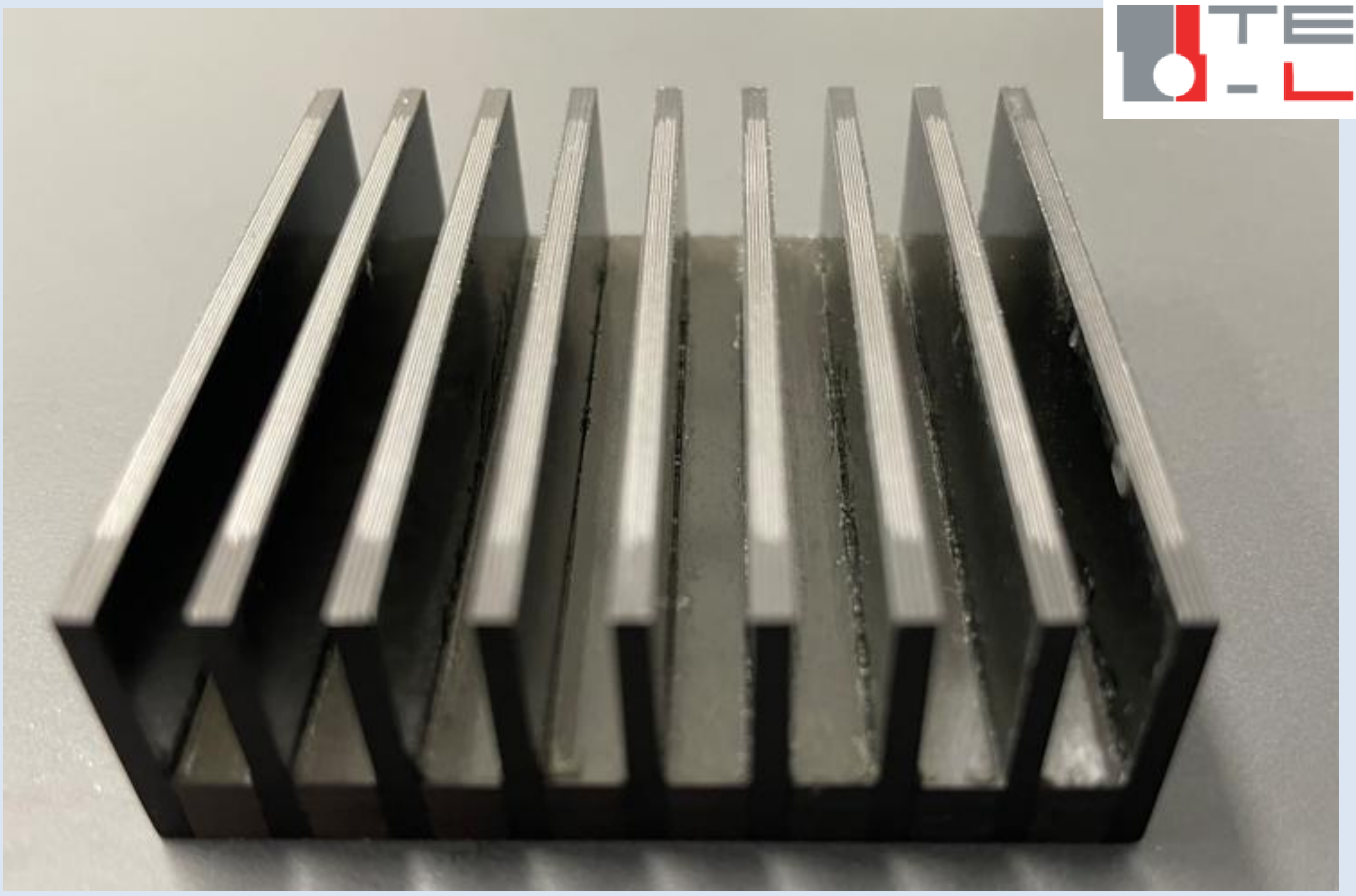
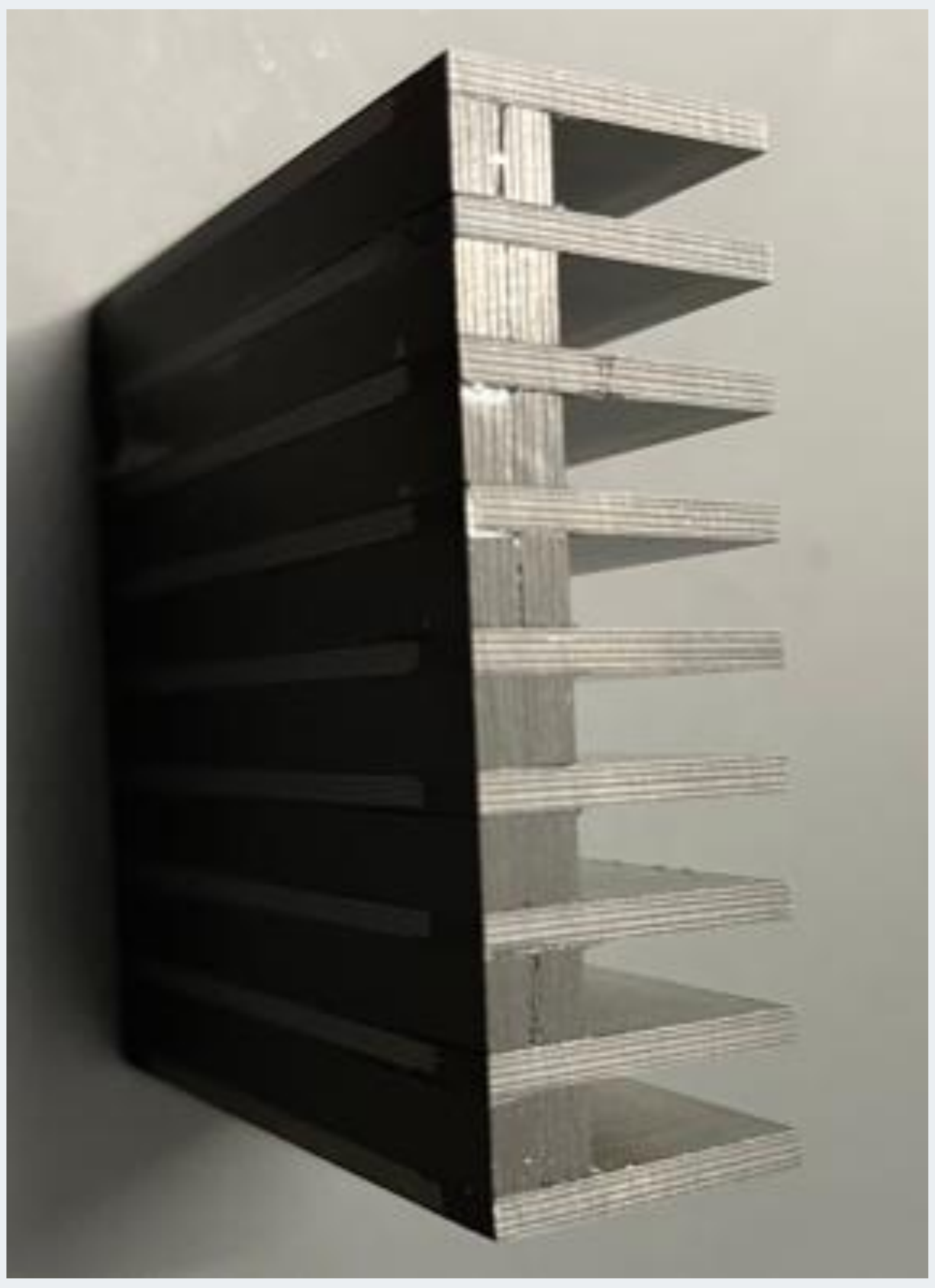
Innovative graphite sheet business development project

GS/CFRP Heat Sink: Space Satellites, Optoelectronic Semiconductor Lasers, Laser Nuclear Fusion

Alternating lamination of 120 µm graphite sheet and 120 µm pitch carbon fiber (K13916)/cyanate resin (#290) resin prepreg to achieve thermal conductivity of 1000 W/mK in two directions

TECH - LAB





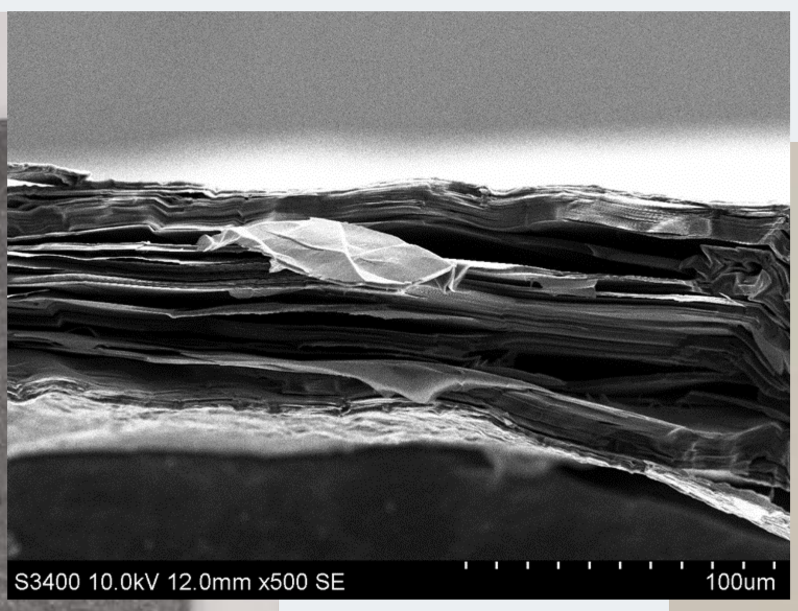
MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

Innovative Graphite Sheet Business Development Project

Applications: Space communication antennas, optical semiconductor lasers, high thermal conductivity C/C

120 µm thick, achieving high thermal conductivity and high density(A single, monolithic piece, not a laminate of thin sheets)



CFRP/graphite sheet laminate structure

Graphite sheet thickness: 120 µm
Thermal conductivity: 1800 W/mK
Alternate lamination with K13916/#290 prepreg Composite: 1000 W/mK
Thermal conductivity 2.5 times that of copper

Patent registered
JP 7718431 (JPN)
P2021P01365US01 (US)

	Density	Thermal conductivity (in-plane)	Thermal conductivity (through-plate)	Electrical conductivity	CTE
	g/cm^3	W/mK	W/mK	×10^{-5}Ω・cm	ppm
Innovation Graphite sheet*1	2.1	1800	5～10	8.3	-3
HOPG*2	2.255~ 2.265	1600~ 2000	80	3.5～4.5	-1

Exhibits properties equivalent to HOPG

*1 This data is an example of the measurement results and differs from product specifications.
*2 This is the catalog value for Momentive

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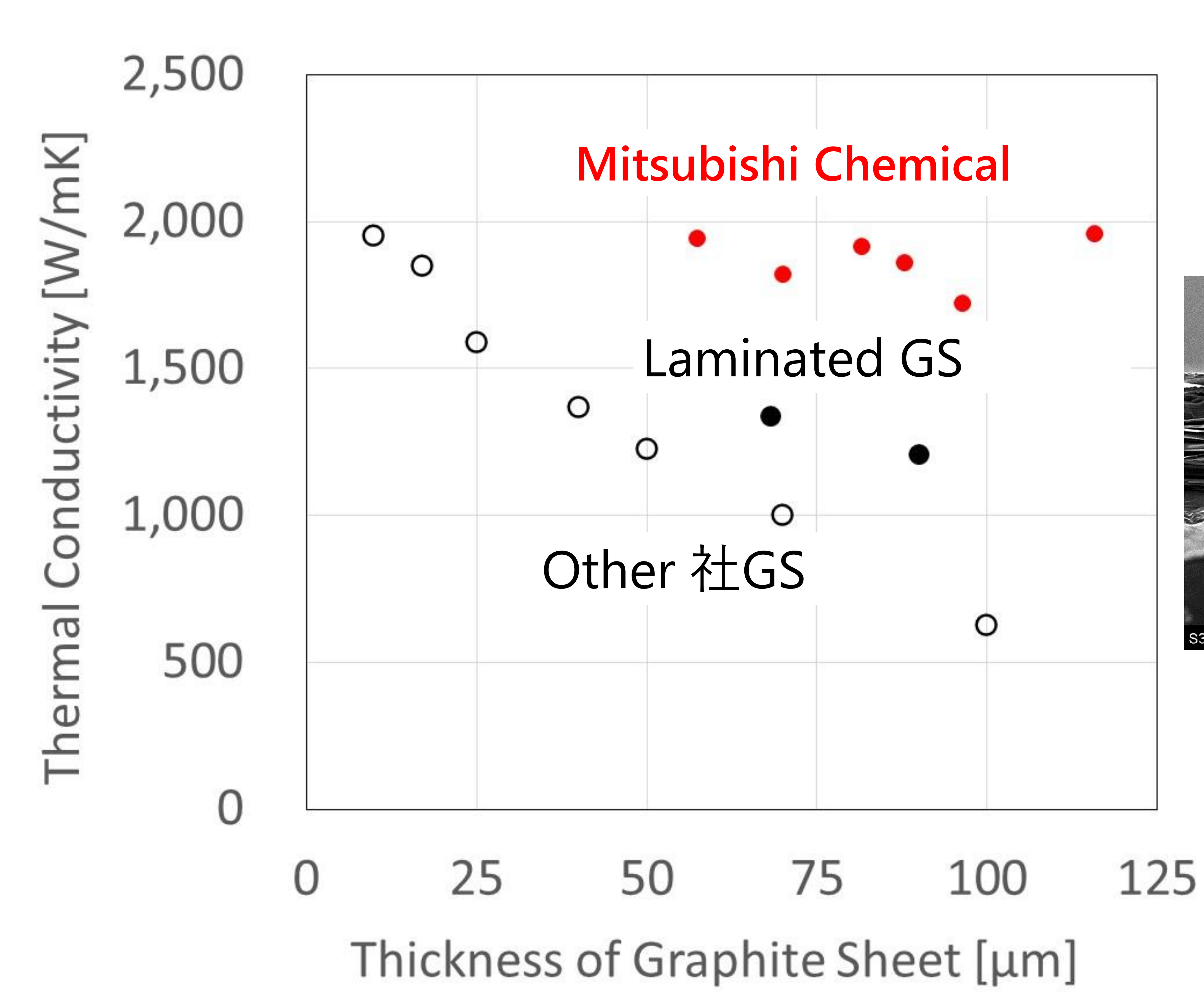
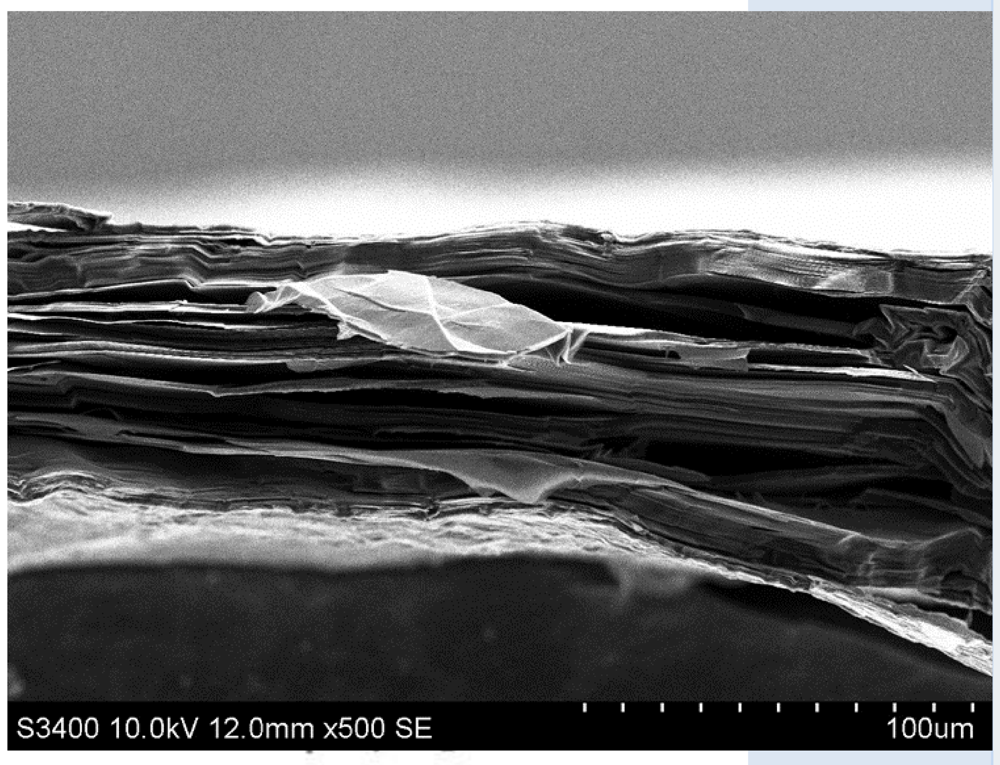
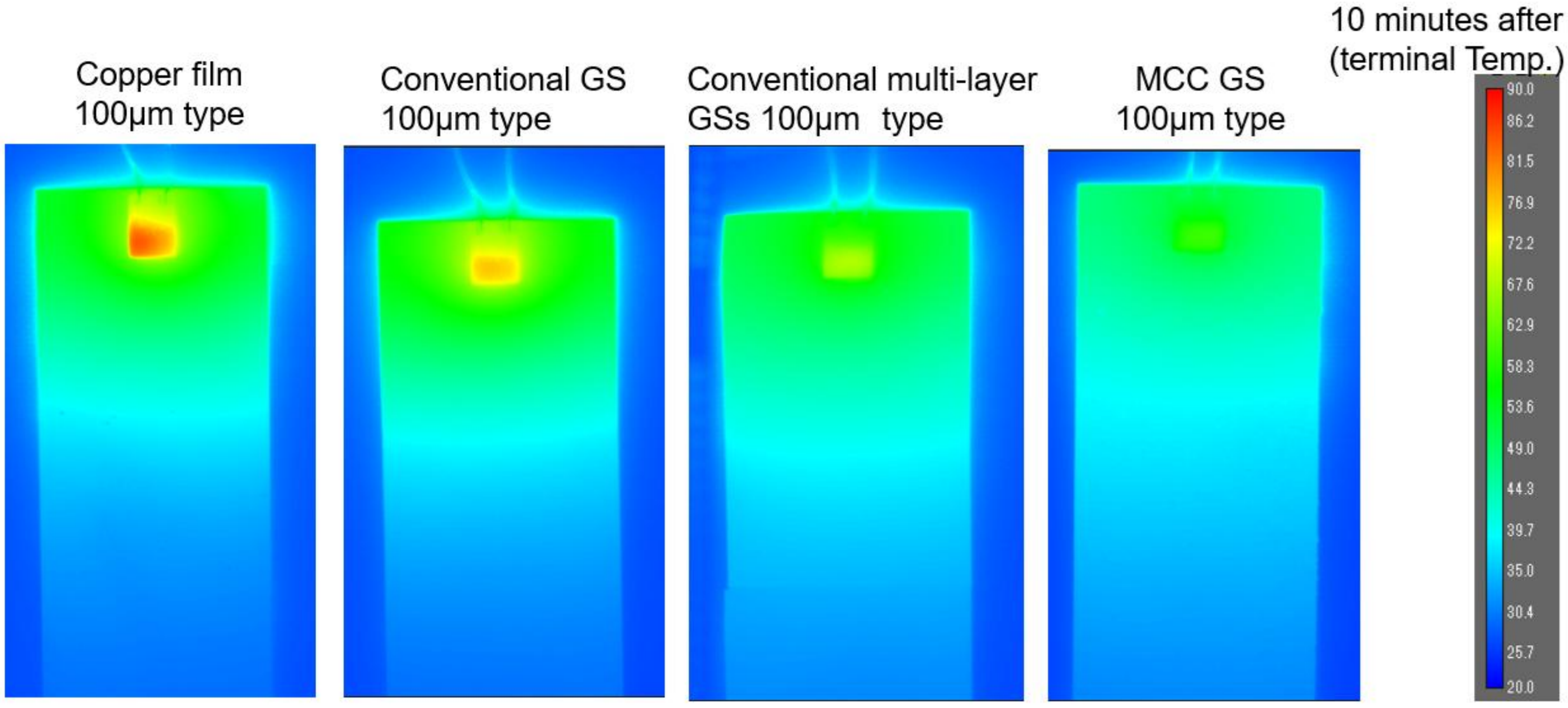
Innovative graphite sheet business development project

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.

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GROUP

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Innovative graphite sheet business development project

Heat Dissipation Plate for Flat Antenna for Space Communication: NICT / Tech Labo Co., Ltd.

