providing high-performance, lightweight solutions to the space equipment industry.



【Prepreg Lineup】

Matrix Resin(Code)	PEI(K70)/Chemical Resistant PEI(K71)/Low Viscosity PEI(K72) PEEK(K42)/Heat Resistant PEEK(K44)
Reinforcement	PAN CF(Regular) / PITCH CF(Super High Modulus)

【Property Example: Outgas Measurment Data ASTM E595】



Every material shows excellent outgas properties in TML/CVCM/WVR.

Published Outgas Data on JAXA Materials Database

Material（Product) Field

Kyron

【Kyron™ULTRA Molded Parts Lineup】

The molded parts such as flat plates and brackets will be in the lineup. L-shaped brackets that take advantage of the strengths of CFRTP, which has high strength and excellent mass productivity, have a thickness of 1.4/2.1 mm and a length of 500 mm as standard specifications.

W30mm×H30mm×L500㎜ T1.4/2.1㎜ Standard Dimension

L-shaped Brakets Made of Kyron™ULTRA

The bracket above is a prototype that differs from the standard dimensions.

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PYROFIL™ CFP/GDL (Gas Diffusion Layer)

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).

【Advantages】

- Carbon paper type / Superior surface smoothness
- Enhanced water management ability by distinctive porous structure
- Excellent process ability in roll-to-roll process

【Packaging specification】

- Cut sheet (300mm × 200mm)
- Small roll sample (W300mm x L10m)
  *Long rolls are also available
  (width and length negotiable)

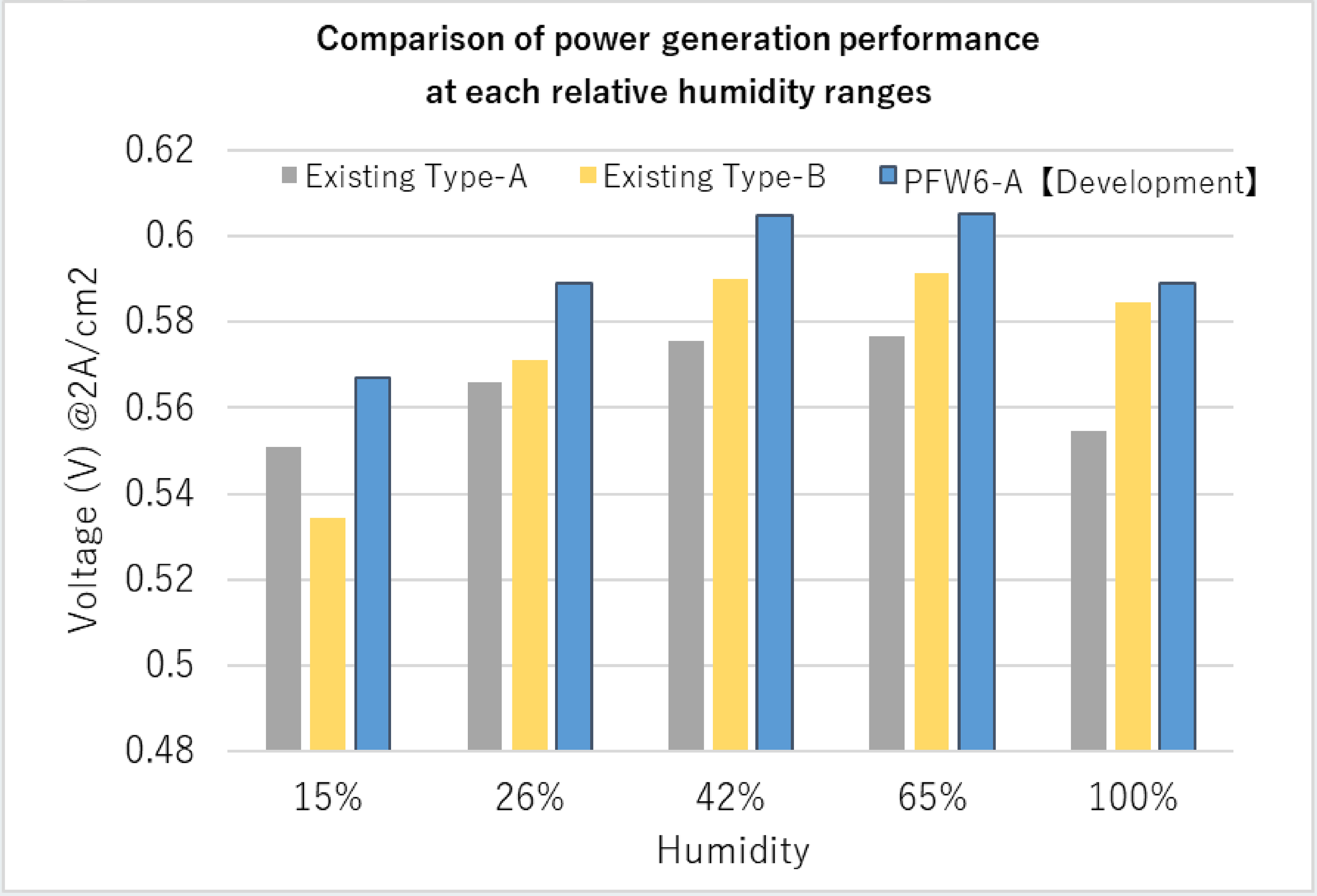
【Product Line-up】

Item	Unit	MFK	MFX	MFL	Development MFKTN	Development PFW6	MFK-A	MFX-A	MFL-A	Development MFKTN-A	Development PFW6-A
Surface Treatment	-	Non	Non	Non	Non	Non	MPL	MPL	MPL	MPL	MPL
Thickness	[mm]	0.205	0.170	0.125	0.160	0.120	0.220	0.190	0.150	0.173	0.137
Compressed Thickness	[mm] @1MPa	0.180	0.140	0.110	0.129	0.089	0.200	0.160	0.120	0.145	0.104
Area Weight	[%]@1MPa	12	18	12	19	26	9	16	20	16	24
Bulk Density	[g/m^2]	63	57	39	45	40	79	73	55	59	54
Gas Permeability	[g/cm^3]	0.31	0.34	0.31	0.28	0.34	0.36	0.38	0.37	0.34	0.39
TP Electrical Resistance	[mL/cm^2/hr/Pa]	200	950	700	260	600	10	40	30	10	10
Compression Ratio	[mΩ・cm^2] @1MPa	5.7	5.7	4.5	5.0	4.1	7.6	7.0	6.5	5.5	5.5
MD Flexural Strength	[MPa]	39	33	34	-	-	35	31	31	-	-
TD Flexural Strength	[MPa]	27	43	19	-	-	25	41	17	-	-
Porosity	[%]	83	80	83	84	81	80	79	80	81	78