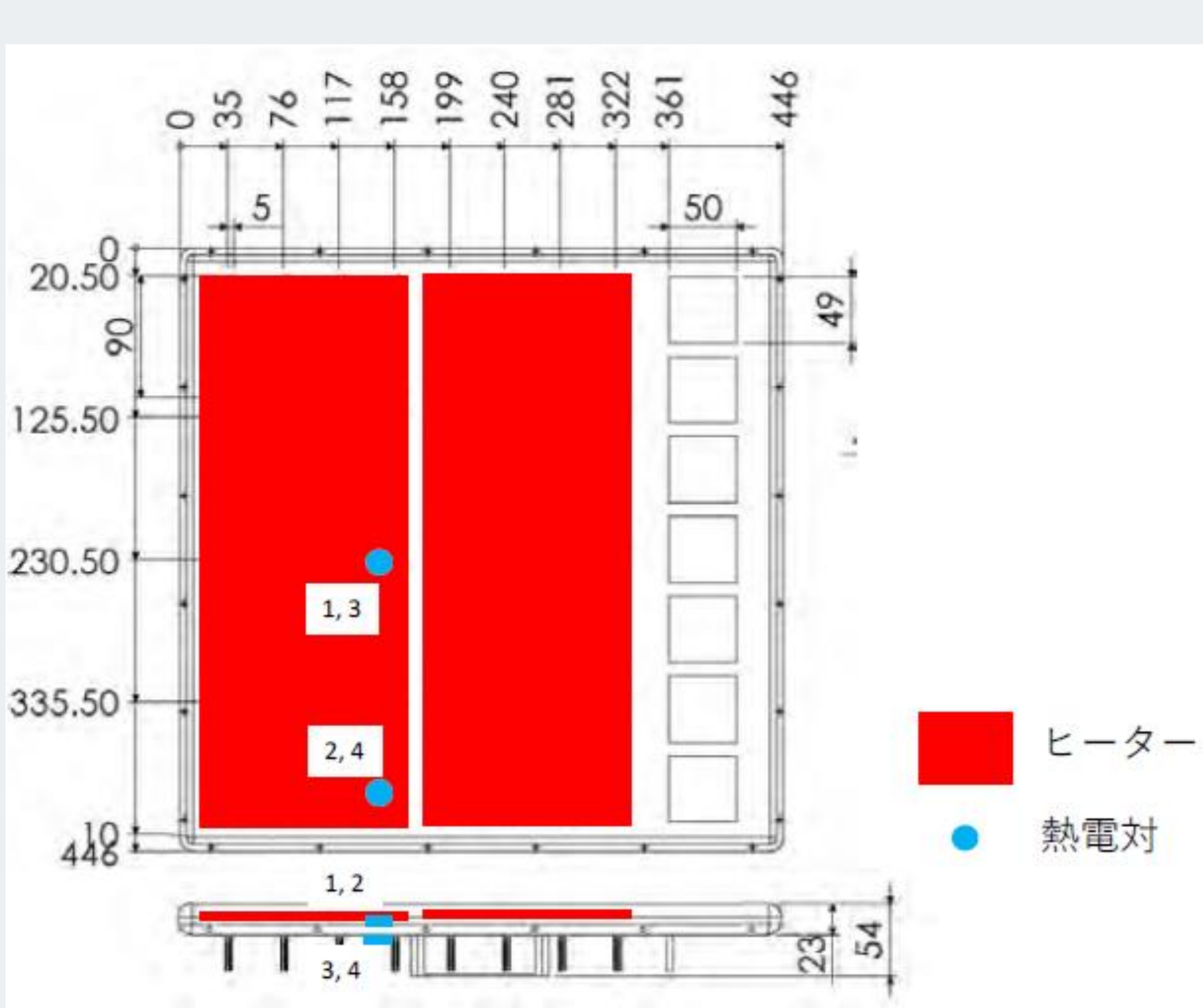
Development Activities for Flat Antennas Installable on NTN Platforms

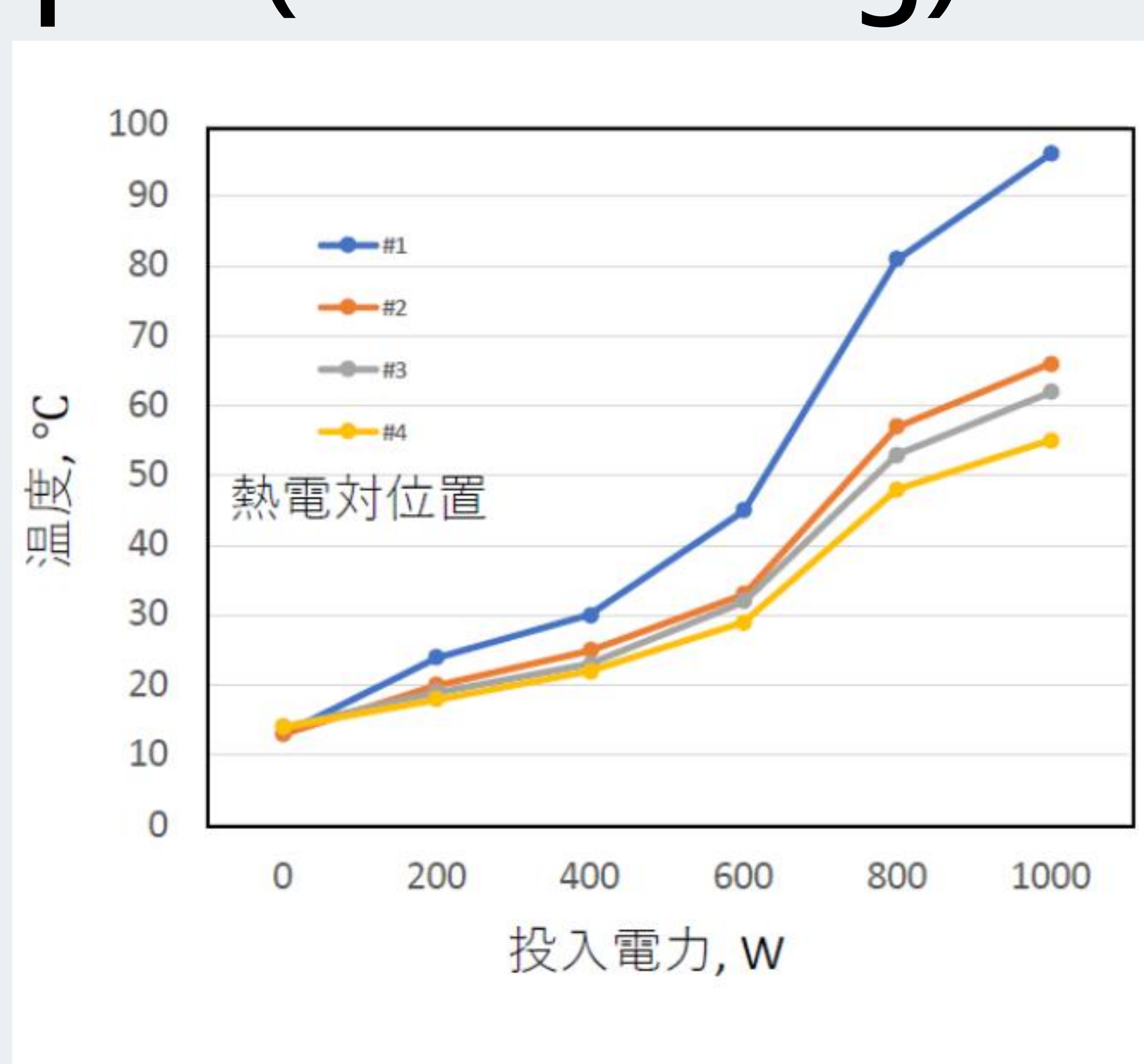
•Research and development of flat antenna systems installable on flying cars, drones, and similar platforms
•Research and development of various materials and heat dissipation structures enabling miniaturization and thinning of flat antennas according to different heat sources and terminal shapes
•Research and development of integration technologies for flat antennas on NTN platforms

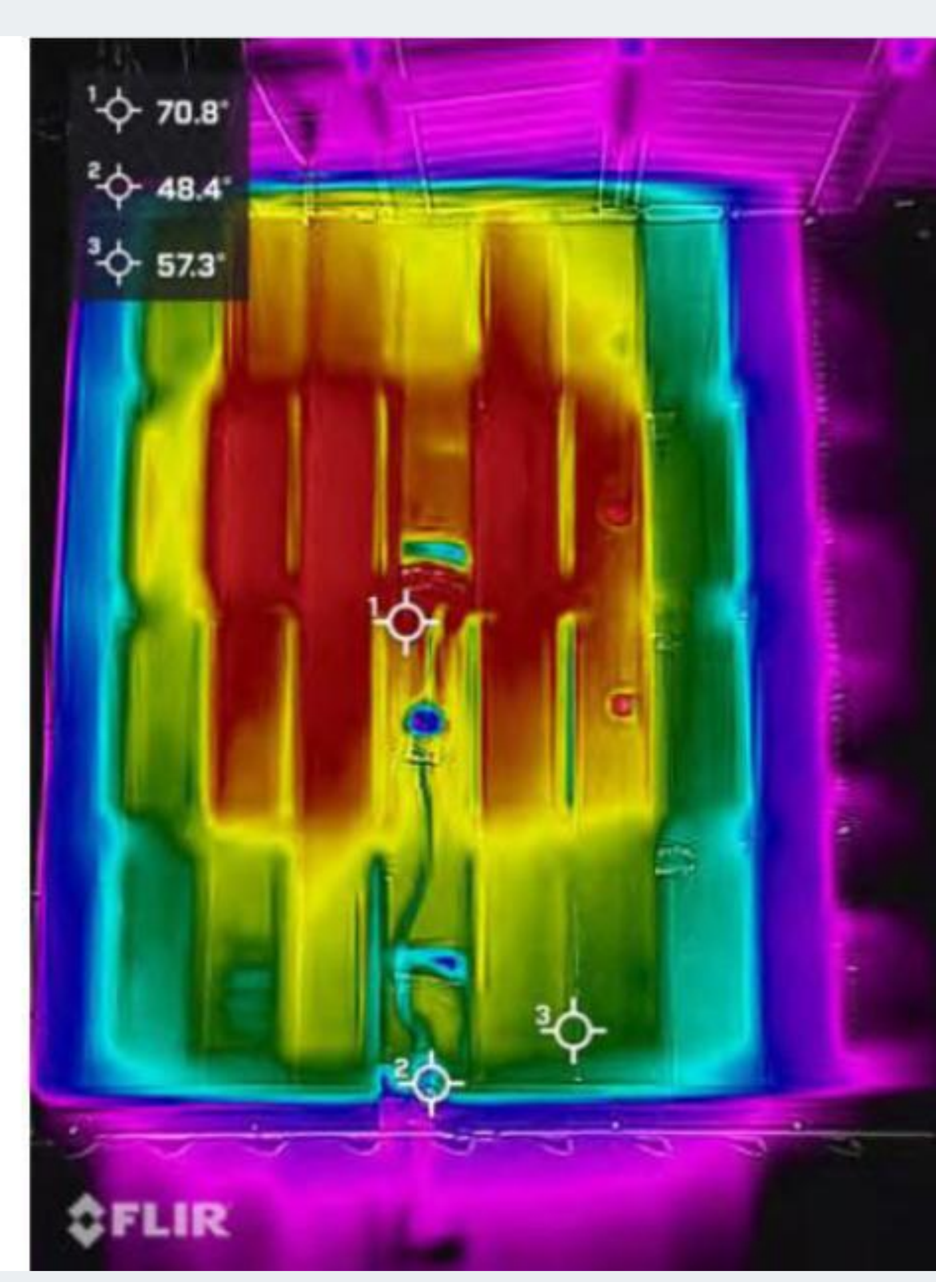
SHARP TECH-LAB NICT

Achieving compact, slim, and lightweight antenna systems for integration into any mobile platform

Temperature Change and Thermal Imaging at 1000W Input (Air Cooling)







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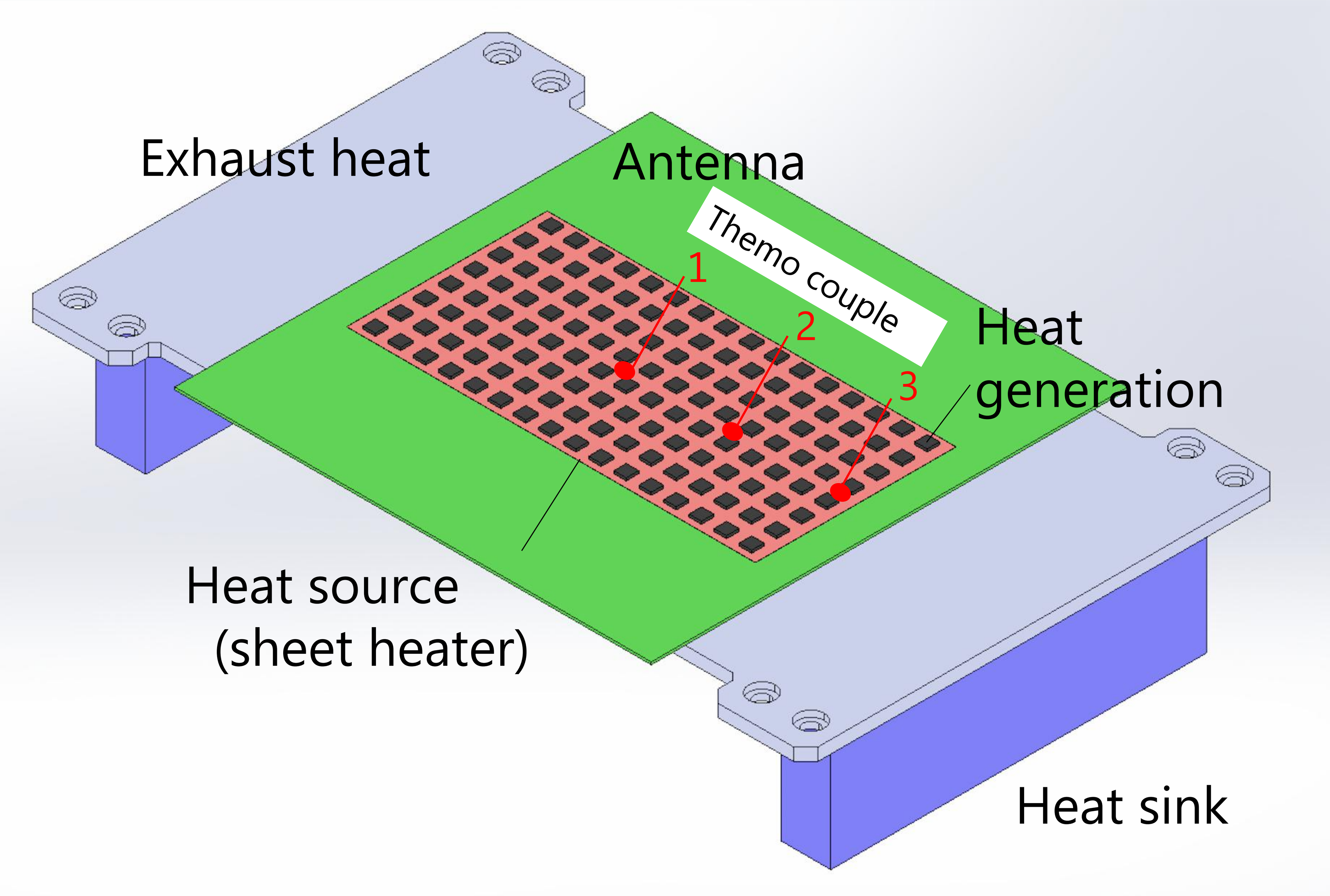
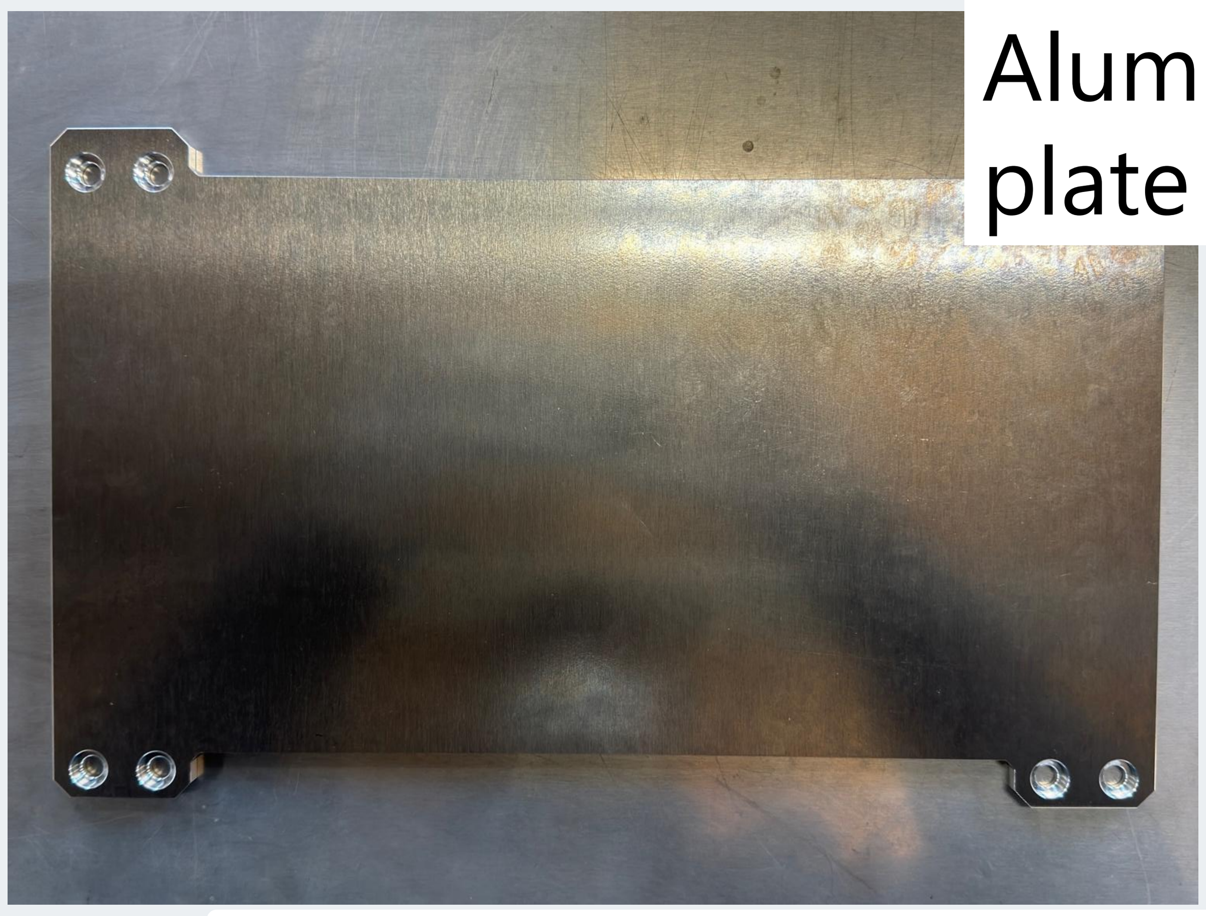
Innovative graphite sheet business development project

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

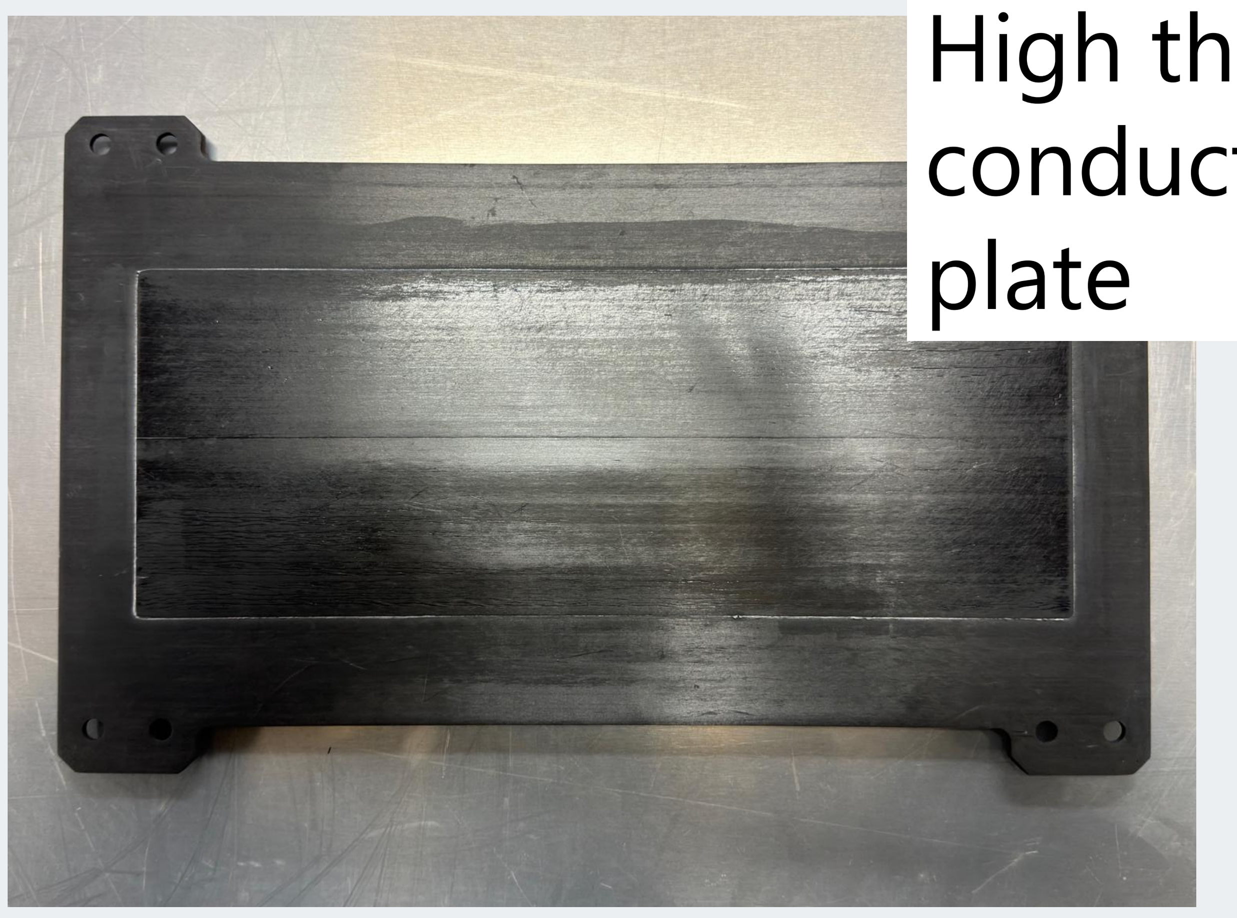
Verification of high thermal conductivity performance through heat generation/exhaust heat model experiments of flat antennas