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

【New Development "PFW6"】

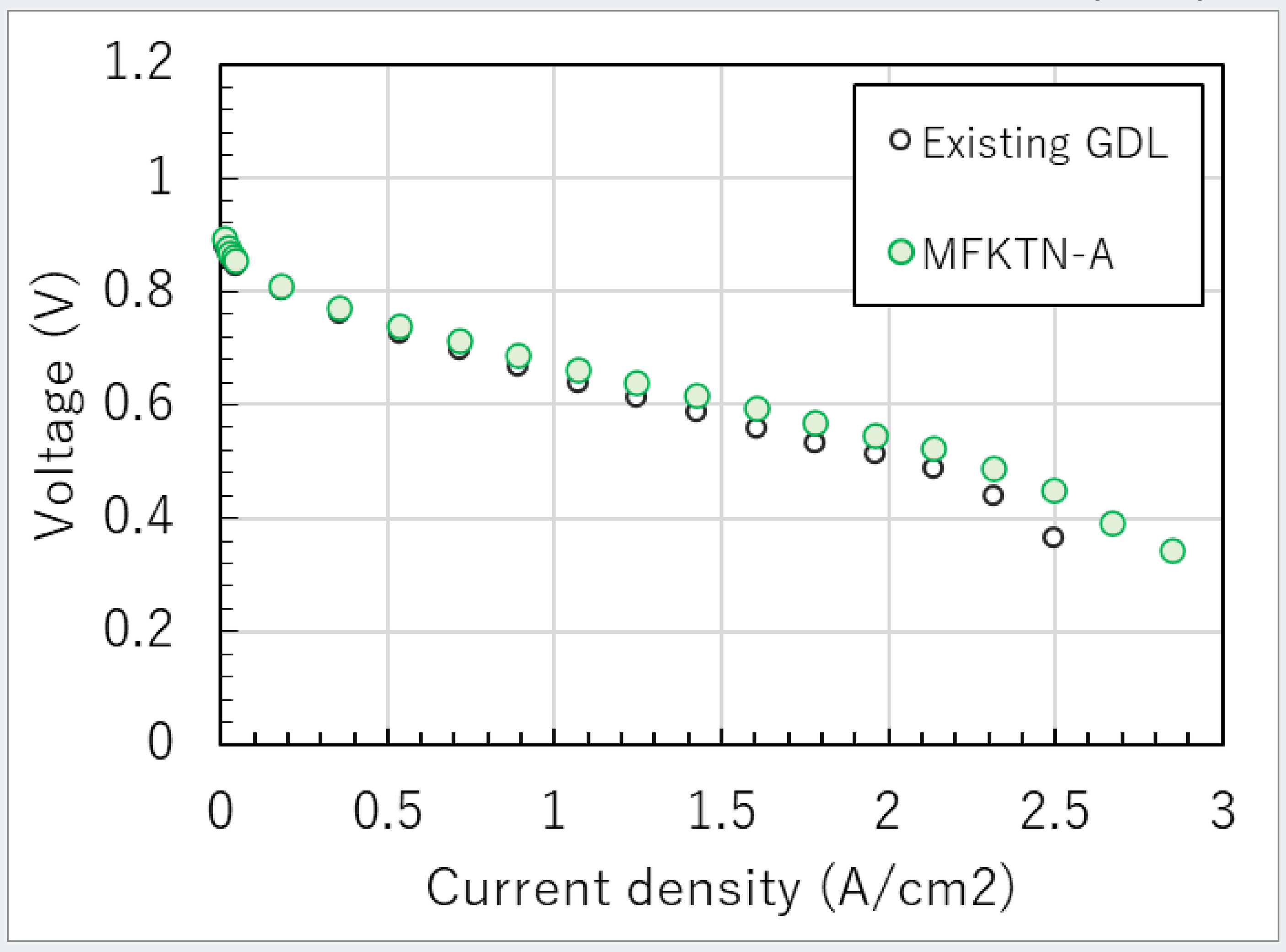
"Highest performance compared to conventional products in each power generation condition"



【New Development "MFKTN"】

"Enhanced power generation performance in dry conditions required for HDVs."

(※HDV=Heavy Duty Vehicle)



(※All data are based on our own comparison and under our standard test conditions, and these results are not guaranteed but just for the reference.)

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Anti-Soil Coating

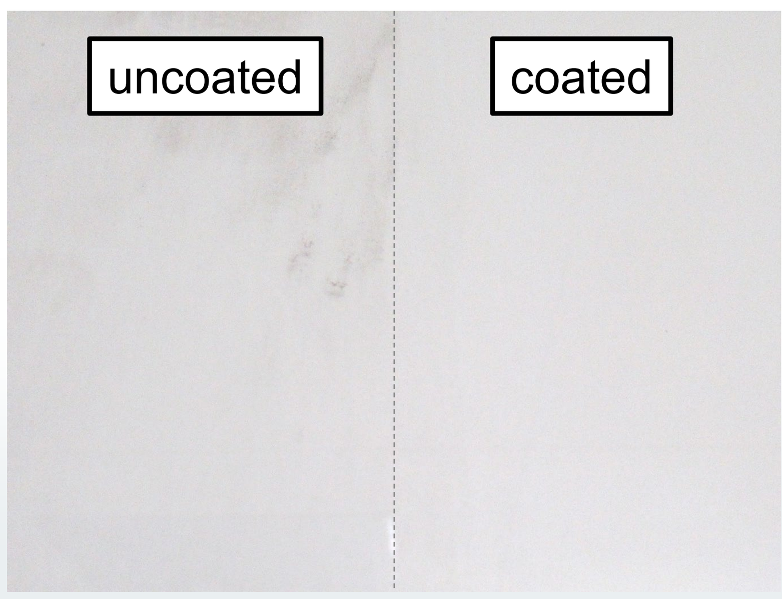
The film formed by wet coating has dust resistance. Its performance was also demonstrated to lunar sand regolith. At Mitsubishi Chemical, we not only provide coatings, but also propose optimal solutions tailored to your coating process.

Suitability for space applications

・Prevents regolith adhering to the surface of the coating.
・There is almost no change in weight because it is coated with a thin film.
・Strong weather resistance and good outgassing properties.

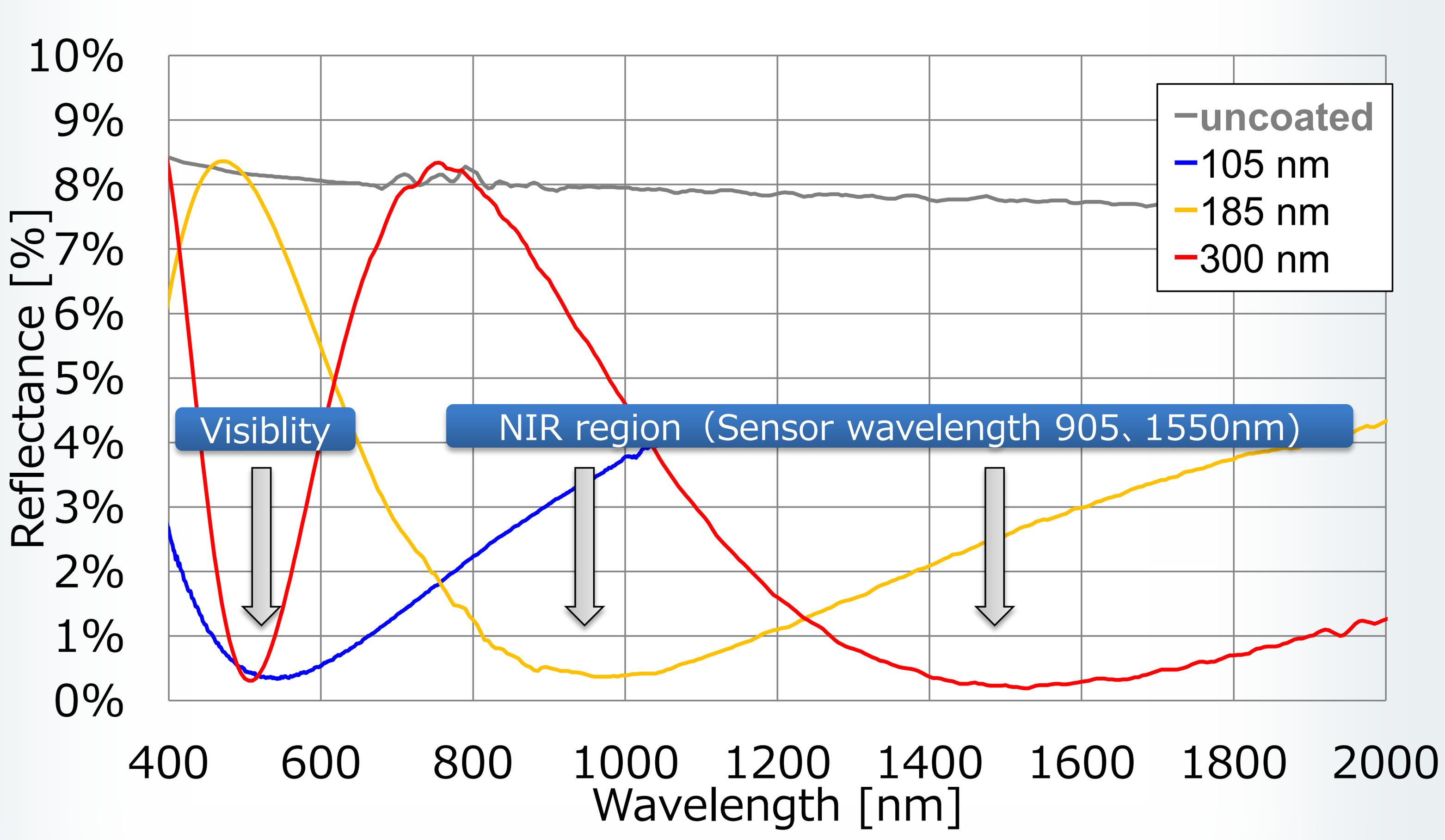
≪Adhesion test using lunar soil simulator "FJS-1"≫

		initial	After regolith adhesion test
Coated glass	Hz (%)	0.11	0.96
	T.T. (%)	94.24	94.24
Uncoated glass	Hz (%)	0.15	20.66
	T.T. (%)	90.77	85.63



Main characteristics of coating

≪Relationship between thickness and antireflection ≫



＊Double-sided coating on glass

・A thin porous silica film with a low refractive index.

・By adjusting the film thickness, it is possible to prevent reflections from the visible region to the near-infrared region.

・The refractive index can be controlled from 1.18 to 1.35.

・Applicable to various coating methods with wet coating.

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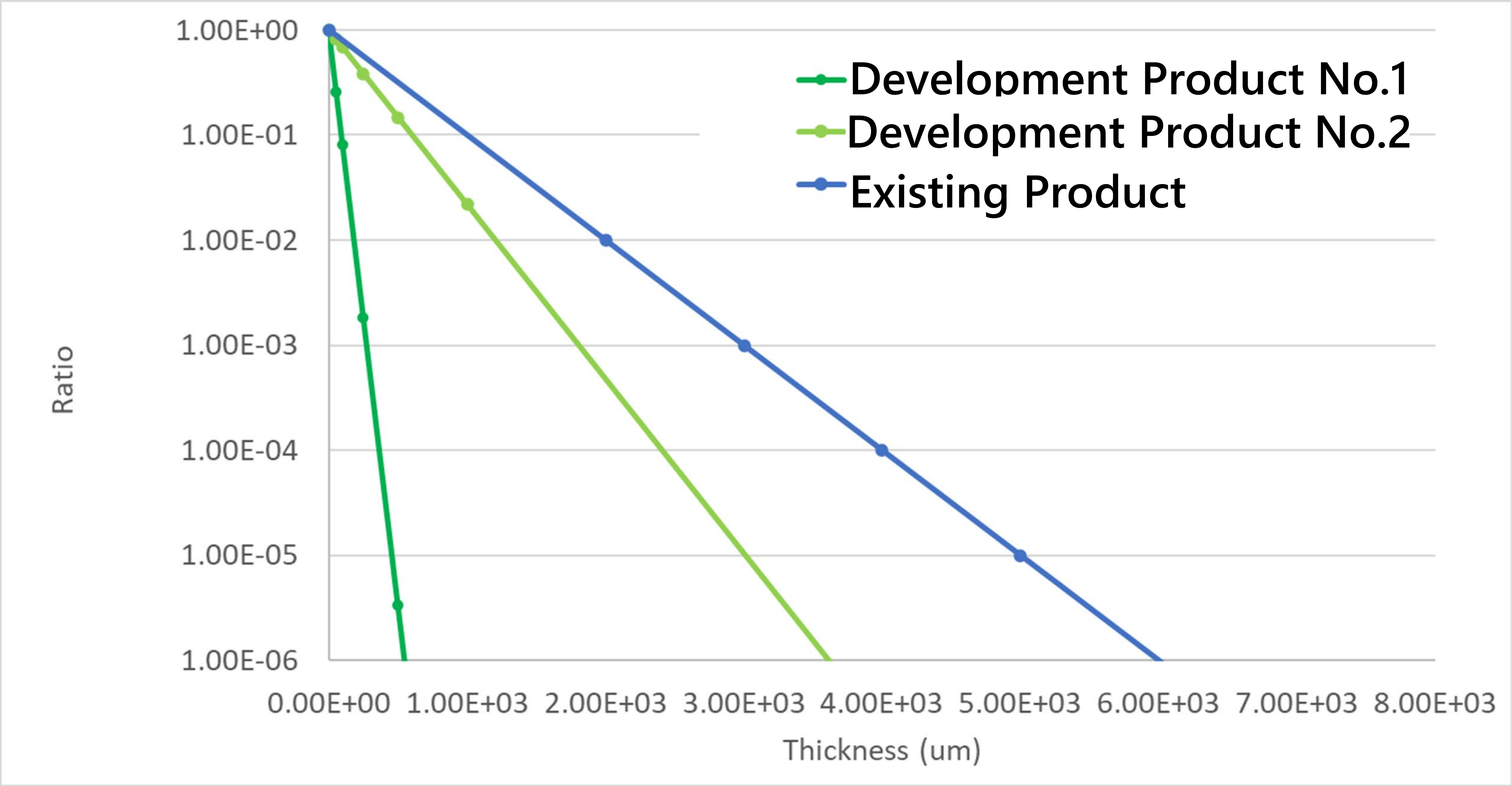
Neutron Shielding Coating
(Development Product)