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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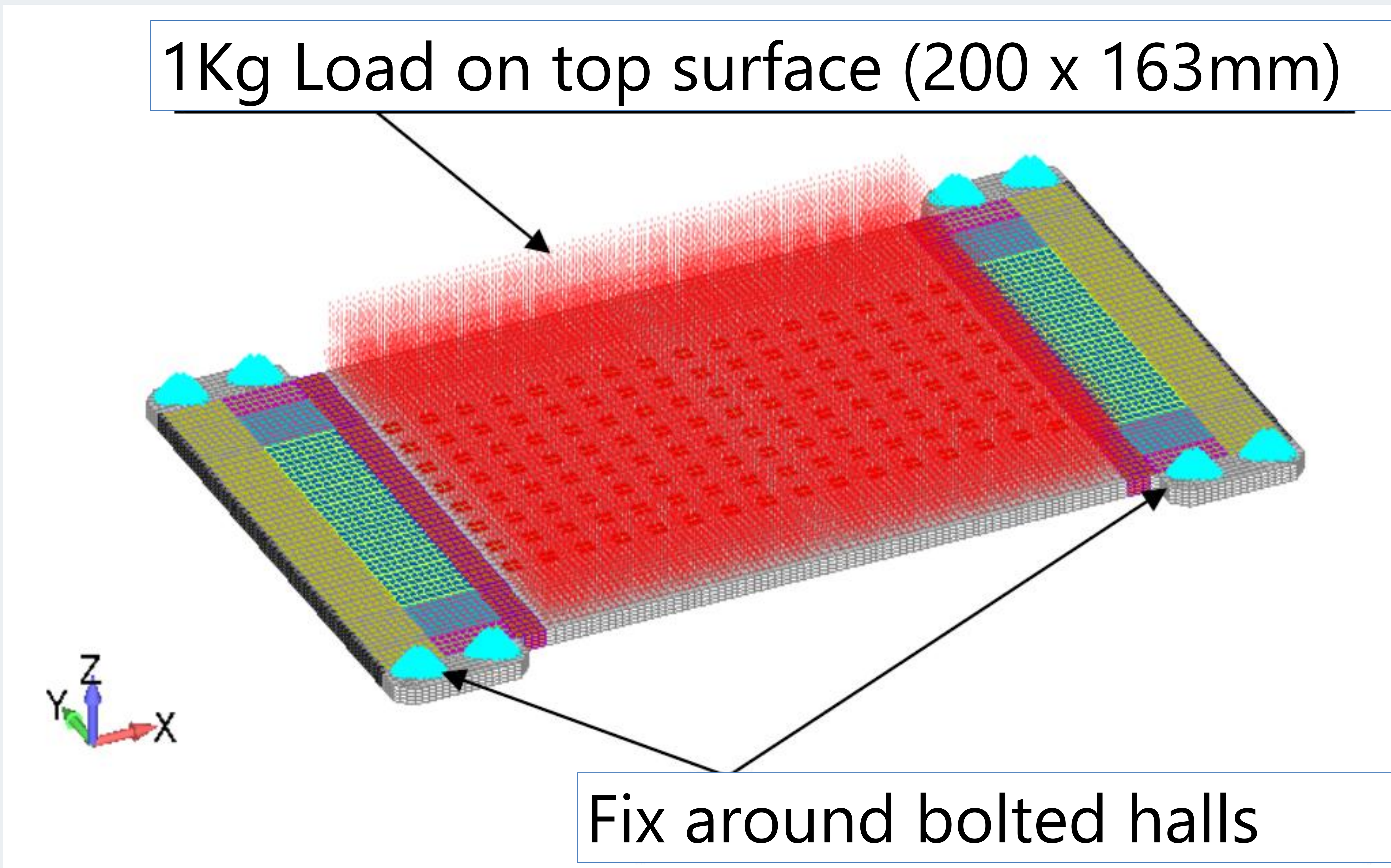
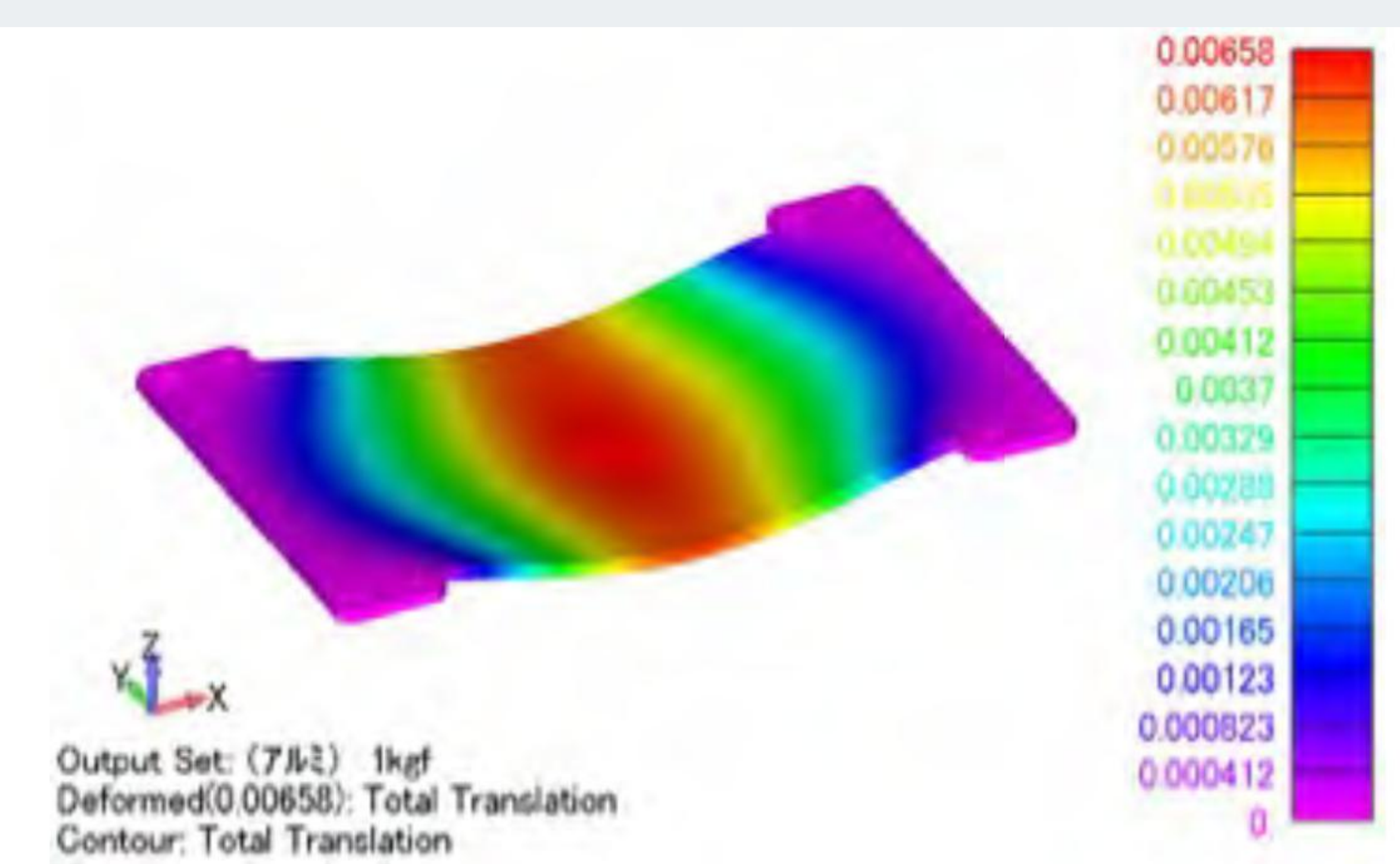
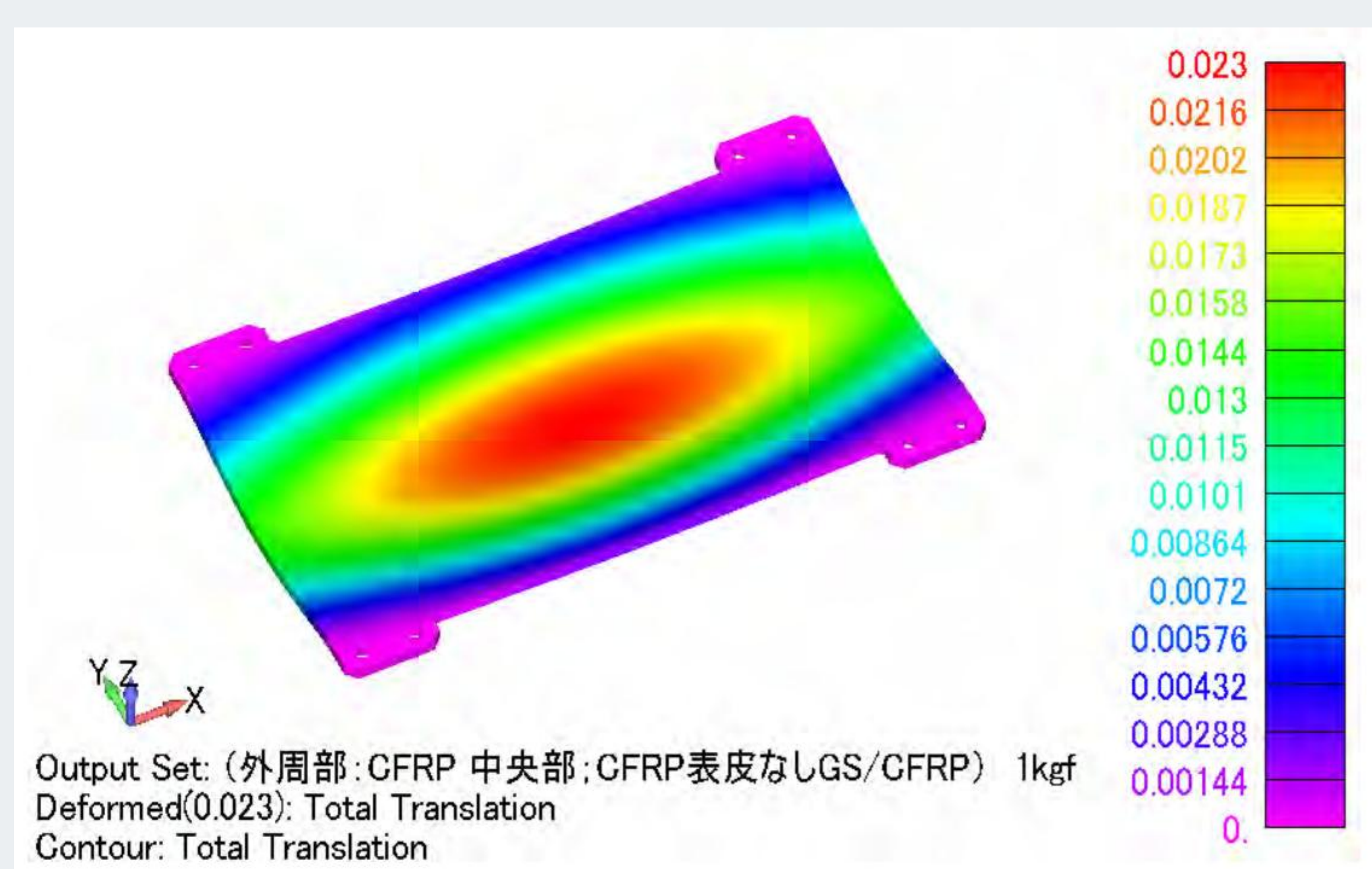
Innovative graphite sheet business development project

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

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





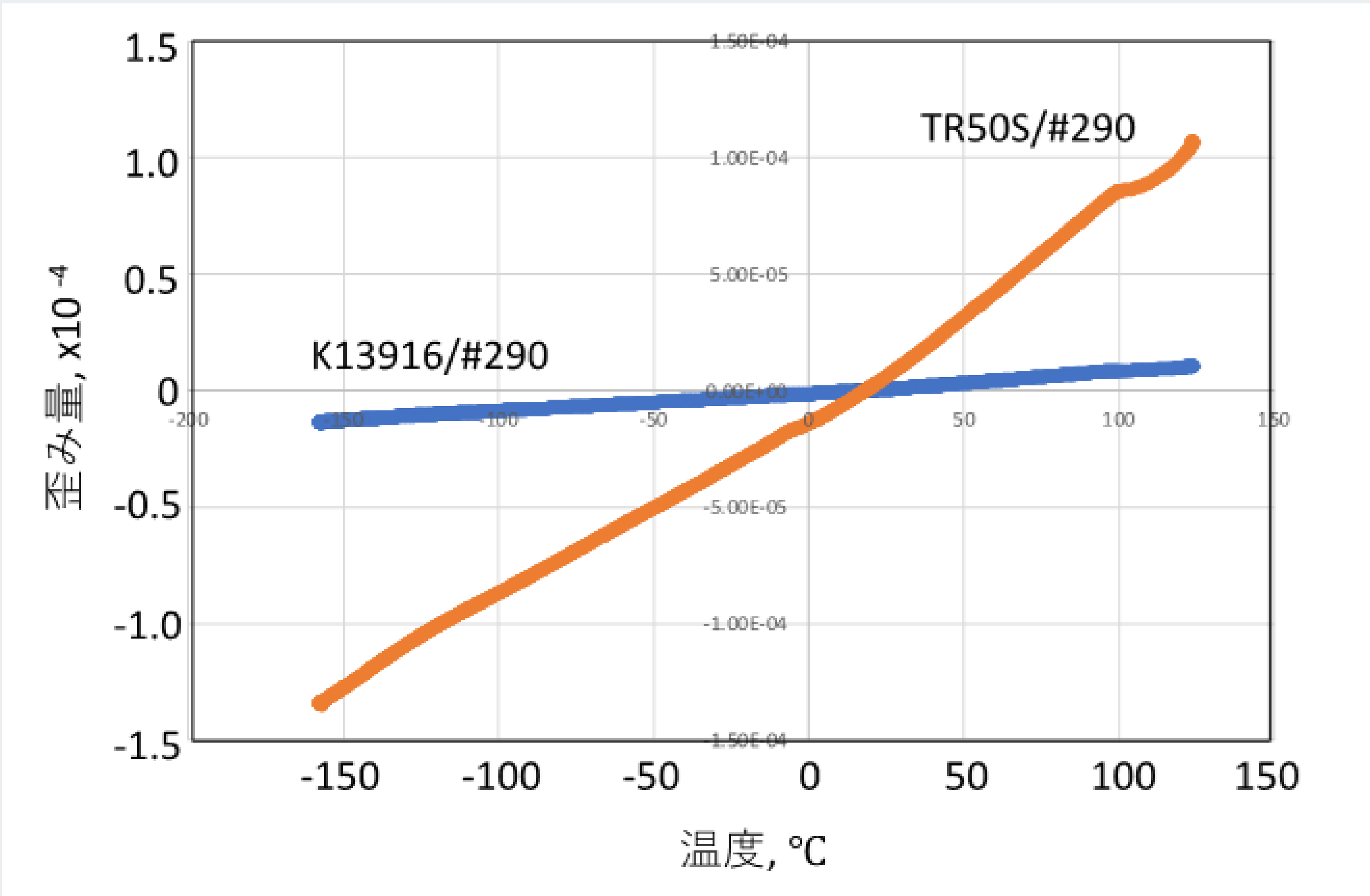


Aluminum heat exhaust plate
Weight: 7.2kg
Maximum displacement: 7μm

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

Zero Thermal Expansion Pitch-Based Carbon Fiber Composites

Evaluation of Zero Thermal Expansion CFRP



・K13916/#290
0.08ppm/℃

・TR50S/#290
3.74ppm/℃

Under the Stardust Program: Evaluation of Prototype Elements for a Long-Range Acquisition and Tracking Subsystem for Lunar Exploration (in FY2024)

Lightweight, High Stiffness
Low Thermal Deformation
Low Moisture Absorption

Φ90 mm CFRP Telescope

	CFRPTelescope (Measured)	Conventional (Calculated)
Main Mirror (M1)	CFRP 63 g	Glass 265 g
Support Structures	CFRP Parts + Glass M2 200 g	Invar Pars + Glass M2 1175 g
Total Mass	263 g	1.44 kg

300mm diameter Primary Mirror

•Weight: 0.55 kg (300 mm diameter) /Glass: 2 kg
•Mirror structure fabrication: 1 day by Autoclave thermosetting molding
in Glass: 1 month by Machining
•Mirror surface formation: 1 day by replication
in Glass: 3 to 6 months by Polishing

MITSUBISHI CHEMICAL GROUP

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Moon Robot YAOKI

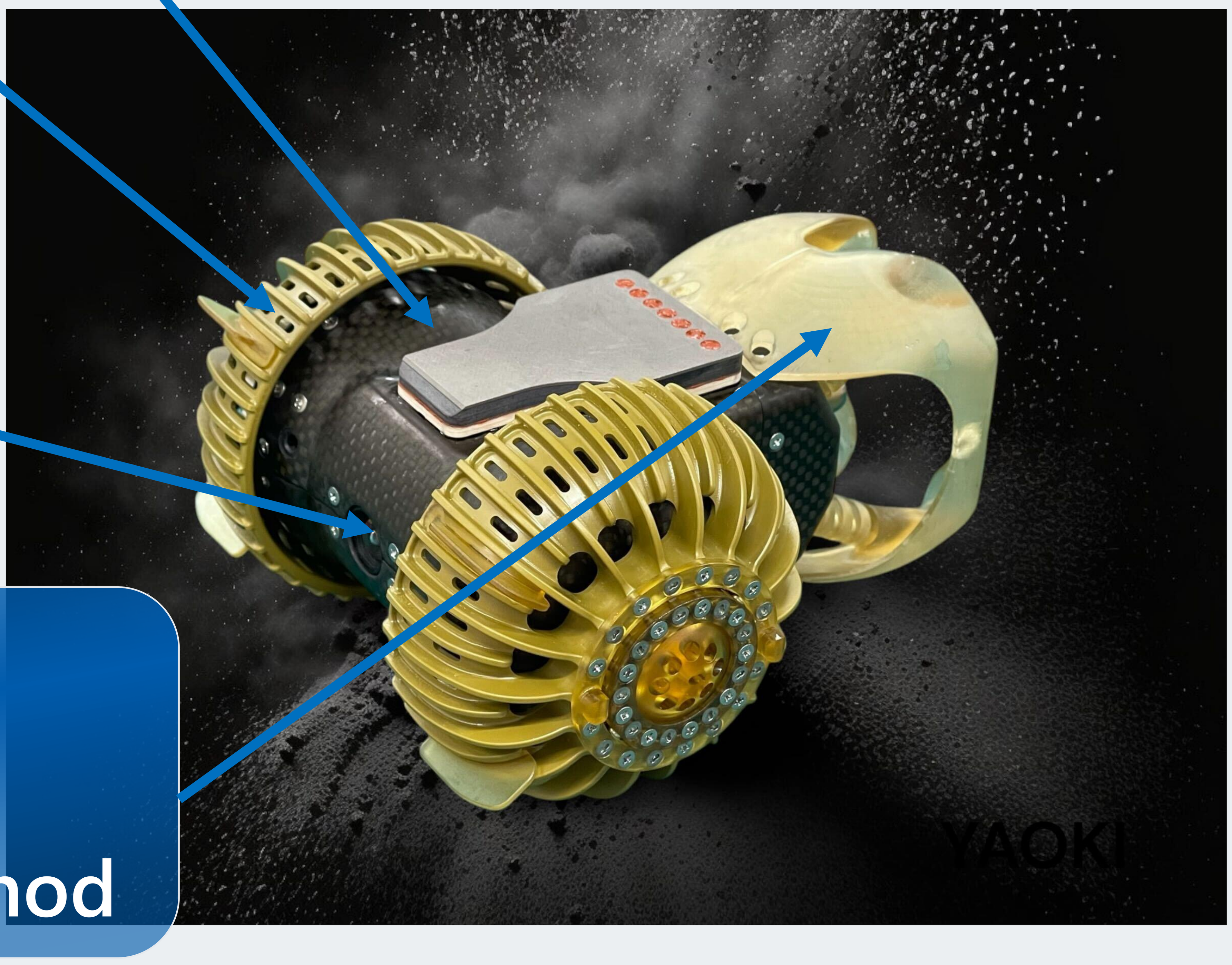
March 7, 2025: World's first photograph taken inside a lunar south pole crater.

Body & Deployer:
Cyanate ester resin CFRP

Tires:
PAI (Super Engineering Plastic/polyamideimide)

Lens:
Suppression of regolith adhesion
Apply coating agent

Slider:
Compliant Mechanism Design & Freeform Injection Molding Method



Anti-regolith coating

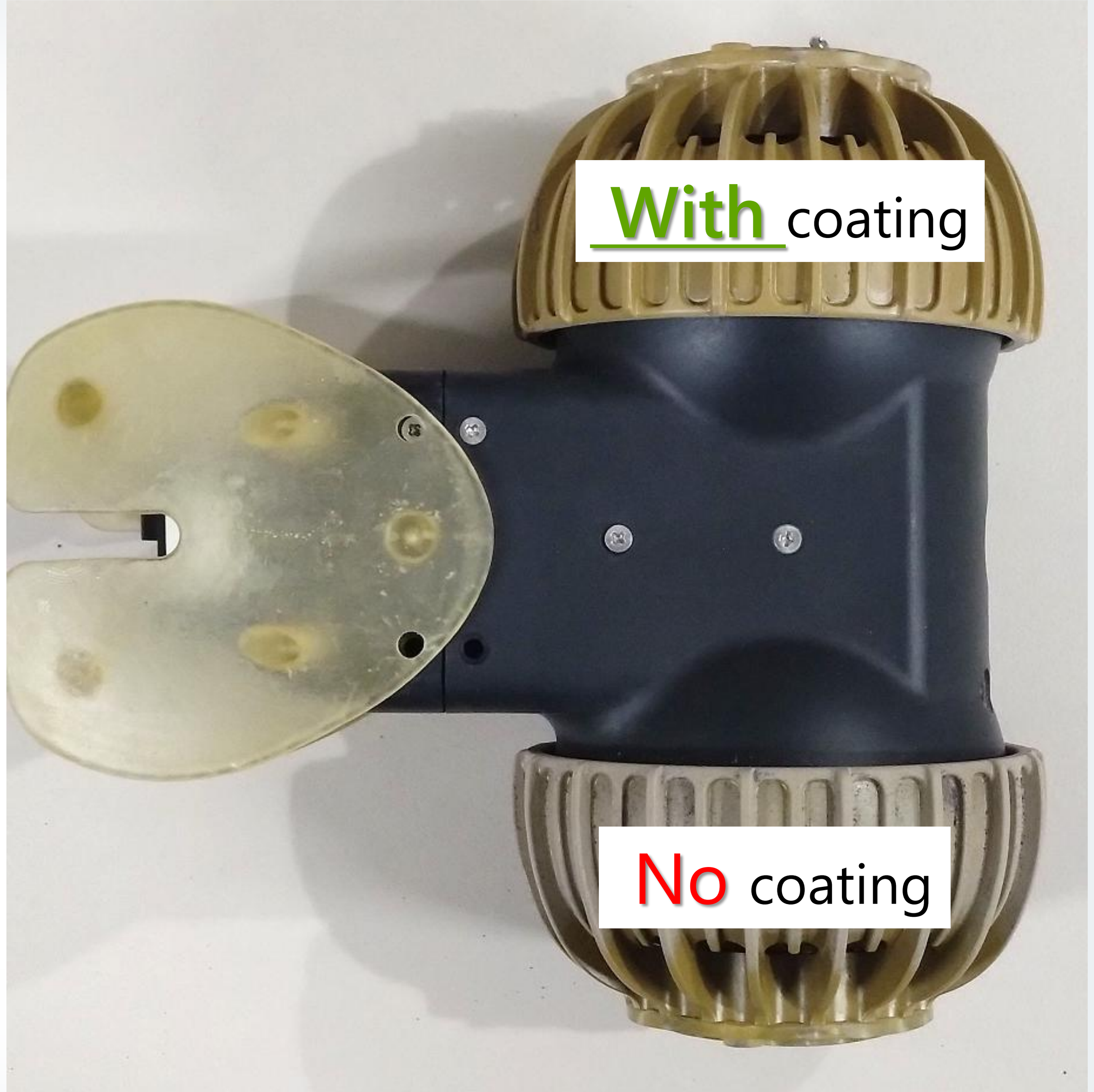
Objective

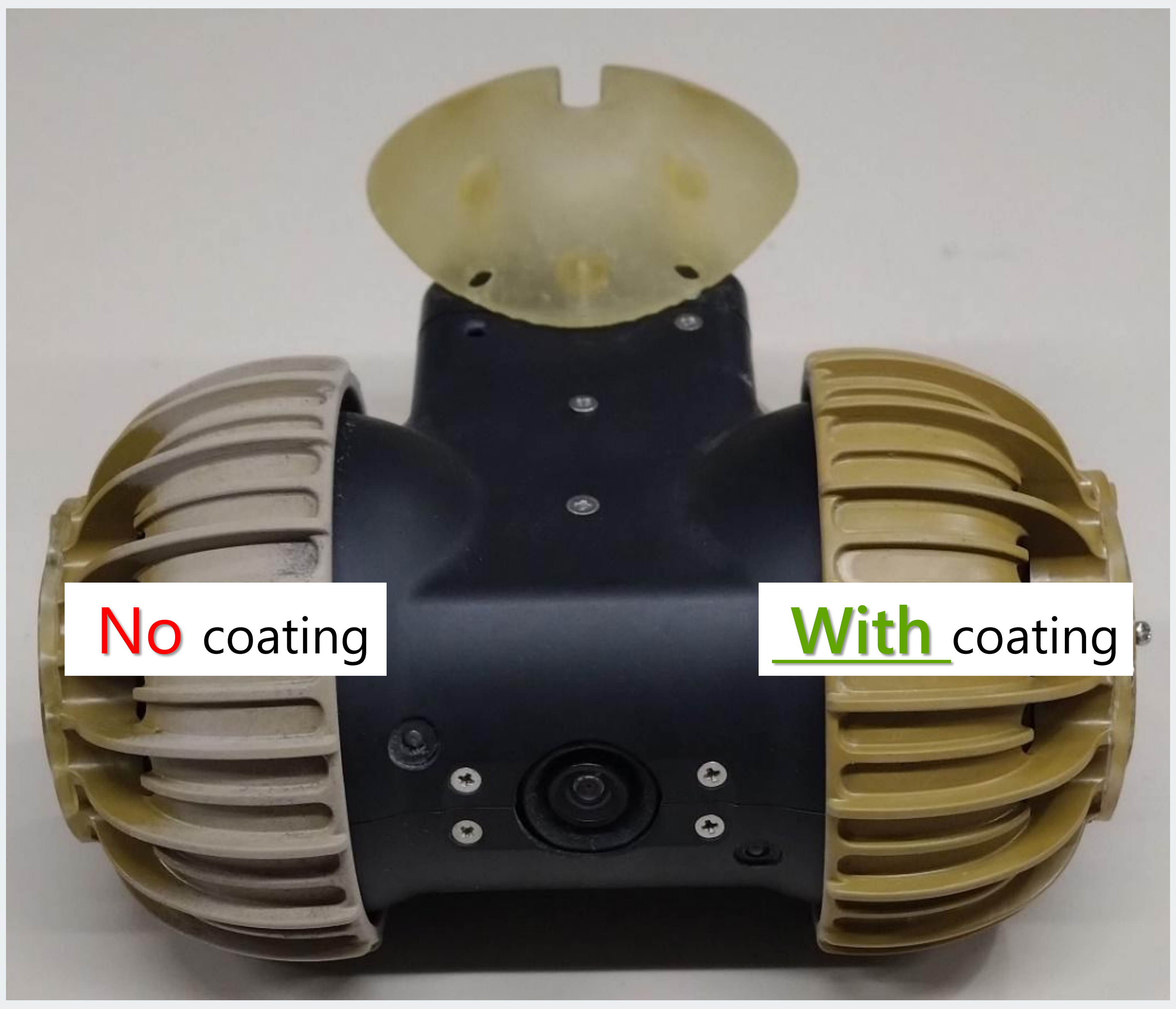
The objective is to evaluate the difference in the amount of regolith adhesion on the wheels of the YAOKI lunar rover with and without Mitsubishi Chemical coatings, and to confirm their effectiveness.