【Characters】

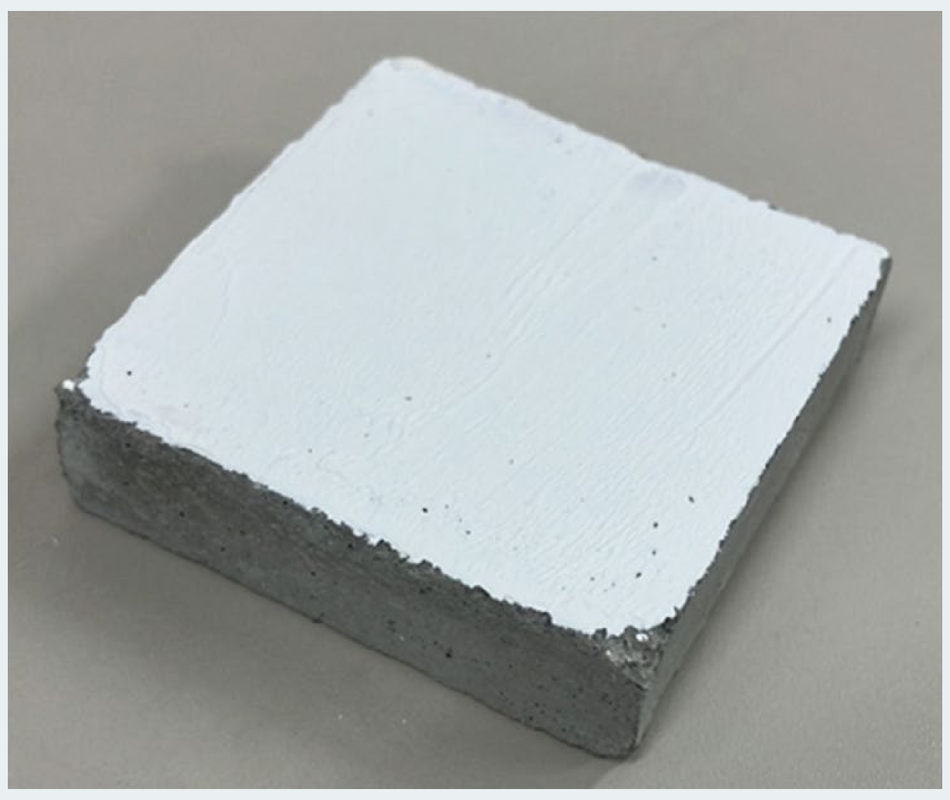
- By blending our developed polymer, we developed a shielding material (water-based coating) with a high concentration of dispersed filler that mainly captures thermal neutrons.
- Due to its high shielding performance, it is possible to reduce the thickness.
- There are wide variety of substrate.

  Aluminum substrate : No peeling in cellophane tape test

50μm coating sample on PET film
Flexible and no crack



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



Can be applied to aluminum and concrete substrates

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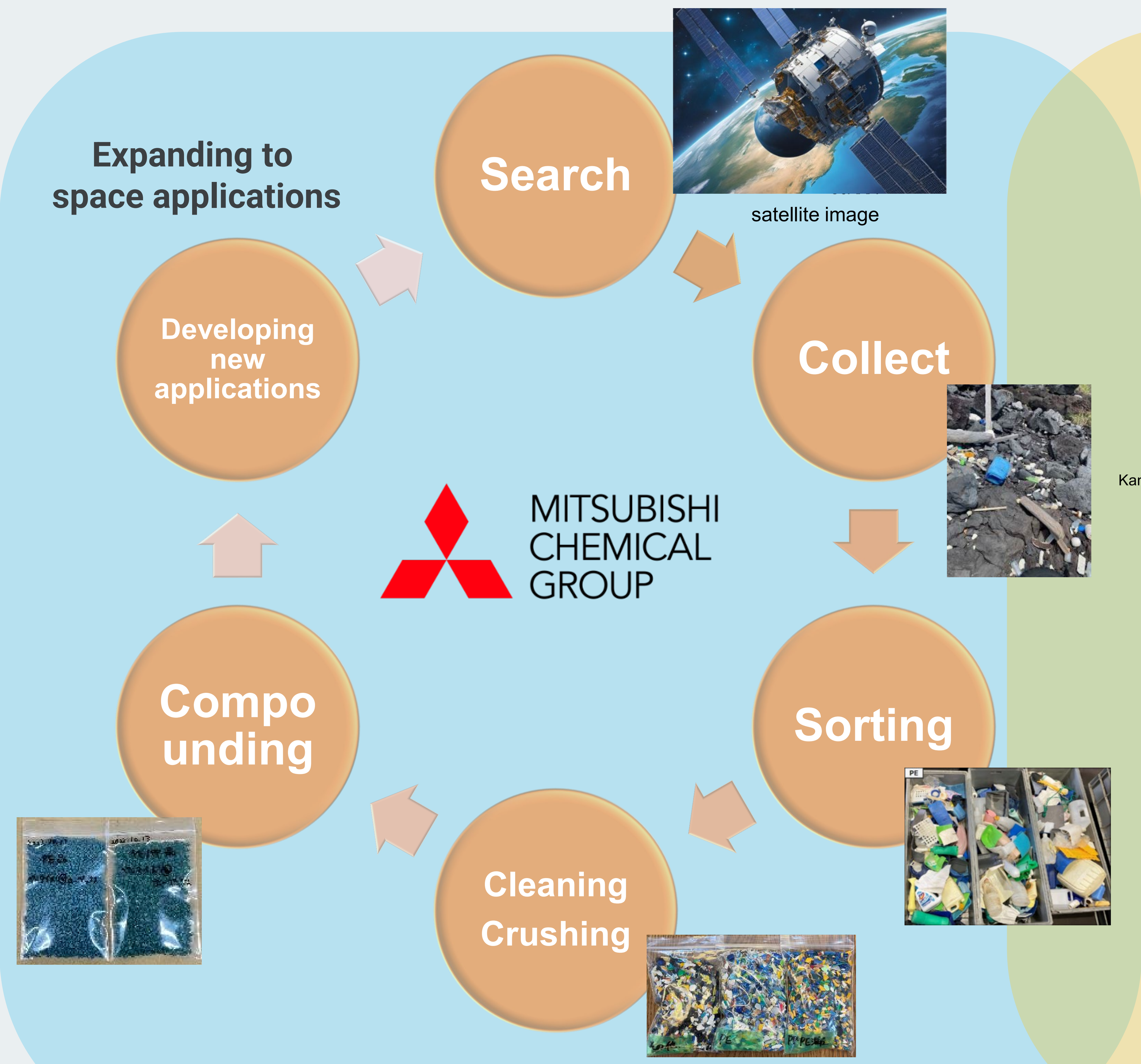
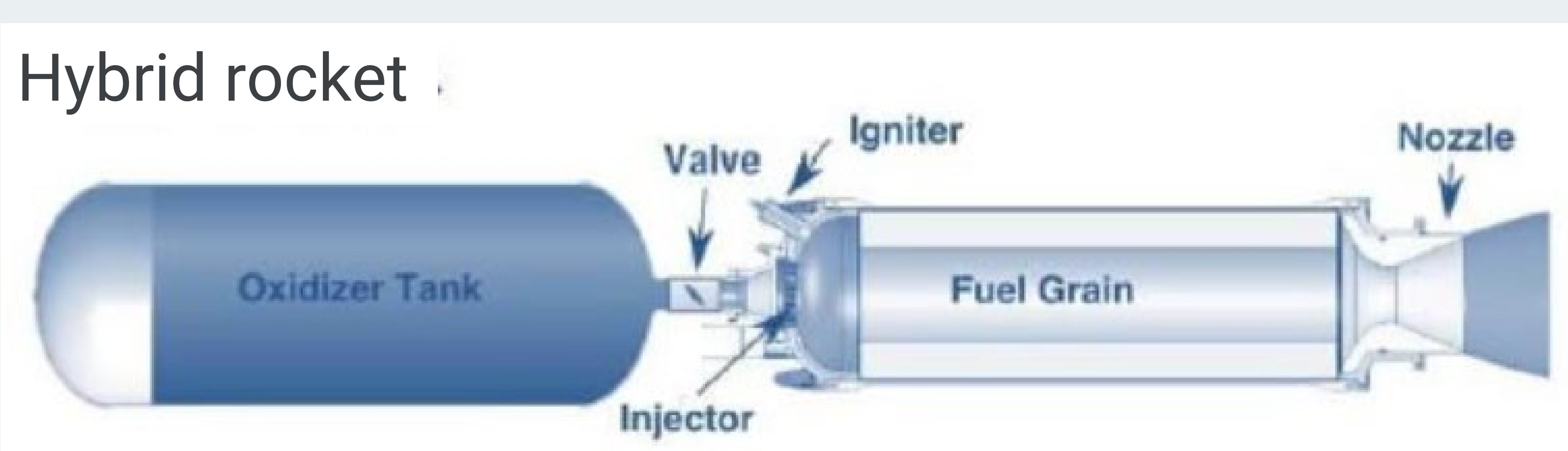
Considering the use of Oceanic plastics for hybrid rocket fuel



Mitsubishi Chemical's plan to solve social issues using satellites

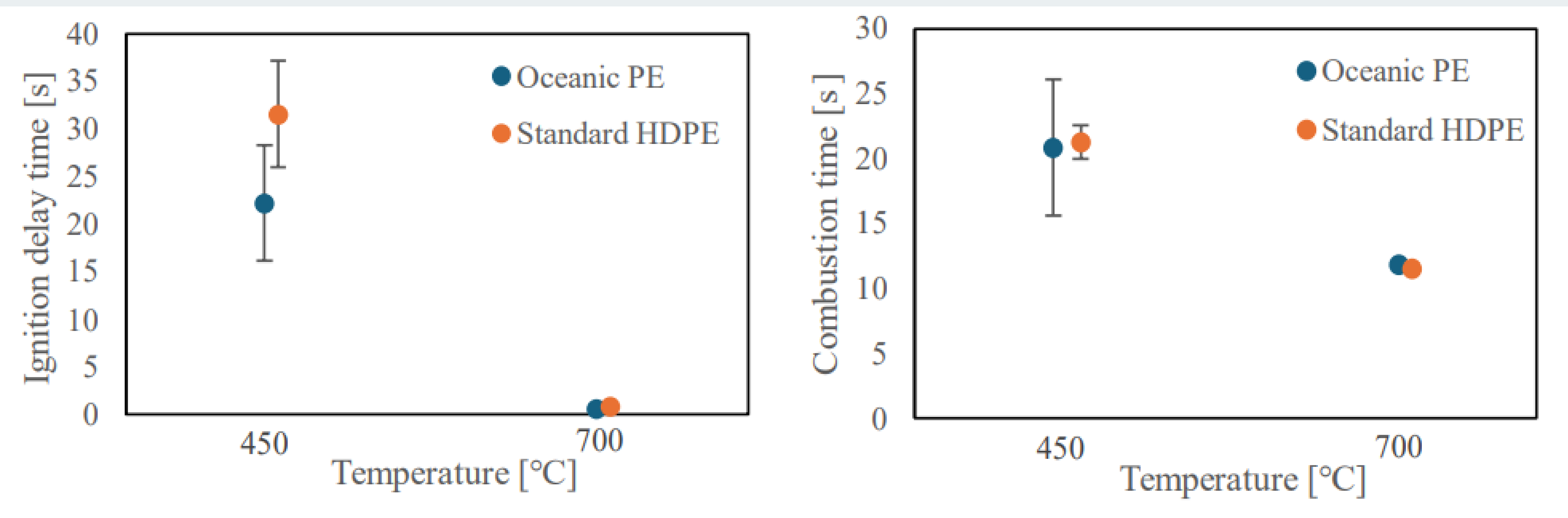
Program of GOI× Kanagawa Univ. Space Rocket Project



https://www.neomag.jp/mailmagazines/topics/letter201909.html

Structure of a hybrid rocket

Oceanic plastic (PE) molded for fuel
（Provided by: Shinshu University Nakayama Laboratory）



Materials provided : Nihon Univ.