Test Method

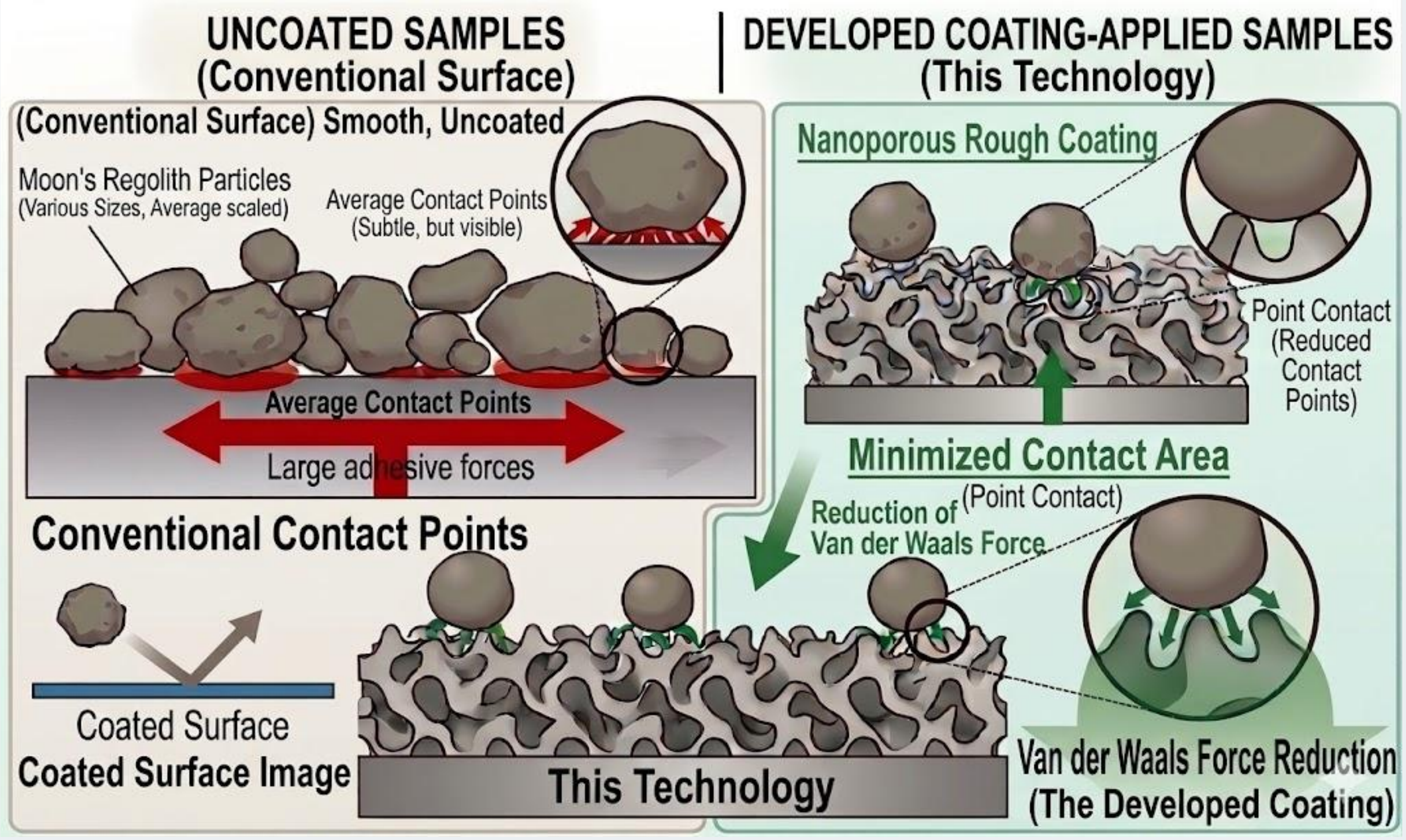
Wheels with and without the coating are mounted on the left and right sides of the YAOKI rover. The rover is driven over simulated regolith soil to compare the amount of regolith adhesion.

Rover: YAOKI replica (Infrared remote-controlled)
Left Wheel: Coated; **Right Wheel:** Uncoated (for comparative study)
Test Path: Simulated regolith soil (Size: 280 x 580 mm, Depth: 45 mm)
Driving: Three 2-second forward runs (to ensure the wheels complete more than one full rotation)





Mechanism for Preventing Regolith Adhesion



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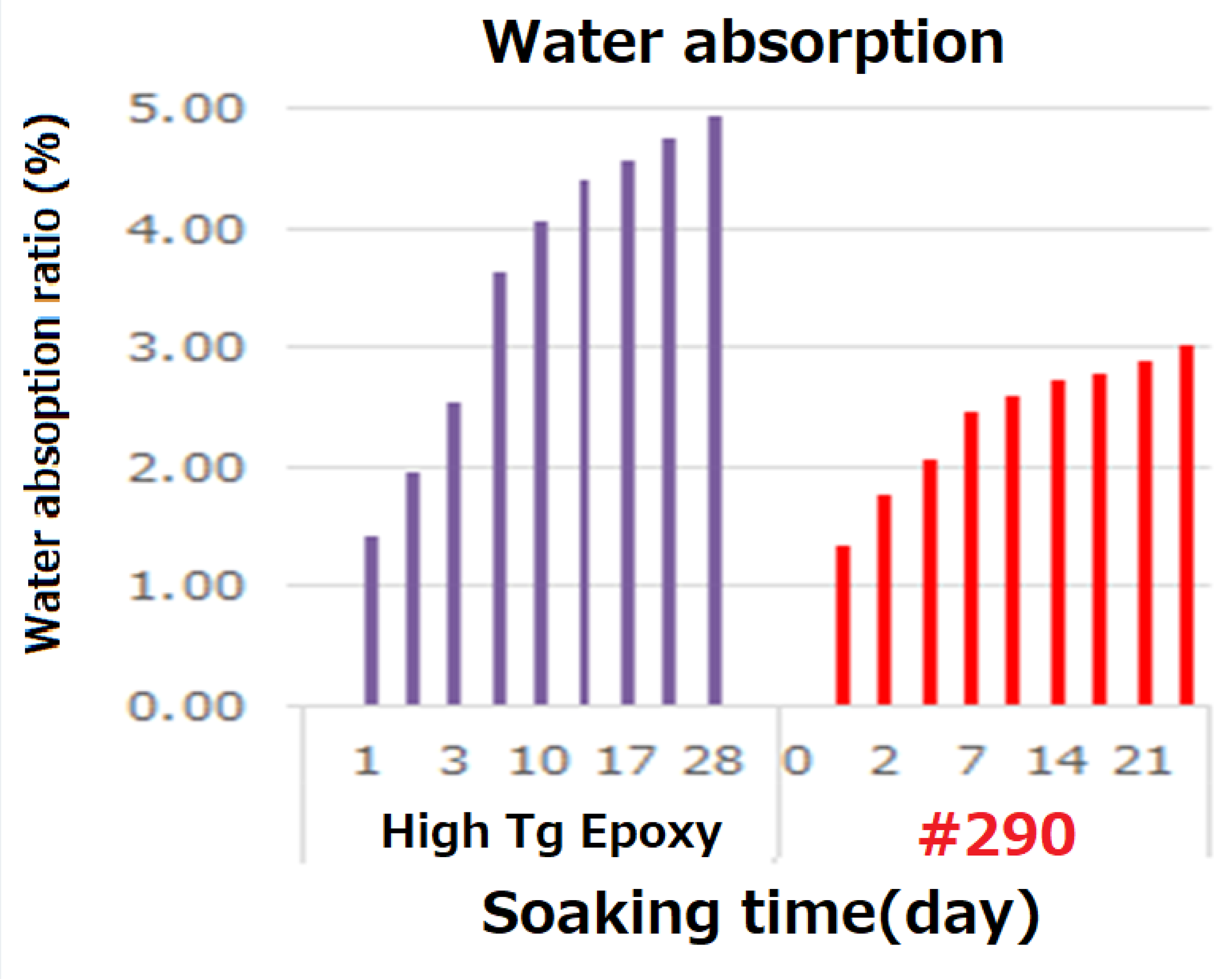
Cyanate ester resin CFRP

Characteristics of cyanate resin CFRP

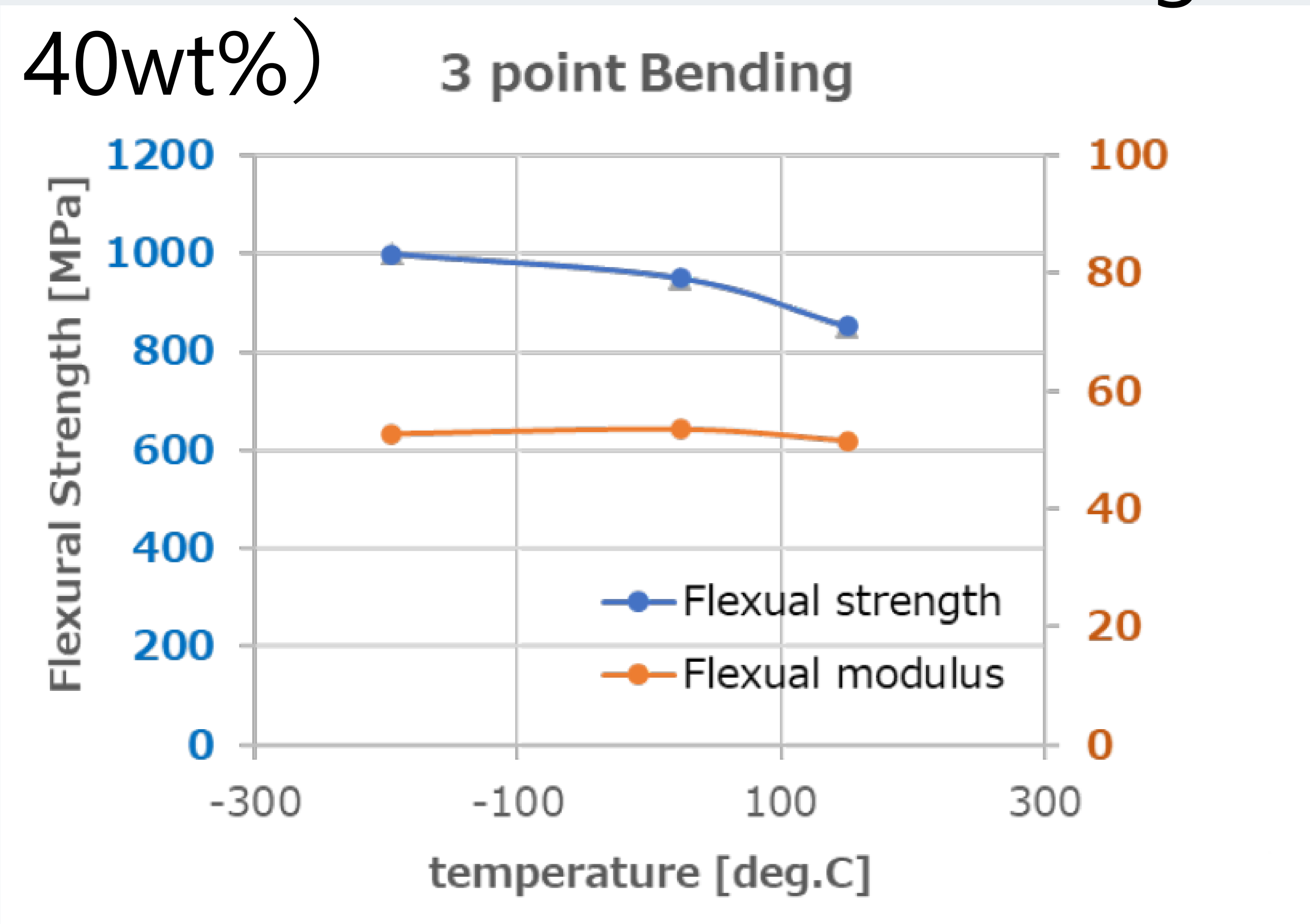
Low moisture absorption ➡ Small Coefficient of Moisture Expansion (CME)
Less cryogenic micro-cracks ➡ No loss of strength at cryogenic temperatures
Low dielectric constant ➡ Low electromagnetic wave loss

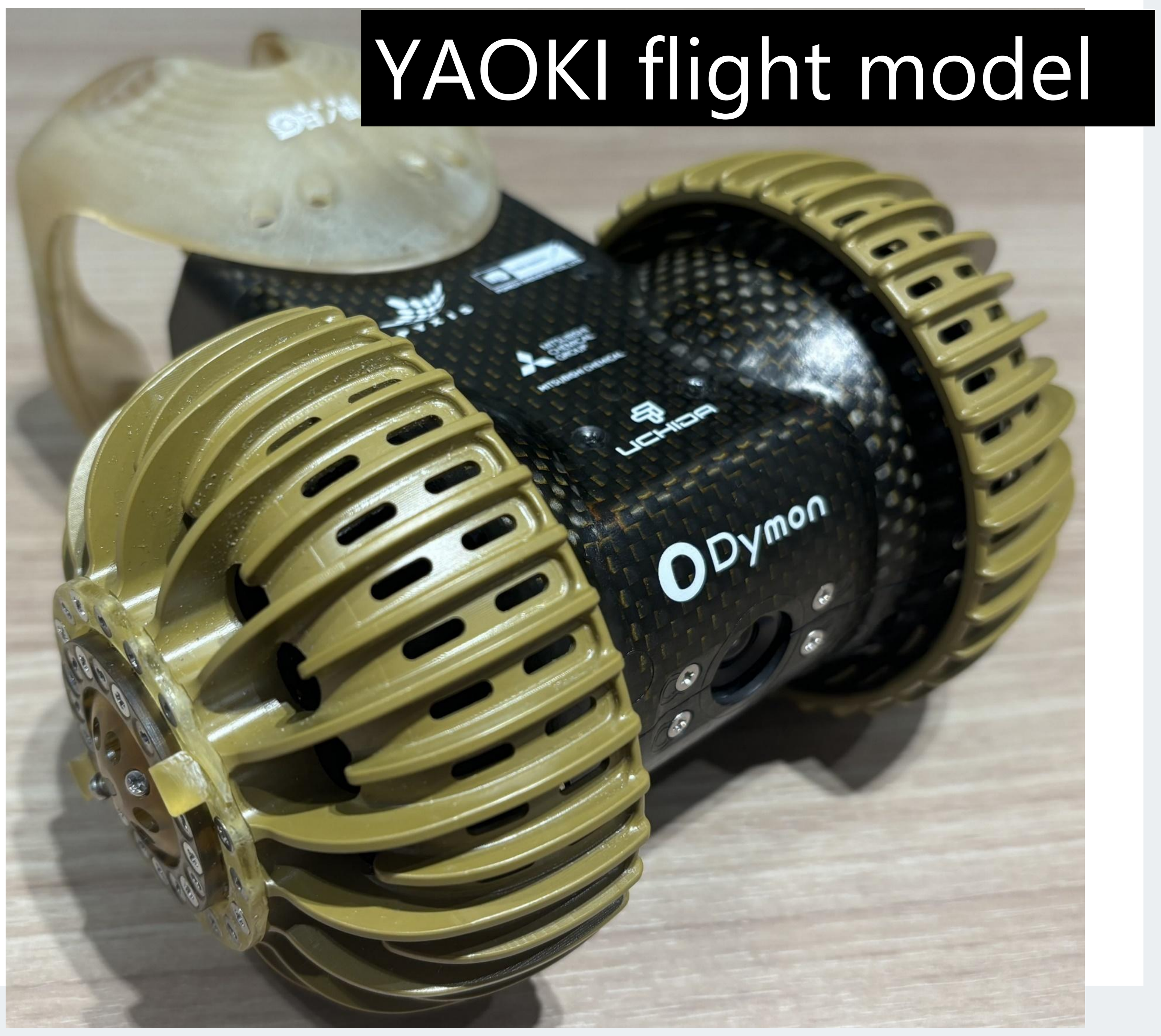
【Characteristic of Cyanate ester resin "#290"】

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

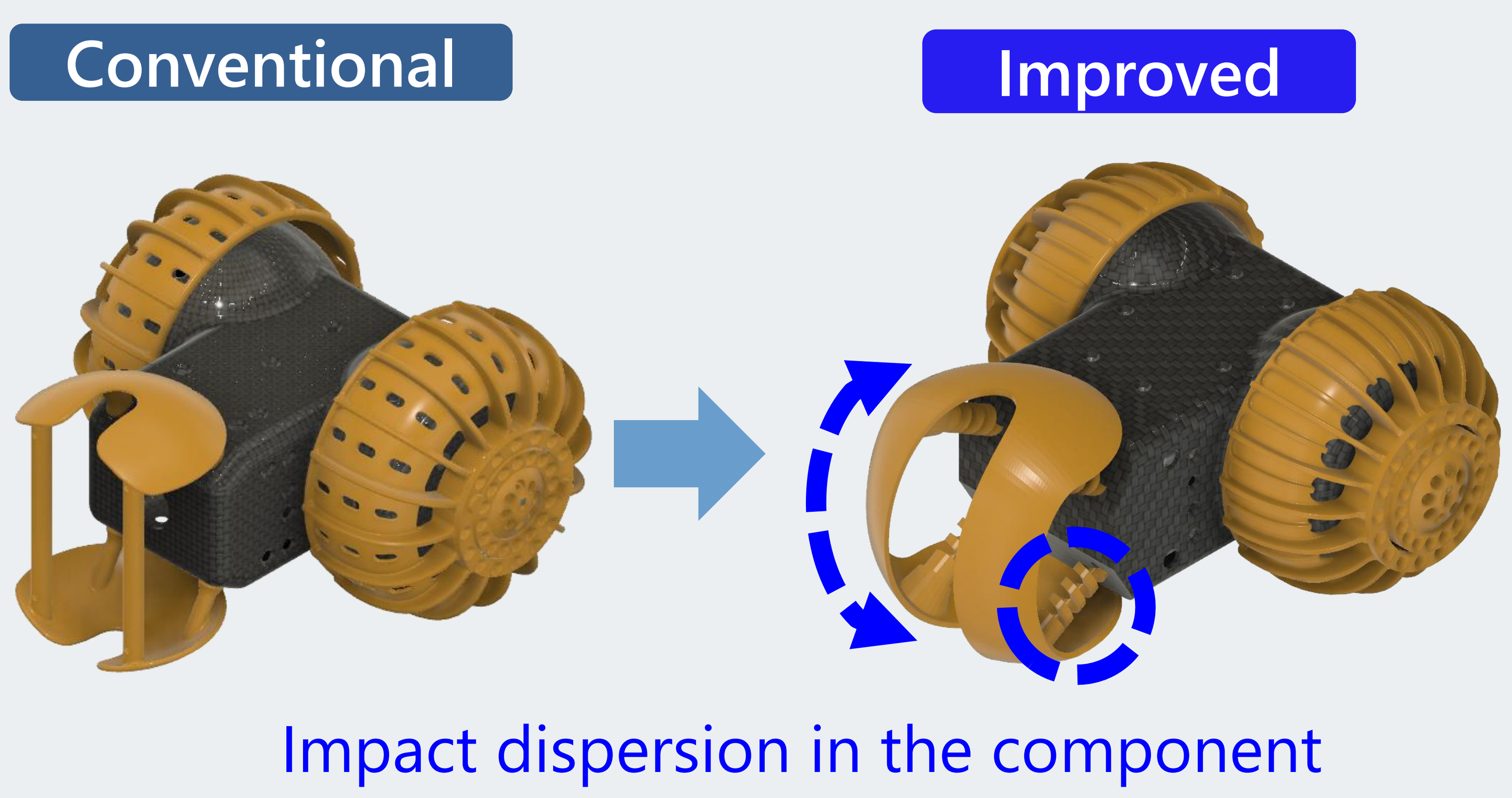
Compliant Mechanism Design

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

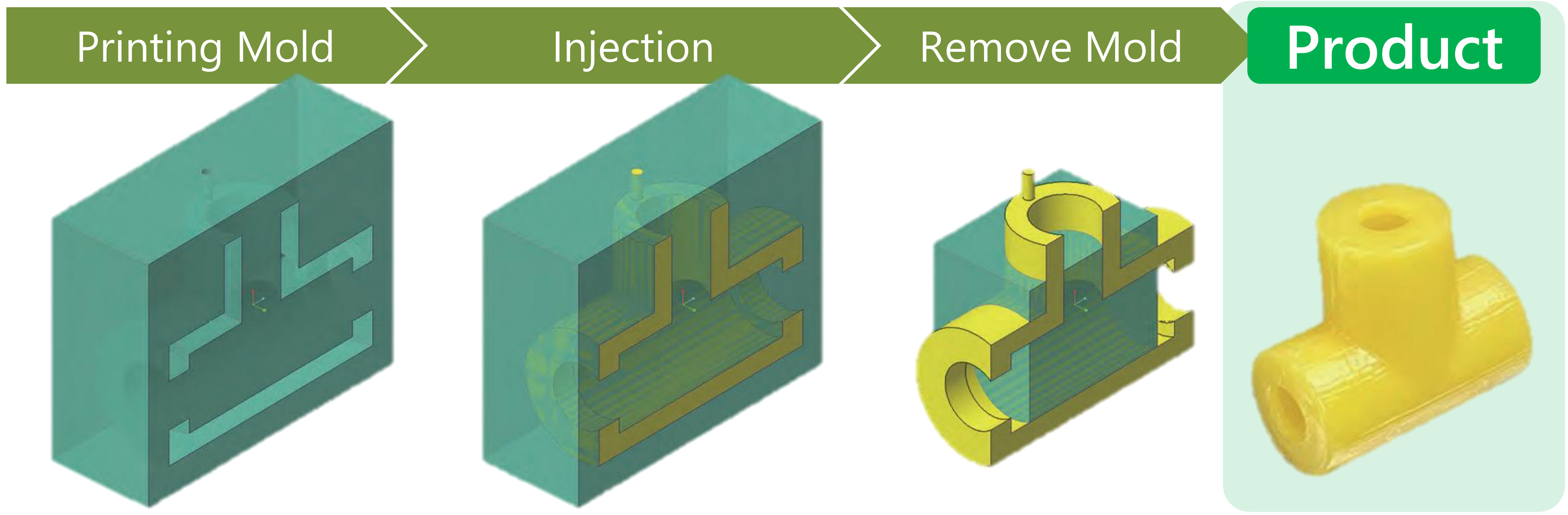
Usually, to improve impact resistance, designs that increase wall thickness to make them sturdier or that use high-strength metals are used. However, in space applications, where strict weight reduction is required in terms of transportation costs, supple design techniques using resins may be effective.