Ignition and combustion performance of oceanic plastic (PE)

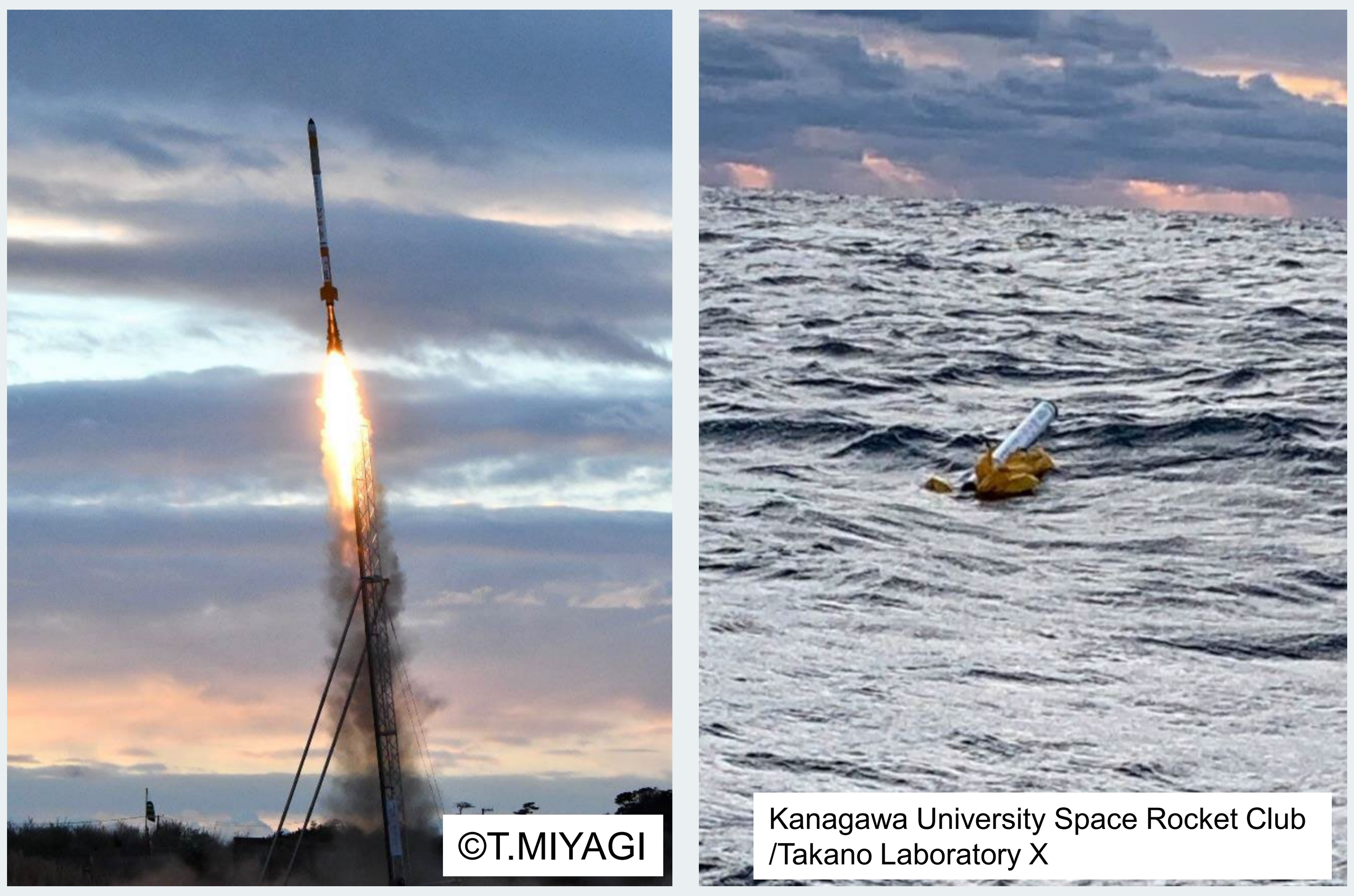


Photo of rocket launch (12/14/2024 @ Minamisoma City)

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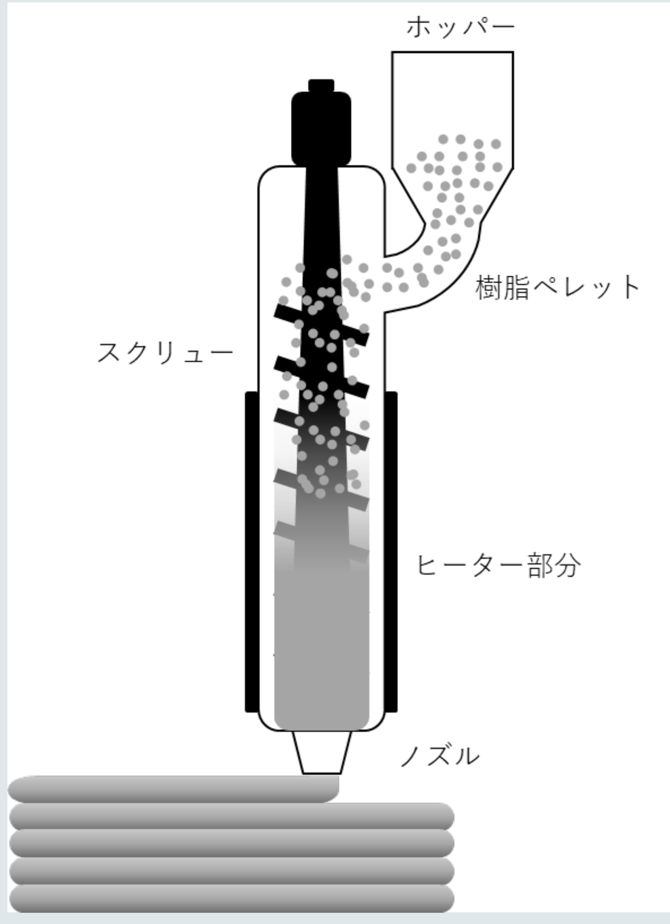
CHEMICAL
GROUP

三菱ケミカル株式会社

3D Printing materials for space

Material for Fused Granular Fabrication (FGF) printer

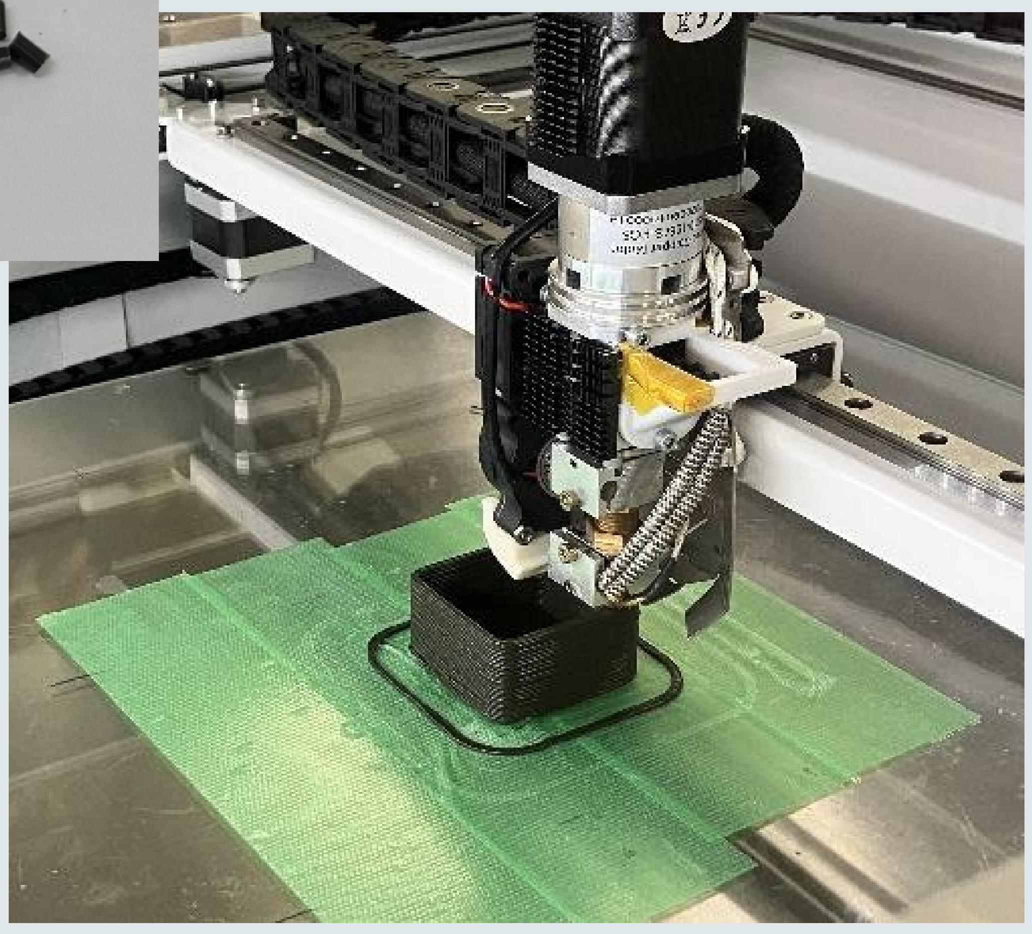


What is Fused Granular Fabrication (FGF) ?

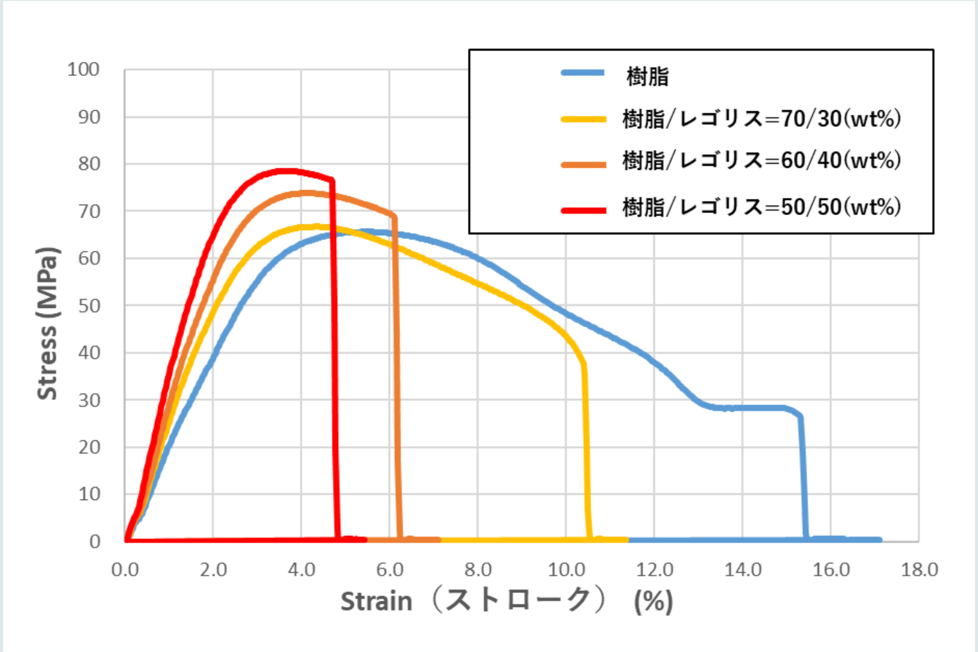
✓ One of the Material Extrusion type 3DP.
✓ Can 3D print directly from pellets.
✓ Can print big object with large extrusion amount.
(Also called as LFAM / LSAM)

Regolith-containing material
"Production on moon, Consumption on moon"