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

Mitsubishi Chemical Corporation

Thermal Neutron Shielding Coating (Under Development)

【Product features】

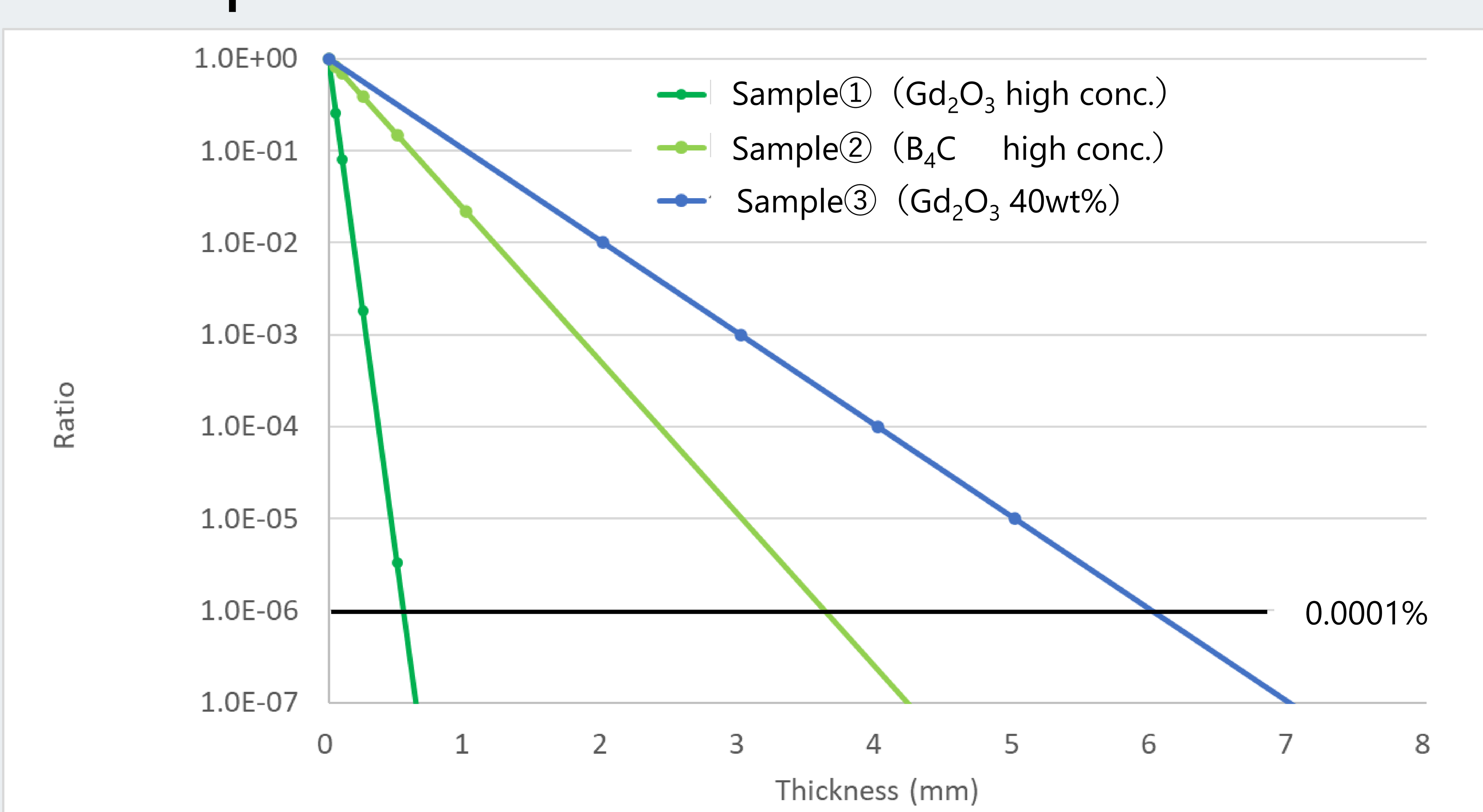
- Our original polymer emulsion in water containing neutron absorption materials in high concentration

Applied to PET film
Thickness : 50μm
No crack

- Applicable to wide range of materials, such as aluminum, concrete, and PET film.

【Thermal neutron (～100meV) shielding test】

- Sample ① and ② show low transmittance with thinner coating than comparative shielding material ③, due to the high concentration of neutron absorption materials.



MITSUBISHI CHEMICAL GROUP

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Heat-Resistant Composite Materials
Carbon/Carbon Composite, CMC Composite

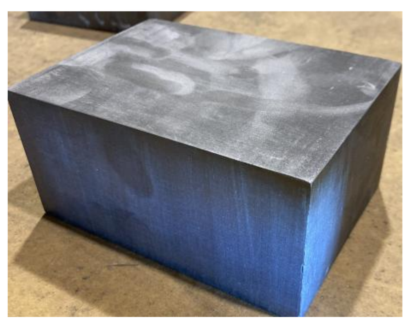
- C/C（Carbon/Carbon）：CF＋Carbon
- CMC（Ceramic Matrix Composite）：CF＋SiC
- Phenolic CFRP , SMC：CF＋phenolic resin

【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】

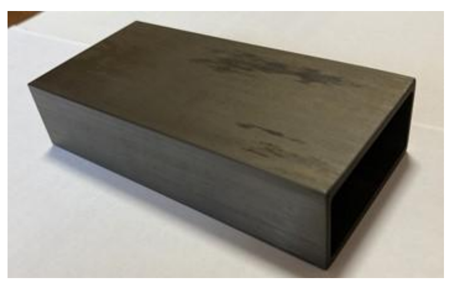
C/C brake & Molding（short CF）

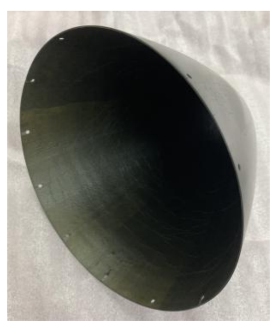


C/SiC brake（development）

C/C, C/SiC hand（long CF／development）

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



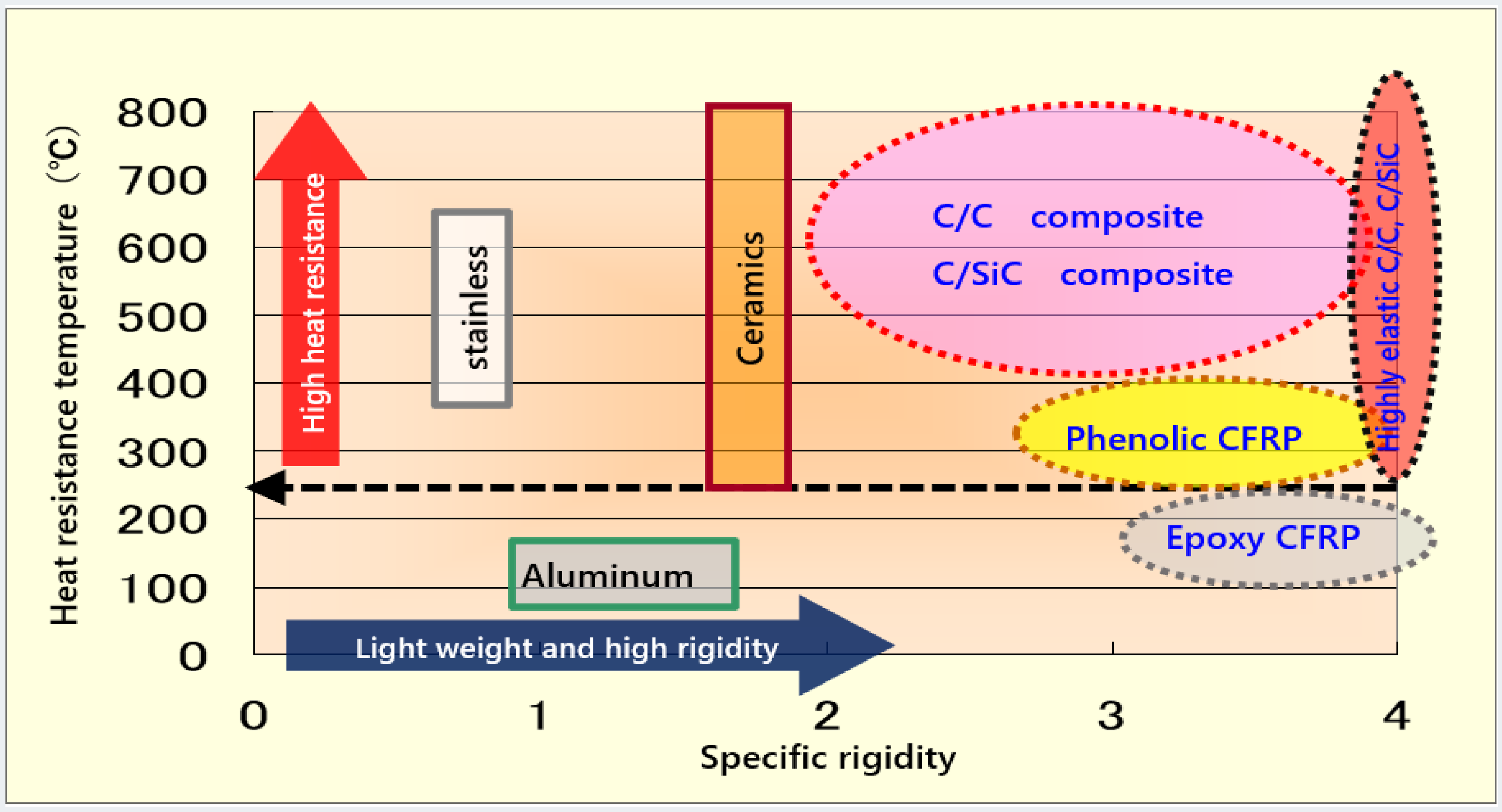


【Typical properties】

Materials	Direction	Bulk density g/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】

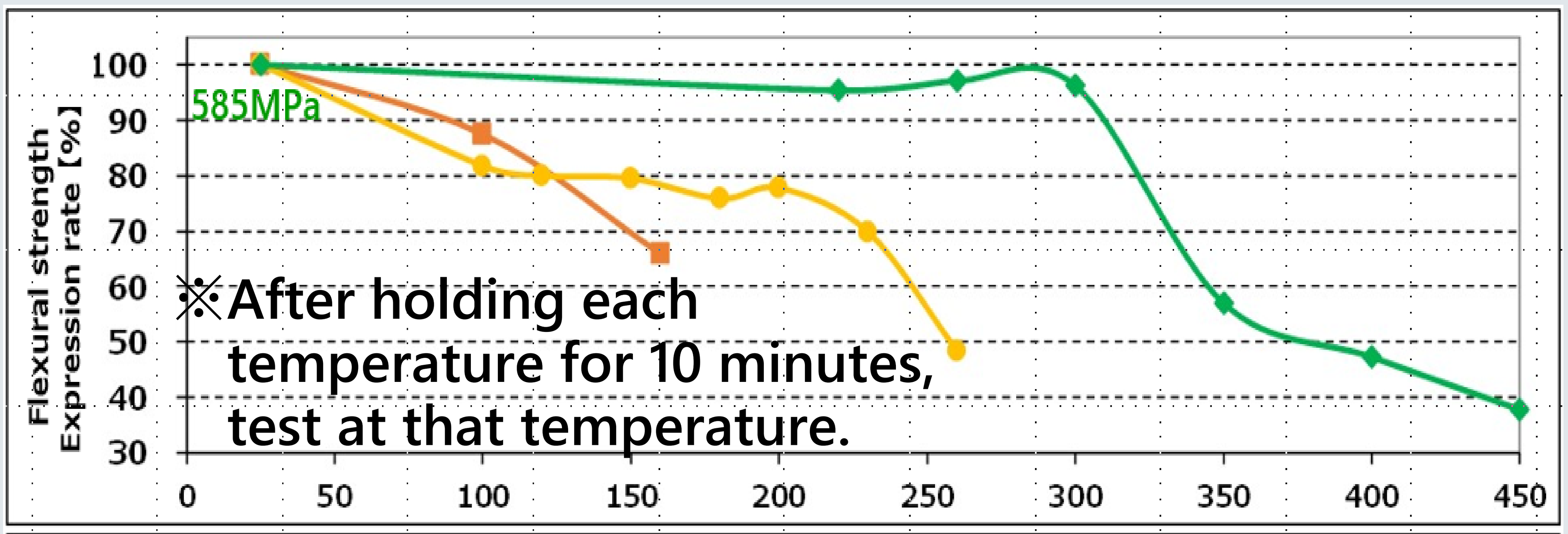


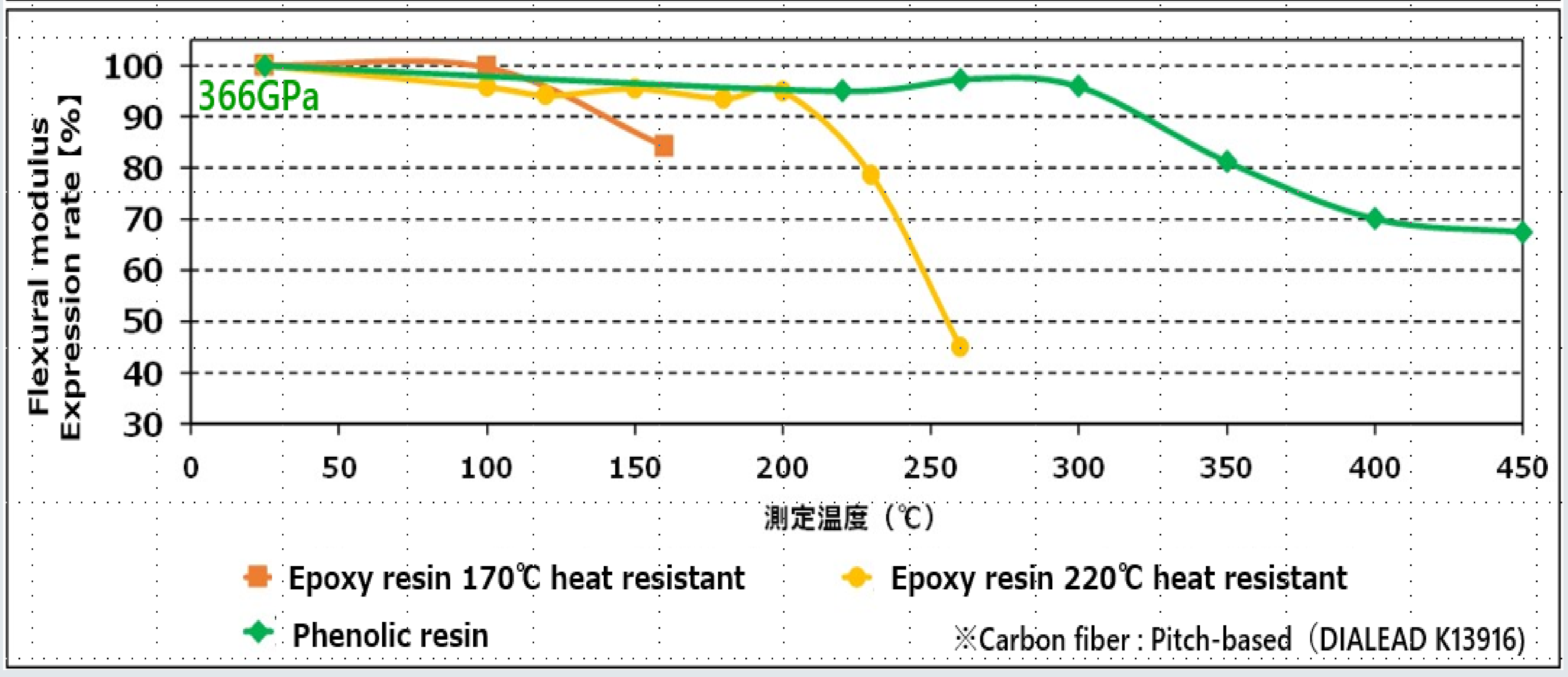
300℃ Heat Resistant Phenolic CFRP

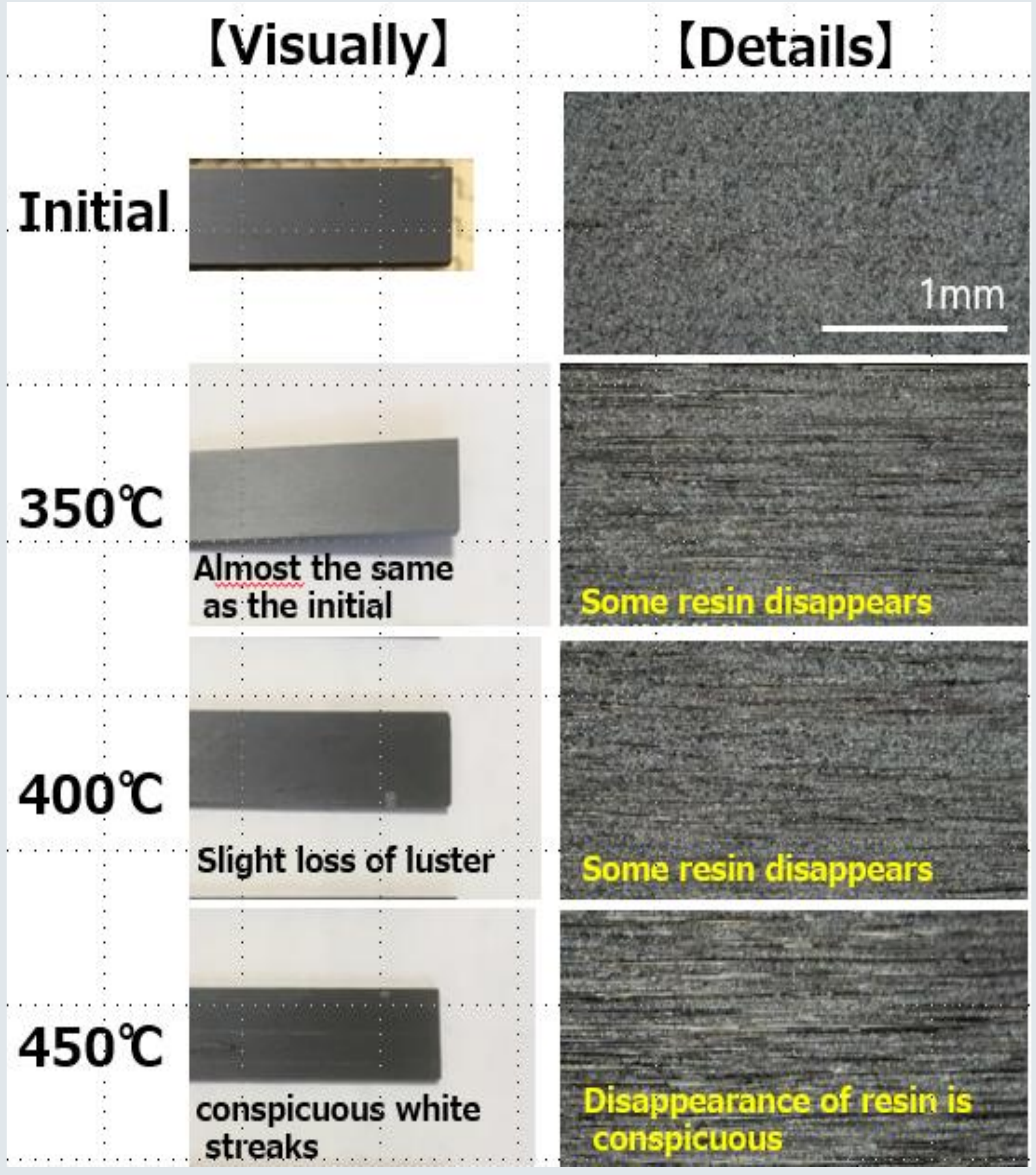
【 Characters 】

- **Light weight：1/4 or less density of steel（1.7 g/cm³）**
- 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

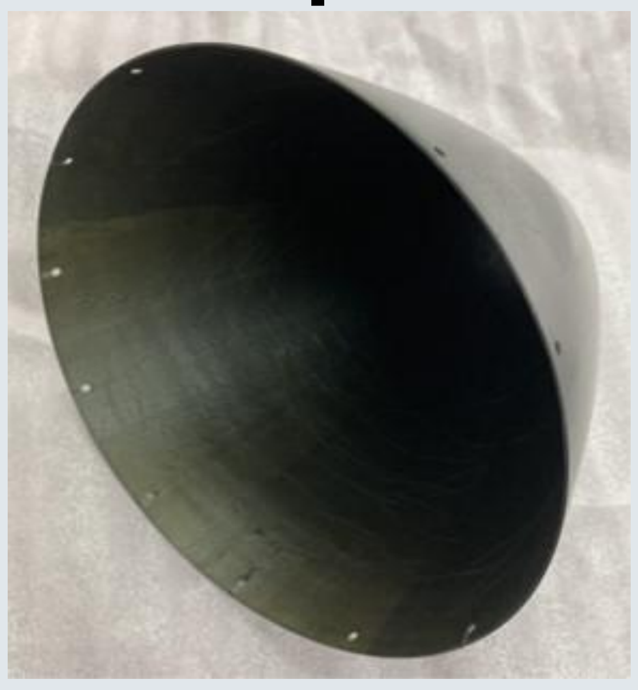






【 Product example 】

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**

Phenolic SMC
（short CF）
CFRP→C/C composite

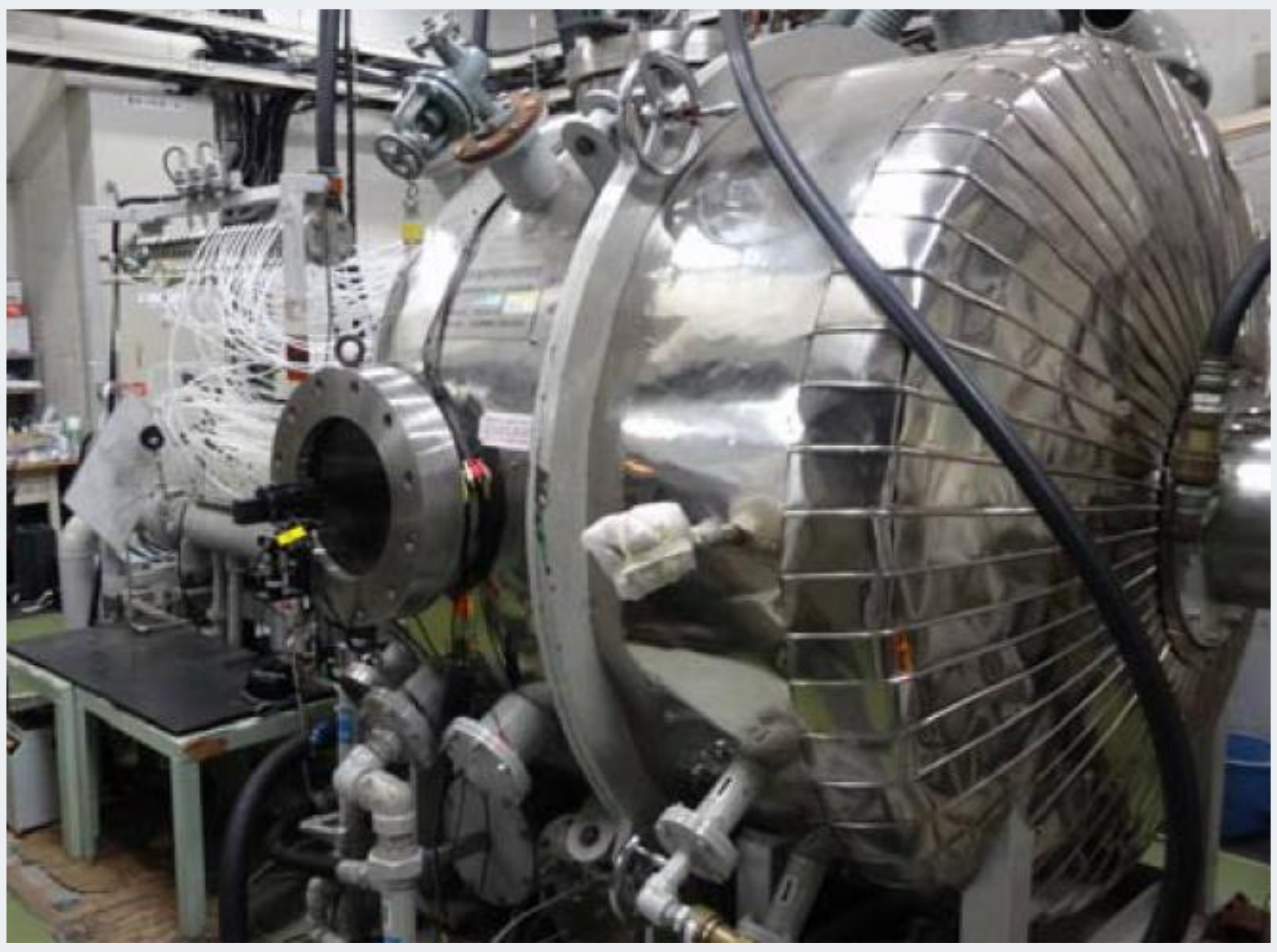
MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

Phenolic-based CFRP for Ablation Applications

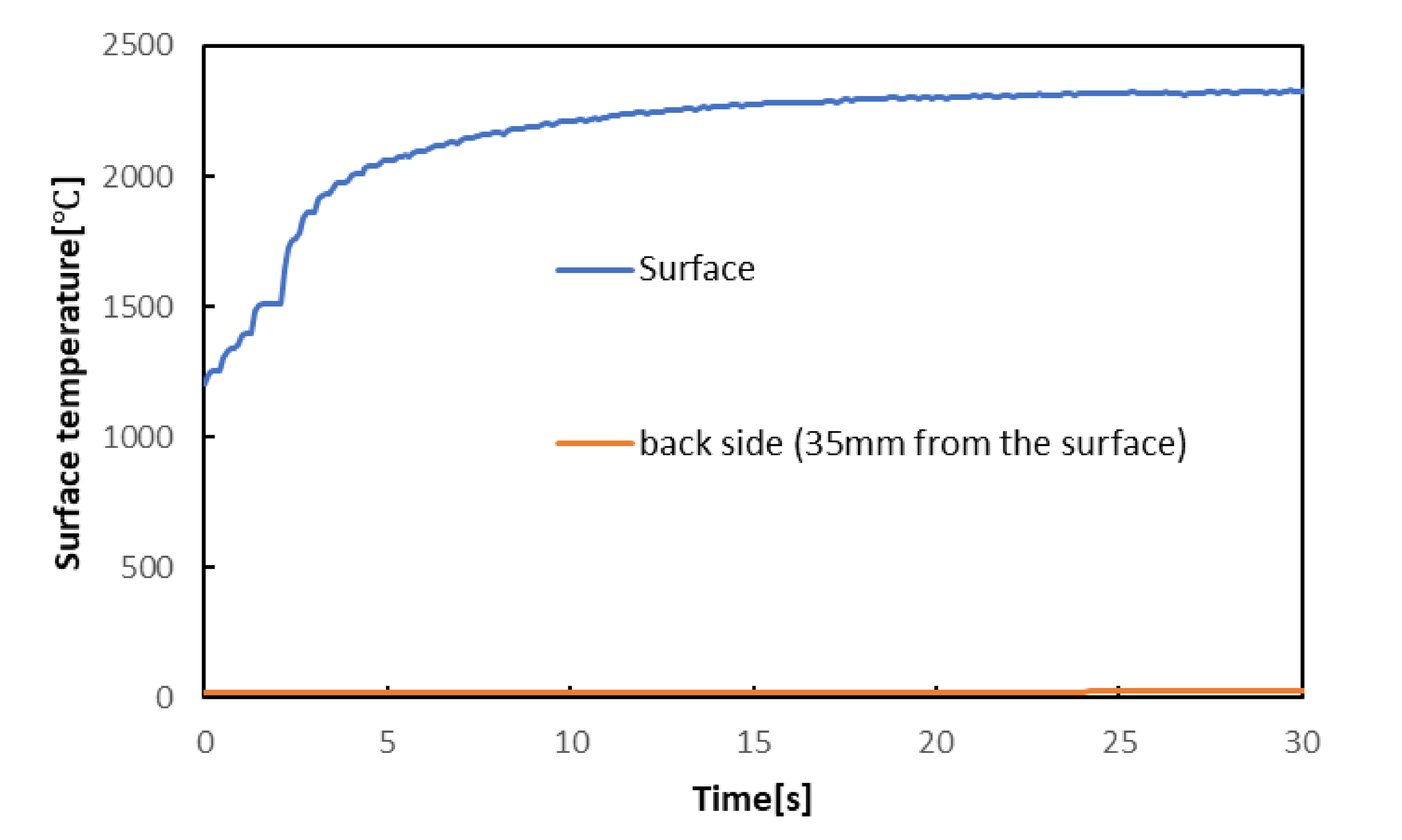
Application: Heat-resistant material for spacecraft Thermal Protection System (TPS)

Arc heating wind tunnel test machine (JAXA)



Surface and Back side Temperature Changes

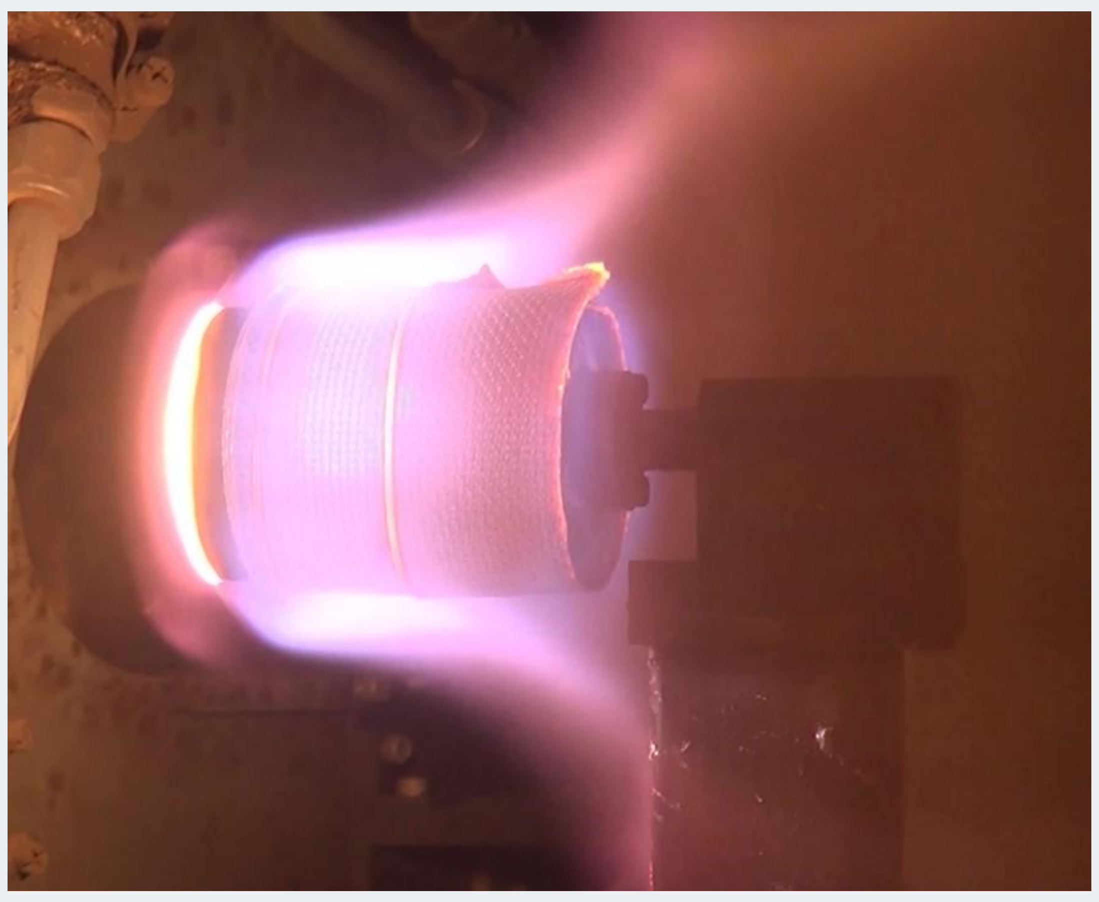
Test Condition: 3.6 MW/m2

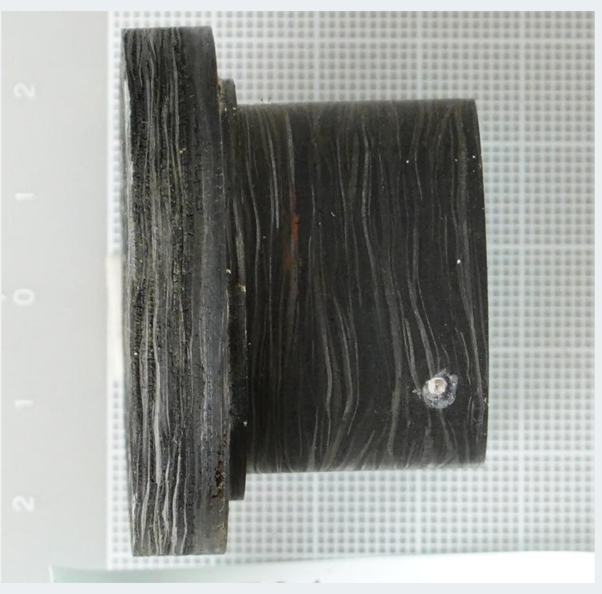


Test Condition／Test Result

sample	Test Condition		Temperature		Thickness		
Density	Heat rate	distance	Surface (MAX)	Back side (MAX)	Before test	After test	Δ
g/cm3	MW/m2	mm	℃	℃	mm	mm	mm
1.54	3.6	100	2329	166	35.41	33.35	-2.06

Test sample picure



Heat rate	Before test	After test
3.6MW/m2		
		

The results of the Arc heating wind tunnel test on the SMC pitch-based phenolic CFRP confirmed that it possesses sufficient heat resistance for a 30-second heating test.

MITSUBISHI CHEMICAL GROUP

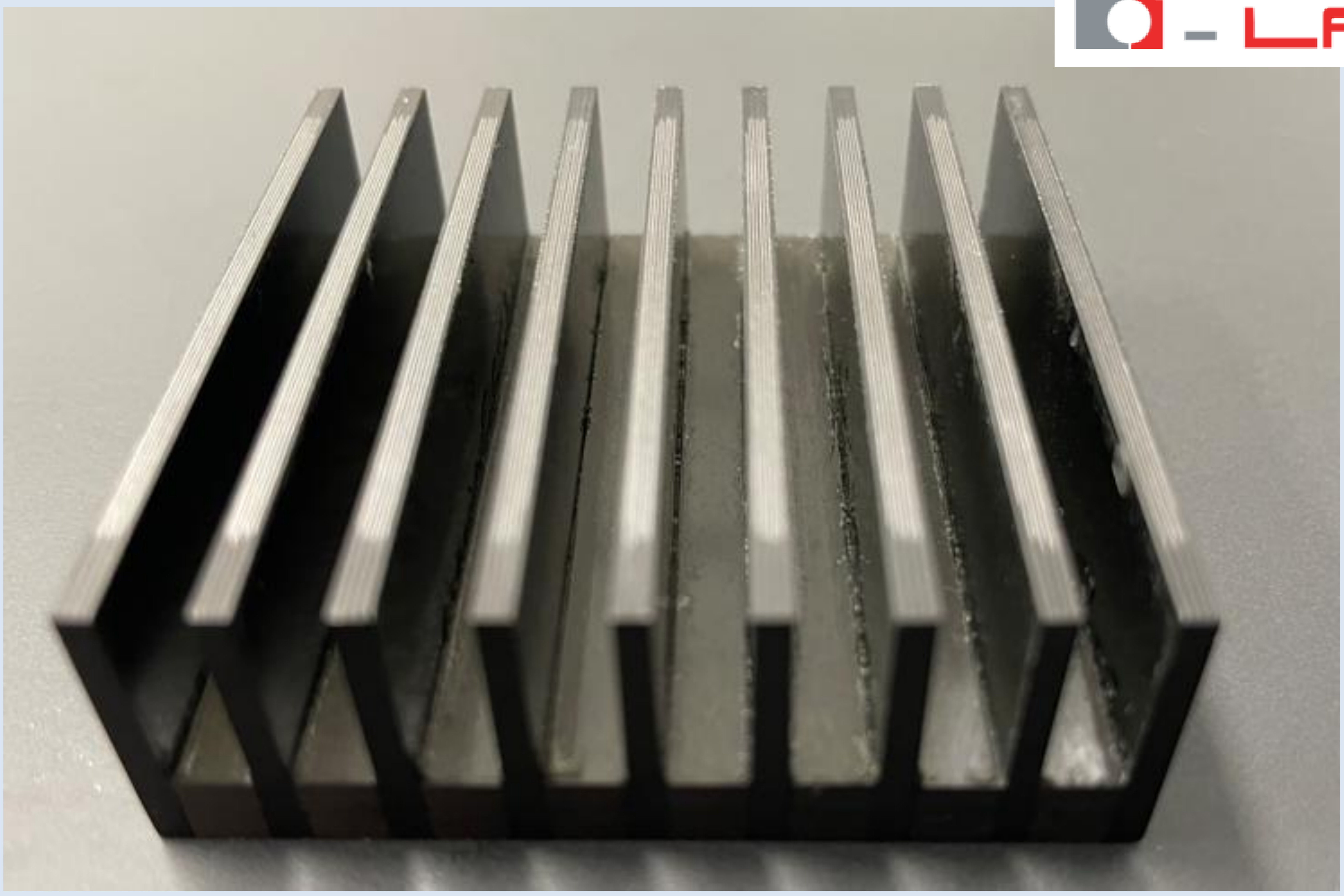
Mitsubishi Chemical Corporation

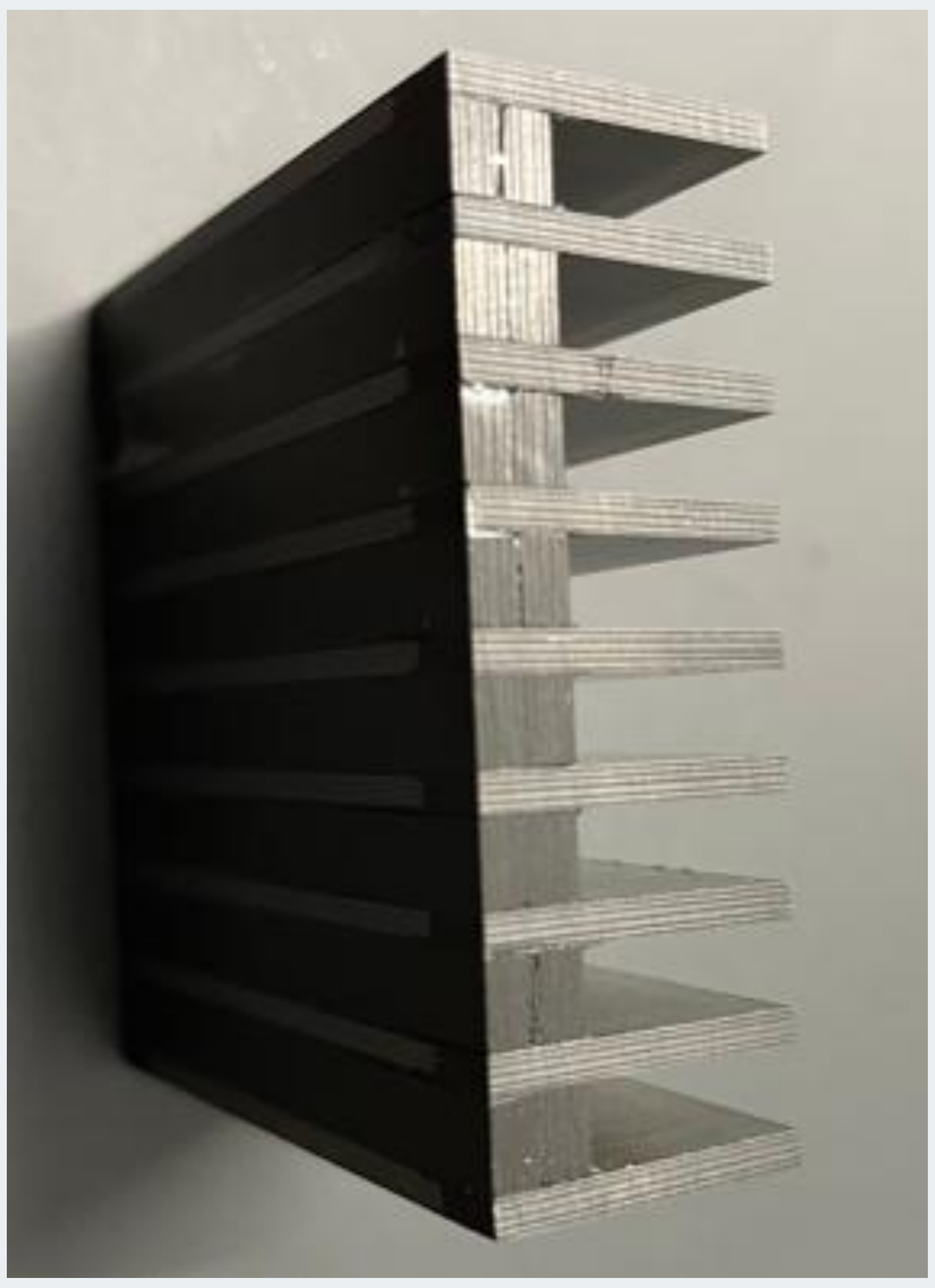
High heat resistance and high thermal conductivity phenolic CFRP

Applications: High heat resistance and high thermal conductivity components for TPS, nuclear reactors, fusion reactors, etc.

Achieved a thermal conductivity of 750 W/m·K in two directions by alternately stacking 120 μm graphite sheets and 180 μm pitch-based carbon fibers (K13916) / phenolic resin prepregs

TECH-LAB





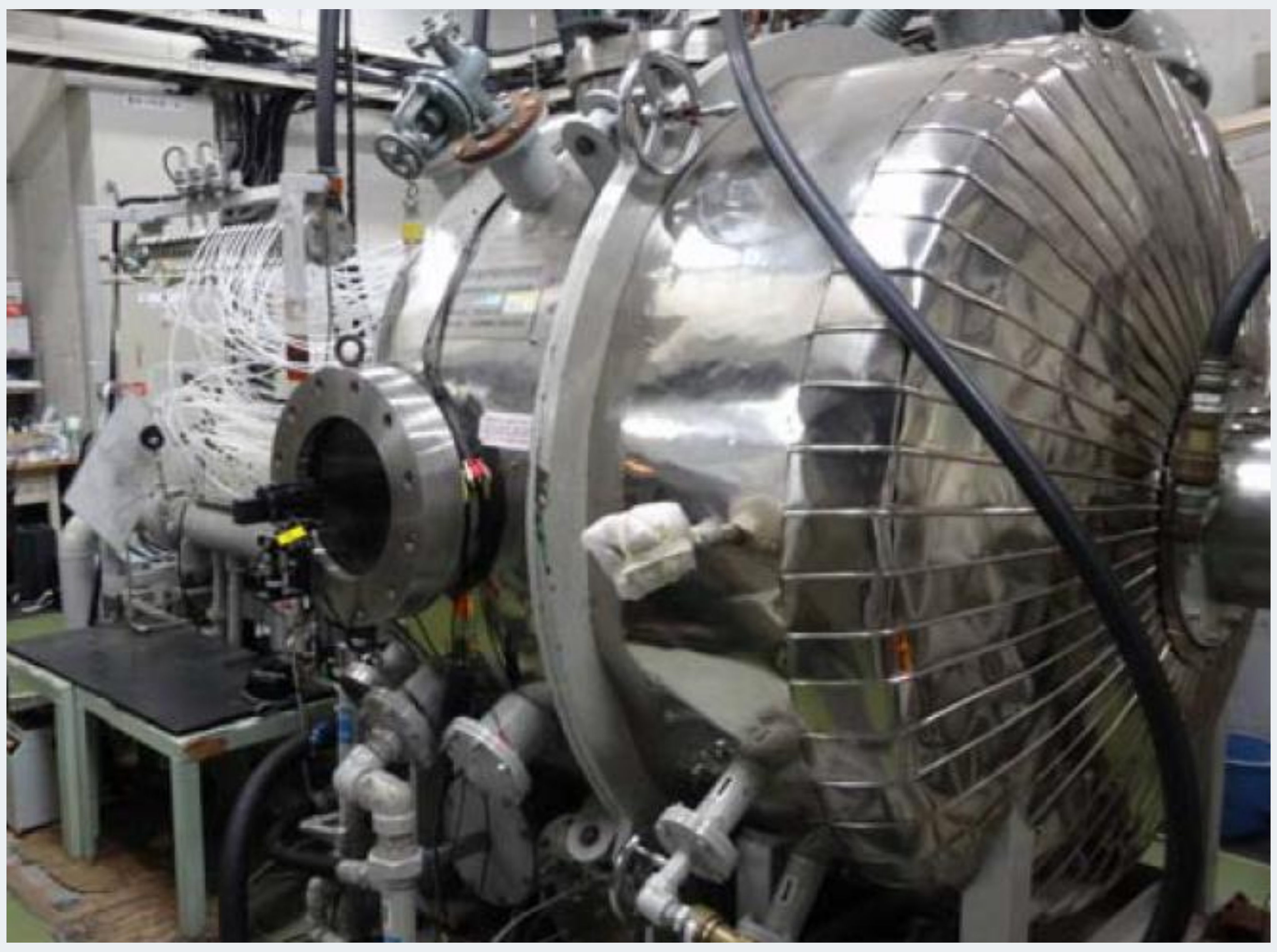
MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