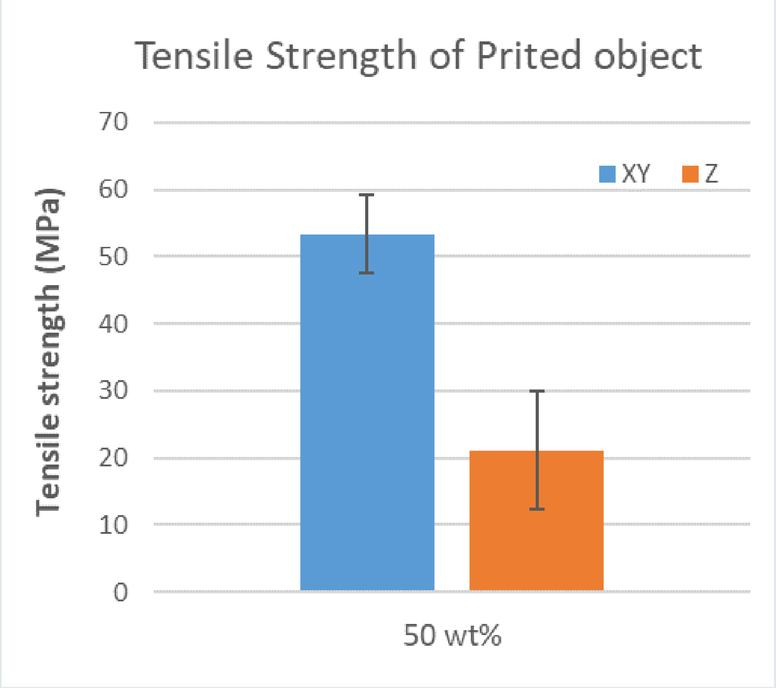
＊Using regolith simulant



<Tensile strength of injection molded specimens>

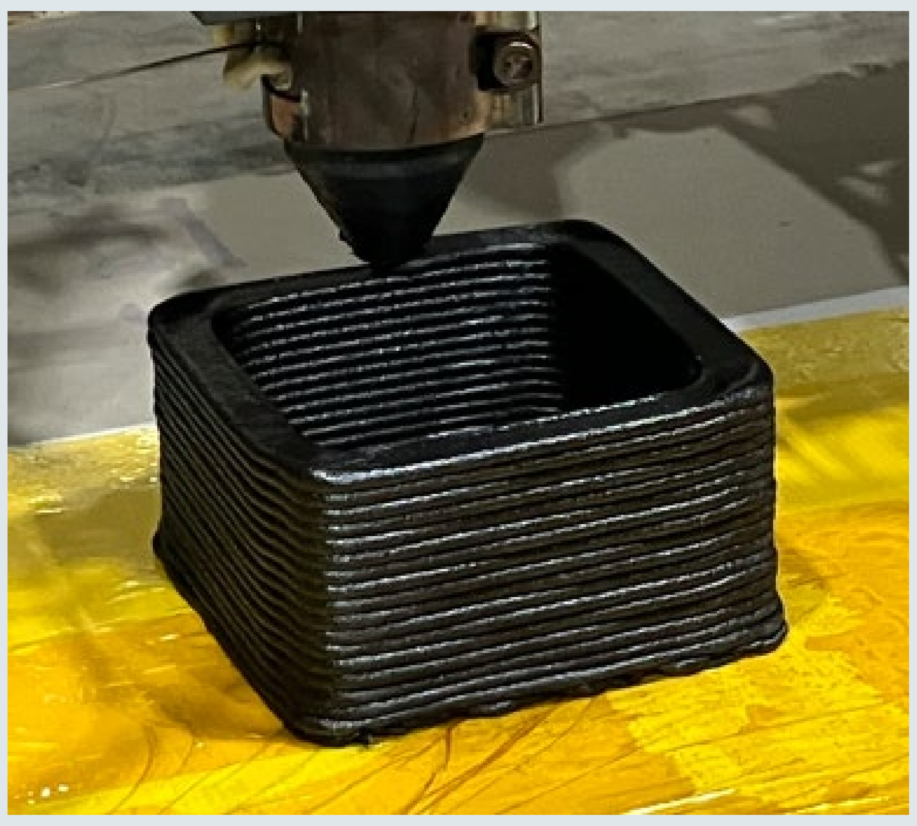


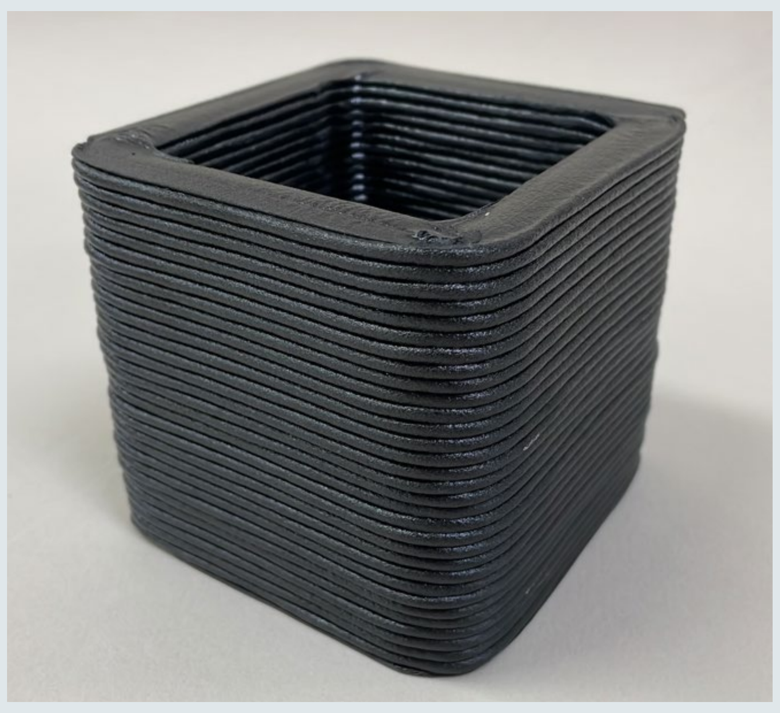
<Tensile strength of 3D-printed parts>



<Print condition>
●Nozzle : 2mmφ
●Temperature : ～240℃

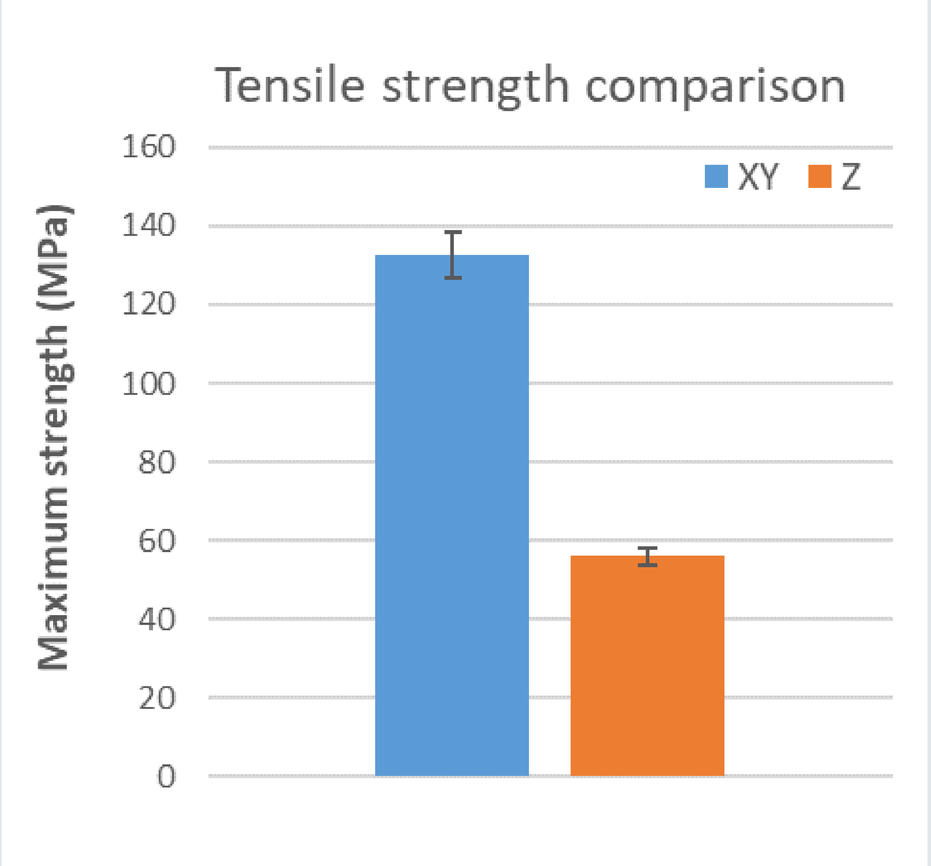
High heat-resistant (PEI/CF) material





<Print condition>
●Nozzle : 8mmφ
●Temperature : ～390℃

<Tensile strength of 3D-printed parts>



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