1,500℃ Heat Resistant Pitch-based CMC composite

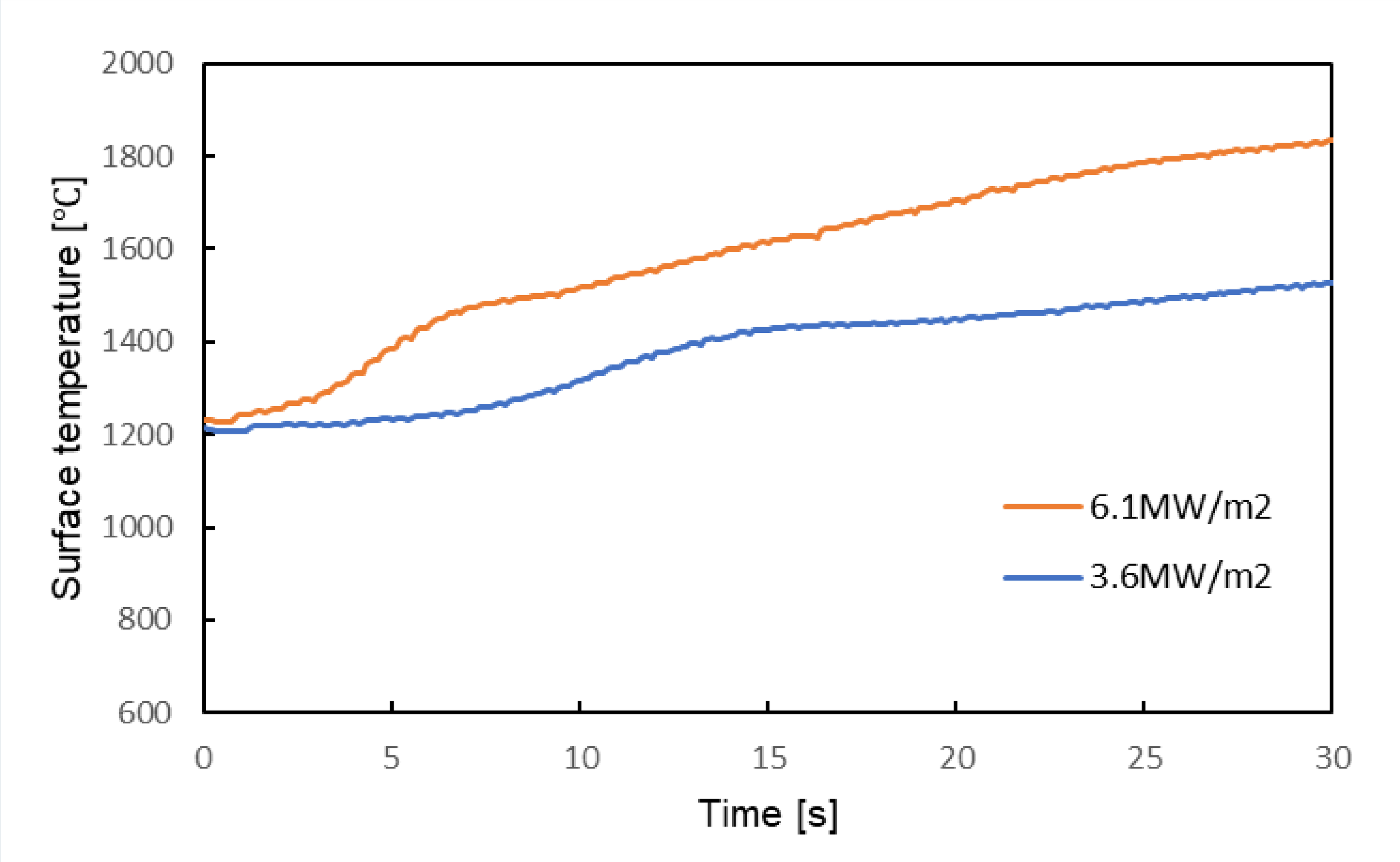
Application: Heat-resistant material for spacecraft Thermal Protection System (TPS)

Arc heating wind tunnel test machine
（JAXA）



Test condition and Temperature

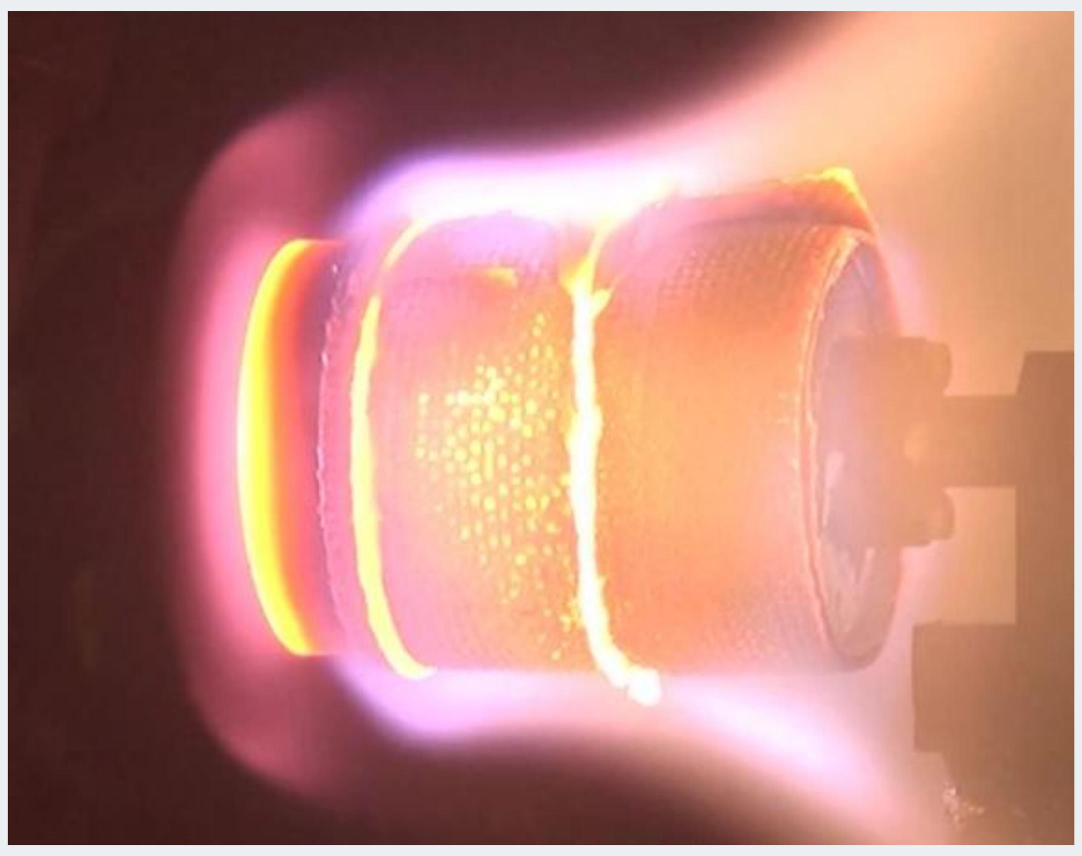
3.6MW/m2　　6.1MW/m2

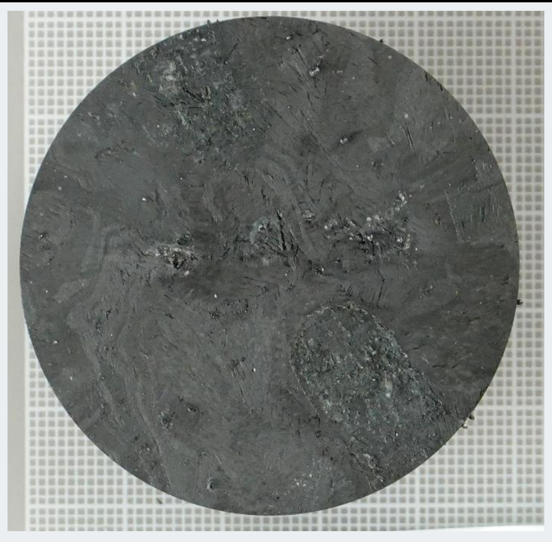


Test Condition／Test Result

sample	Test Condition		Temperature		Thickness		
Density	Heat rate	distance	Surface	Back side	Before test	After test	Δ
g/cm3	MW/m2	mm	℃	℃	mm	mm	mm
2.38	3.6	100	1544	683	29.65	29.87	0.22
2.41	6.1	80	1842	759	29.99	30.12	0.13

Test sample picure



Heat rate	Before test	After test
3.6MW/m2		
6.1MW/m2		

As the result of arc heating wind tunnel tests on SMC pitch-based C/C with metal Si (C/SiC), there were no cases of detachment.

MITSUBISHI CHEMICAL GROUP

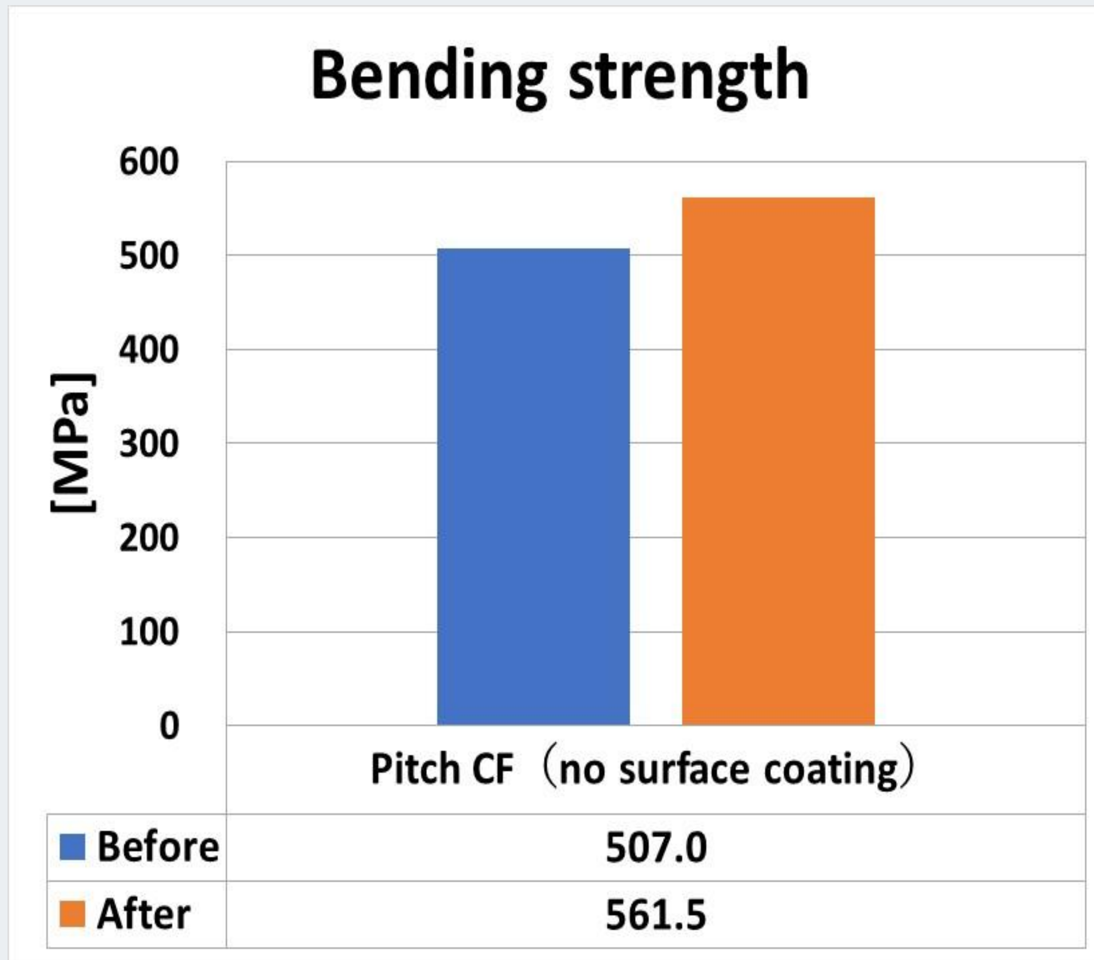
Mitsubishi Chemical Corporation

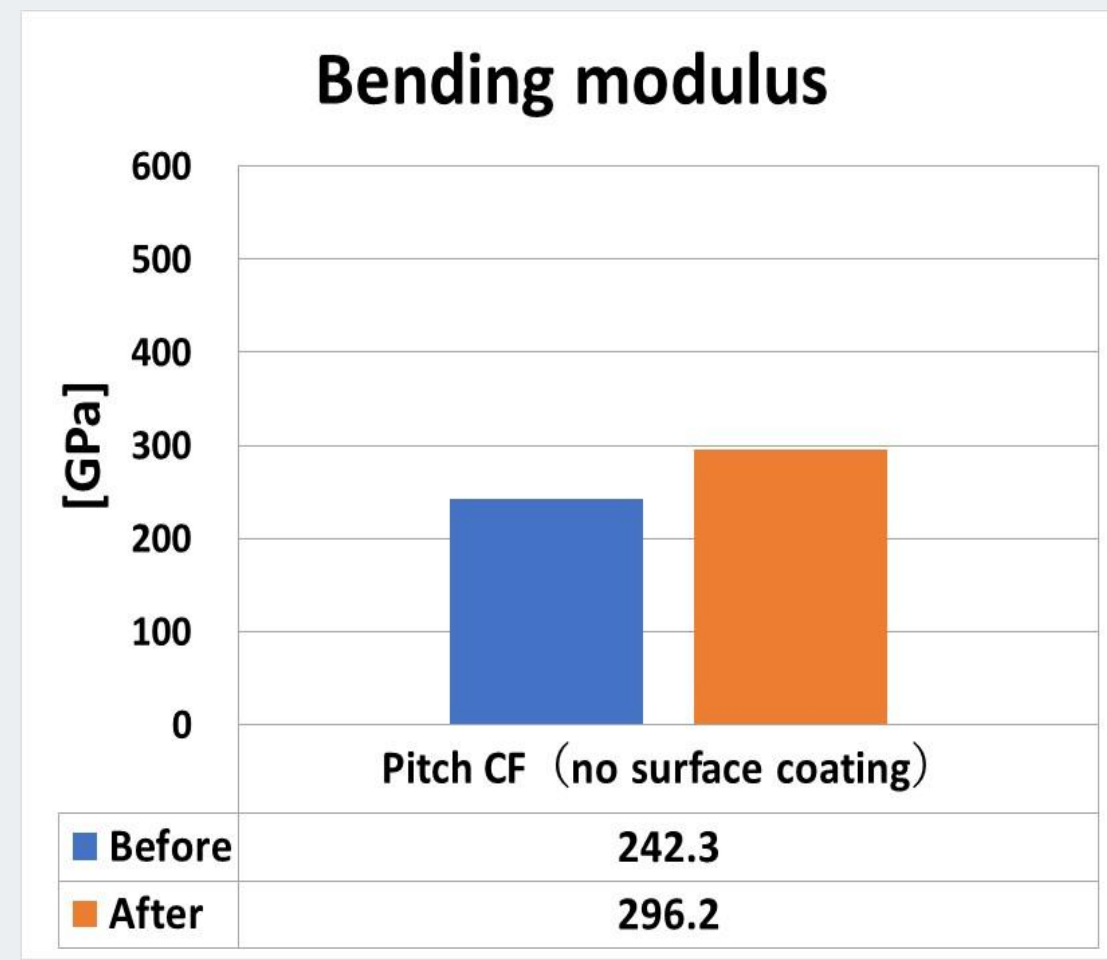
1500℃ Heat Resistant CMC (Pitch-based C/SiC Composite)

Application: Heat-resistant material for spacecraft heat shield tiles

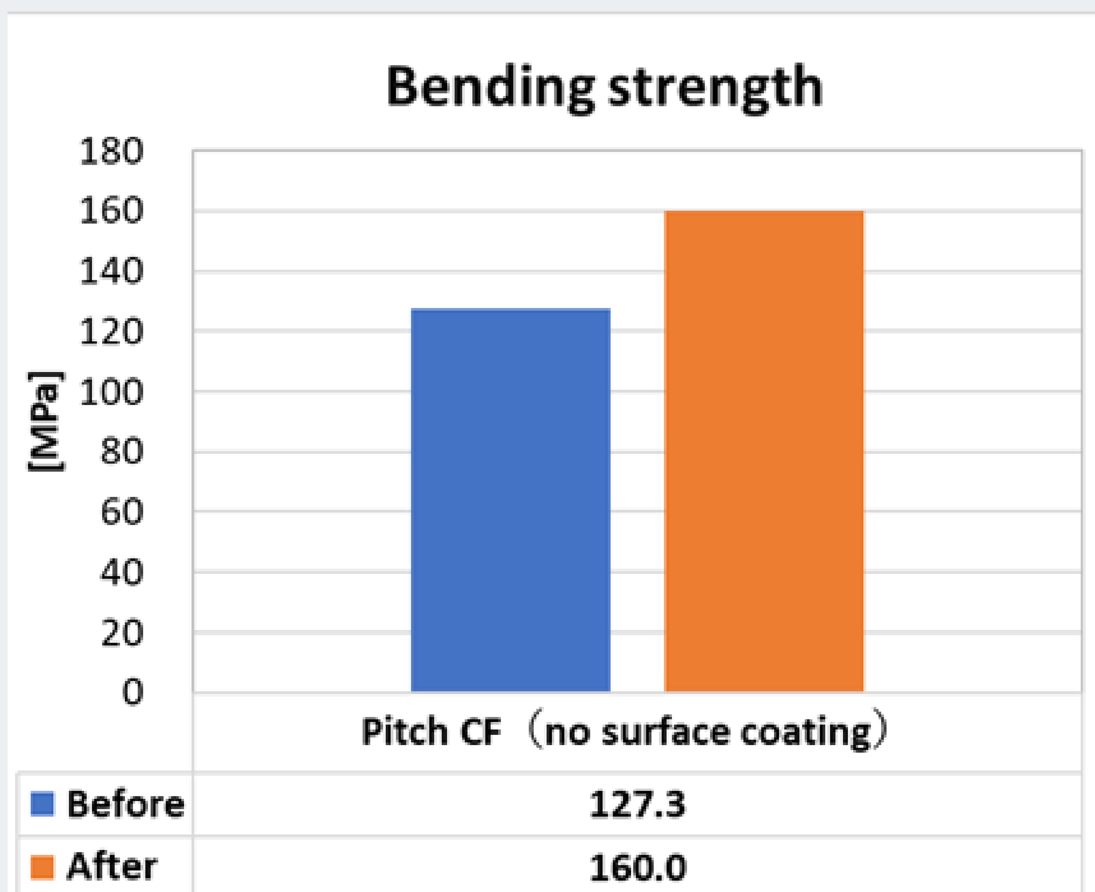
Before vs after at 1,500℃×1 hour （in Air）

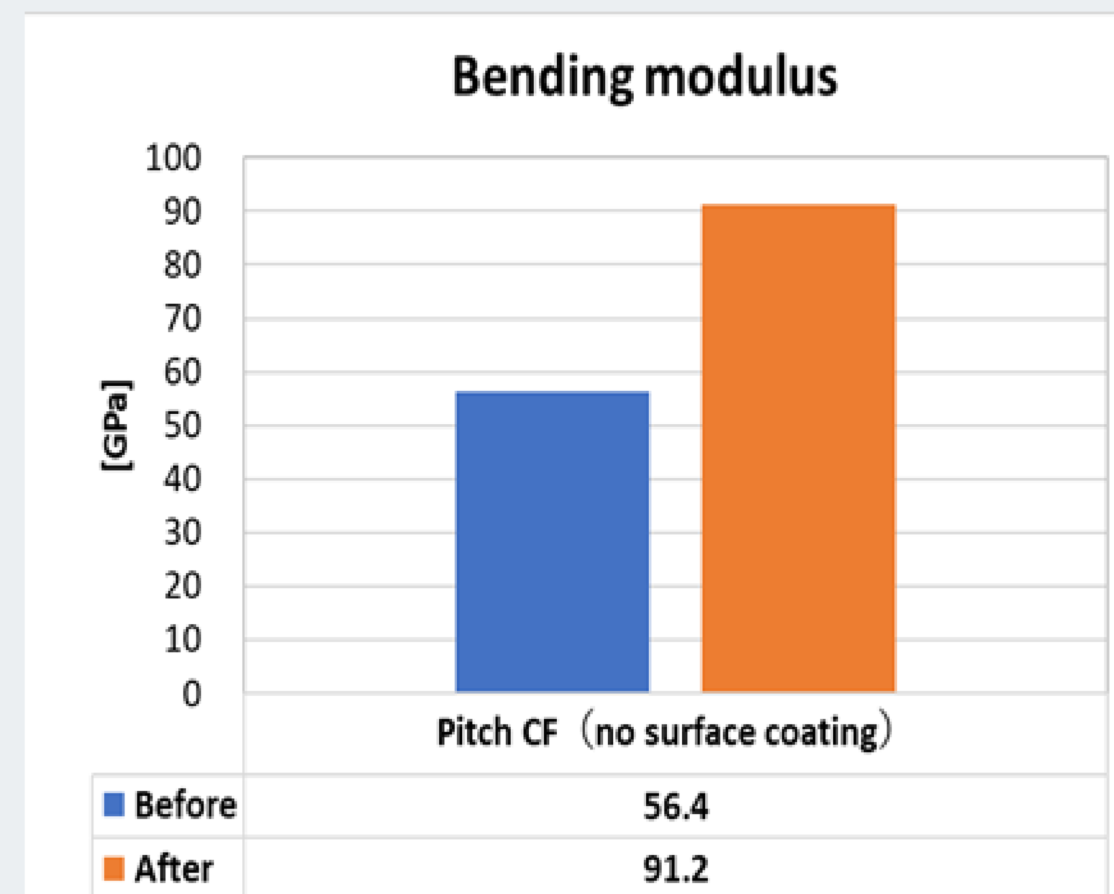
Long-Fiber Type



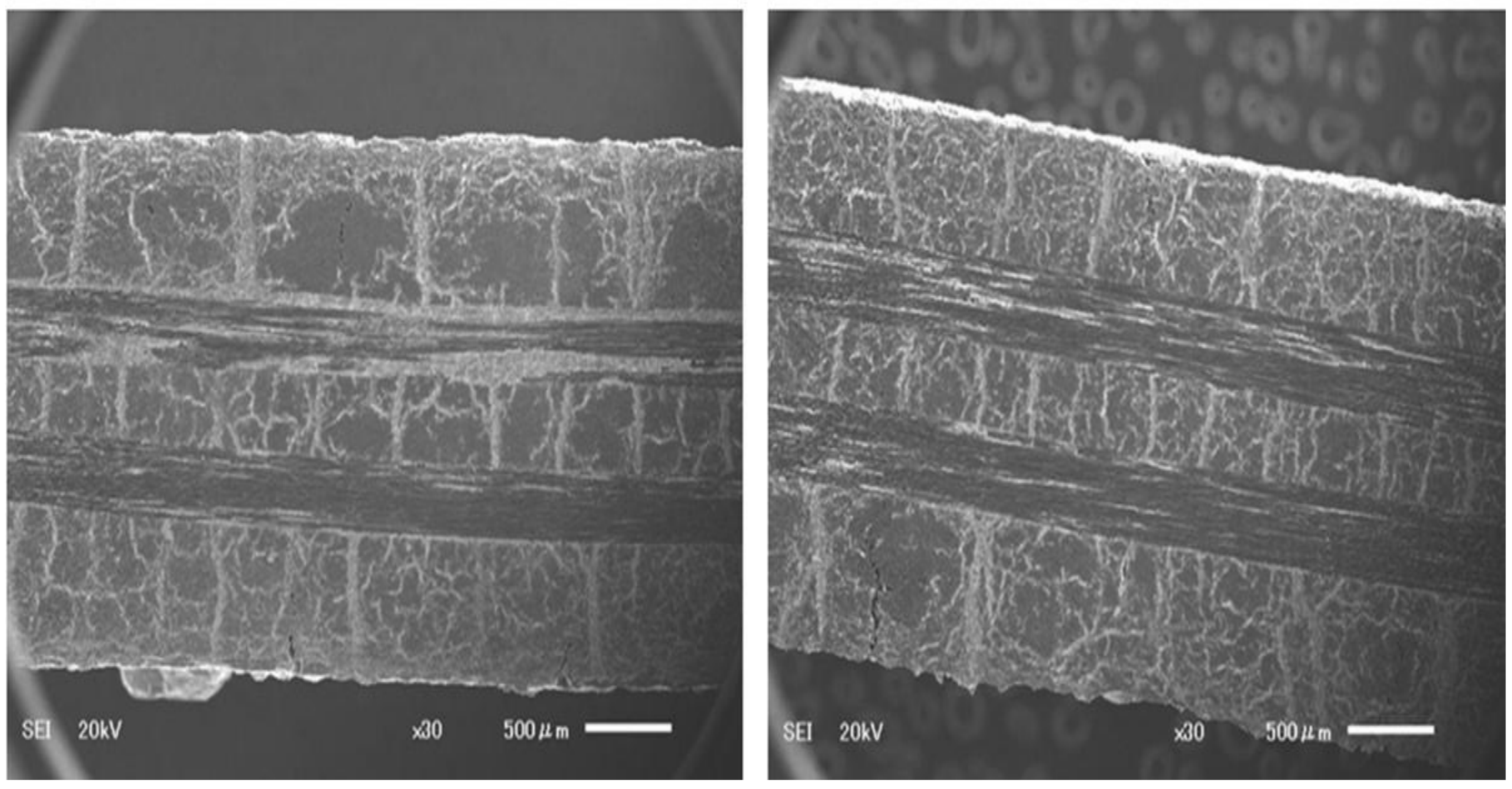


Short-Fiber Type（SMC-based）





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



Before After

- The cross-sectional observation photographs (SEM images) of Long Fiber Type before and after heat treatment in air at 1,500°C for 1 hour
- SiO_2 layer was observed on the surface after heat treatment.

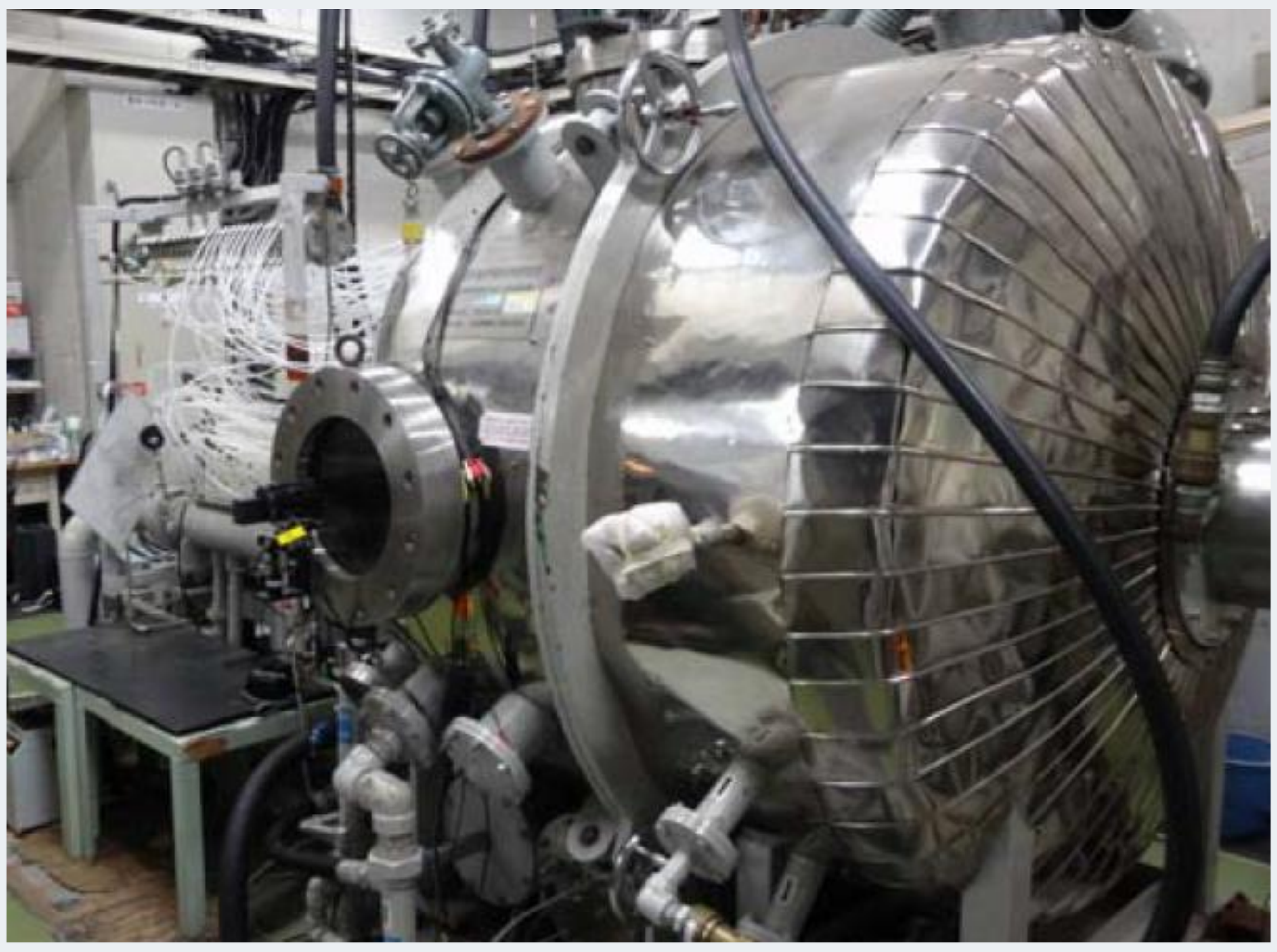
MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

2,500℃ Heat Resistant Pitch-based CMC composite

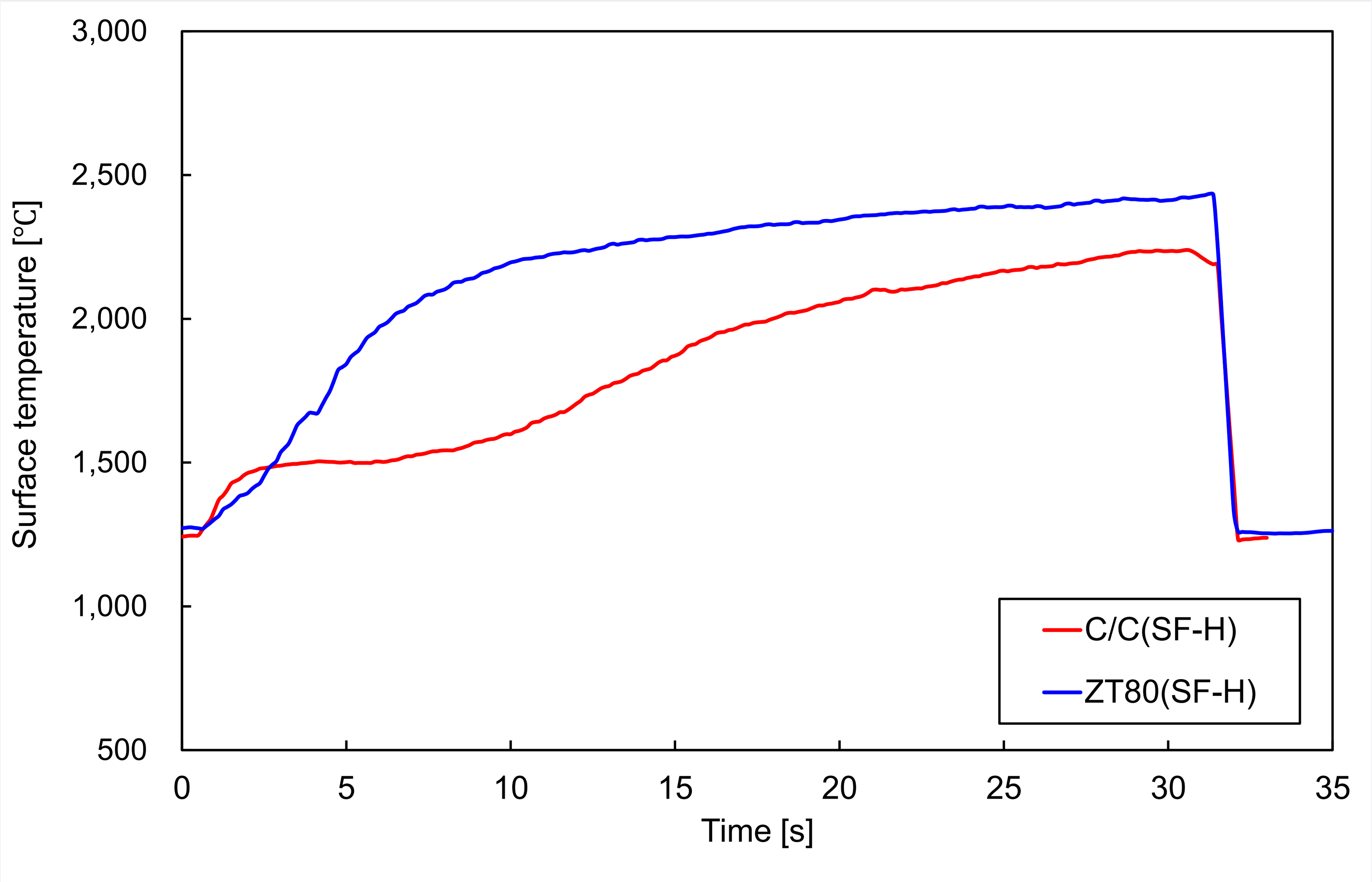
Application：Rocket nozzle, Heat-resistant materials for fusion reactors

Arc heating wind tunnel test machine（JAXA）



Test condition and Temperature

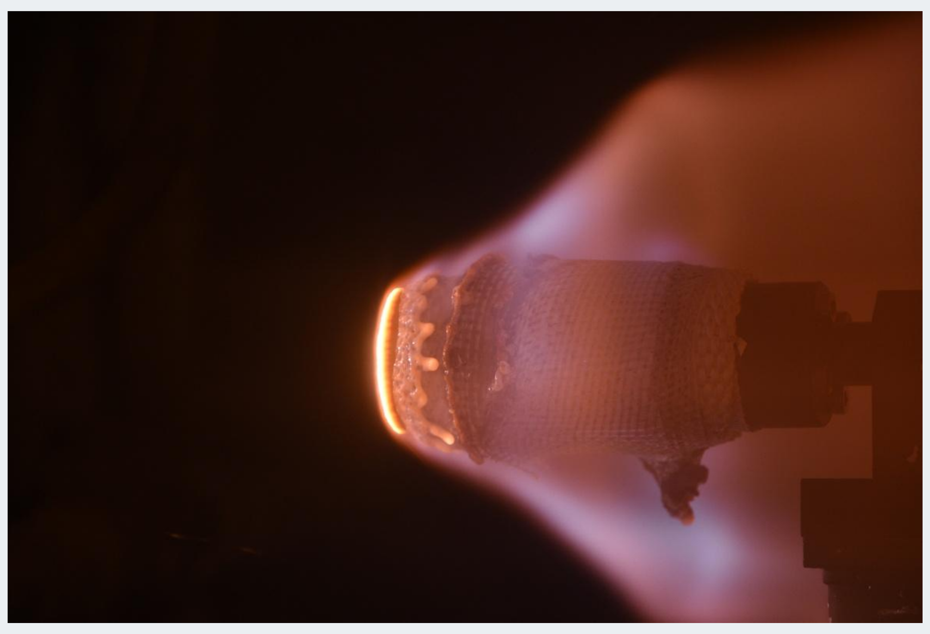
4.71MW/m2　　L=100mm

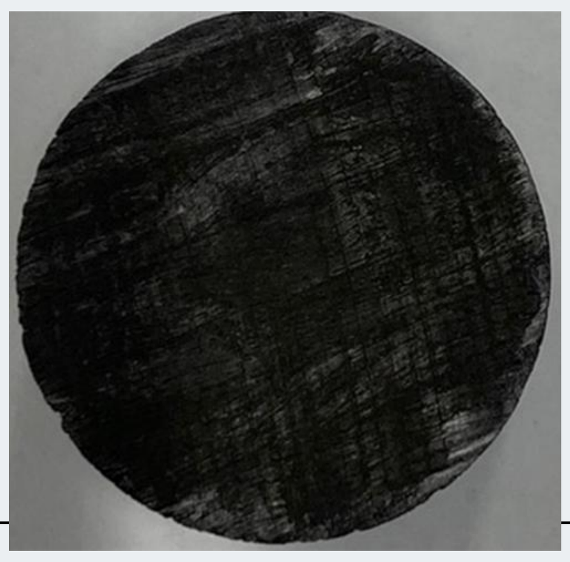
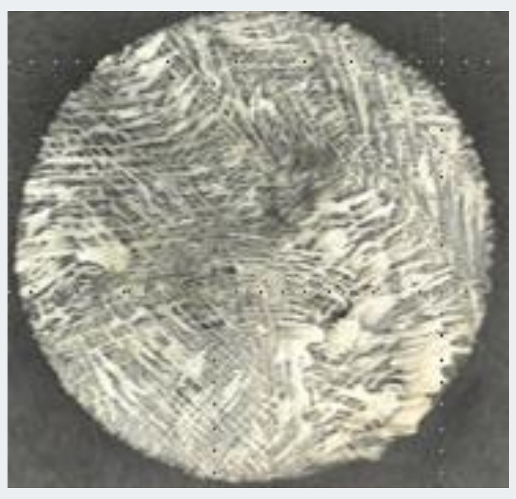
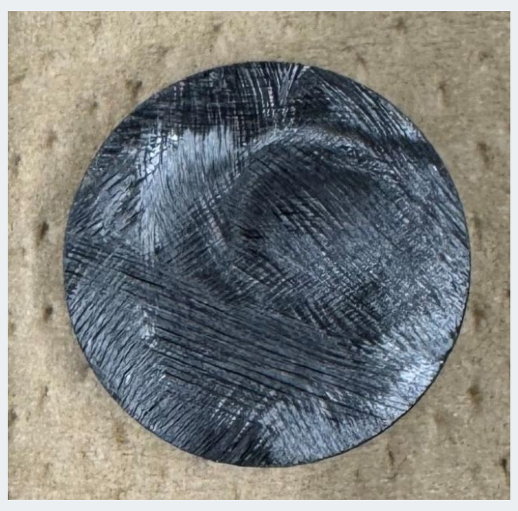


Sample／Test Result

		Thickness		
Sample	**Density**	**Before test**	**After test**	**Δ**
	g/cm3	**mm**	**mm**	**mm**
ZT80(SF-H)	**2.34**	**9.77**	**9.86**	**0.1**
C/C(SF-H)	**1.69**	**8.08**	**7.32**	**-0.8**

Test sample picture



	Before test	**After test**
ZT80(SF-H)		
C/C(SF-H)		

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

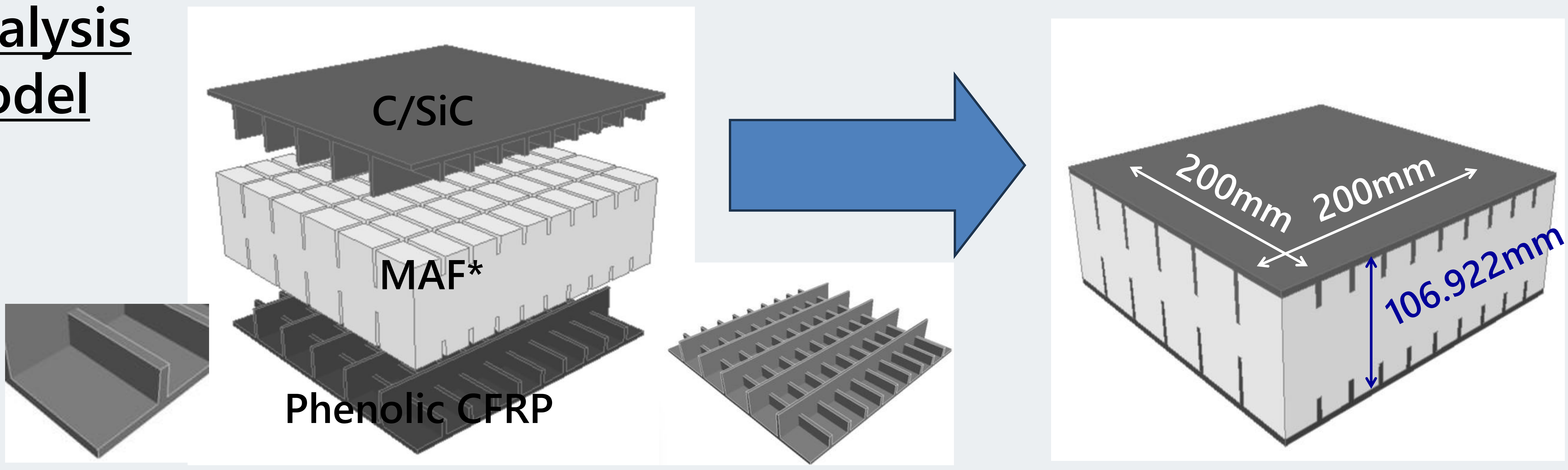
MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

Thermal Protection System（Analysis）

Application：Heat-resistant material for spacecraft heat shield tiles

Analysis Model

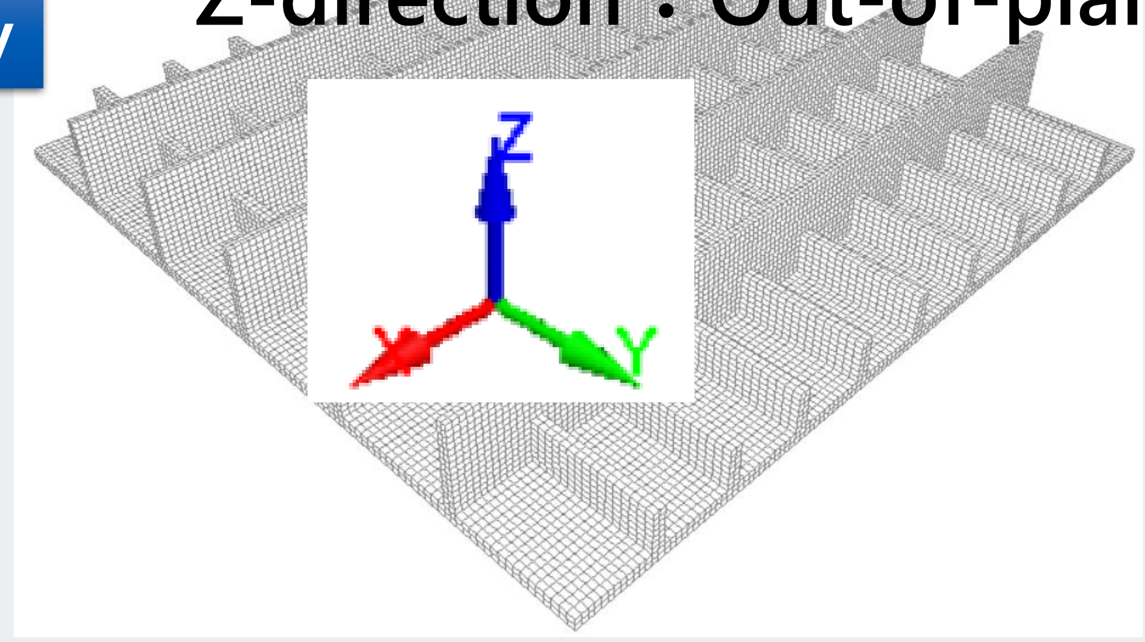


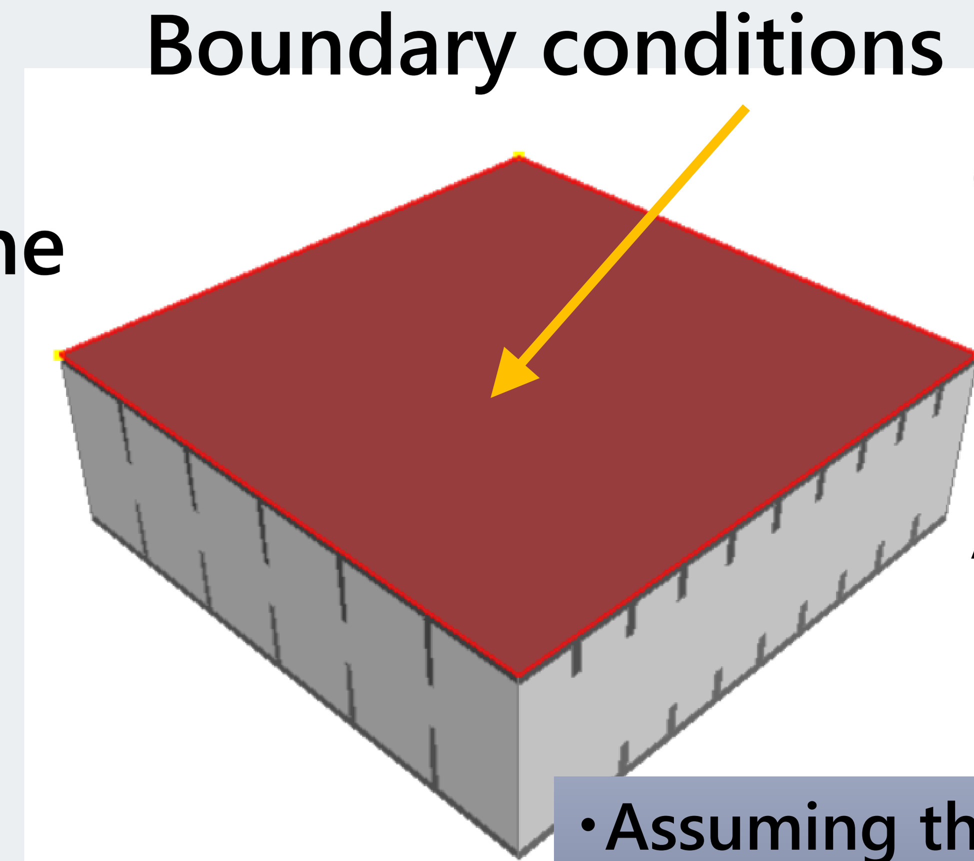
*https://www.maftec.co.jp/

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

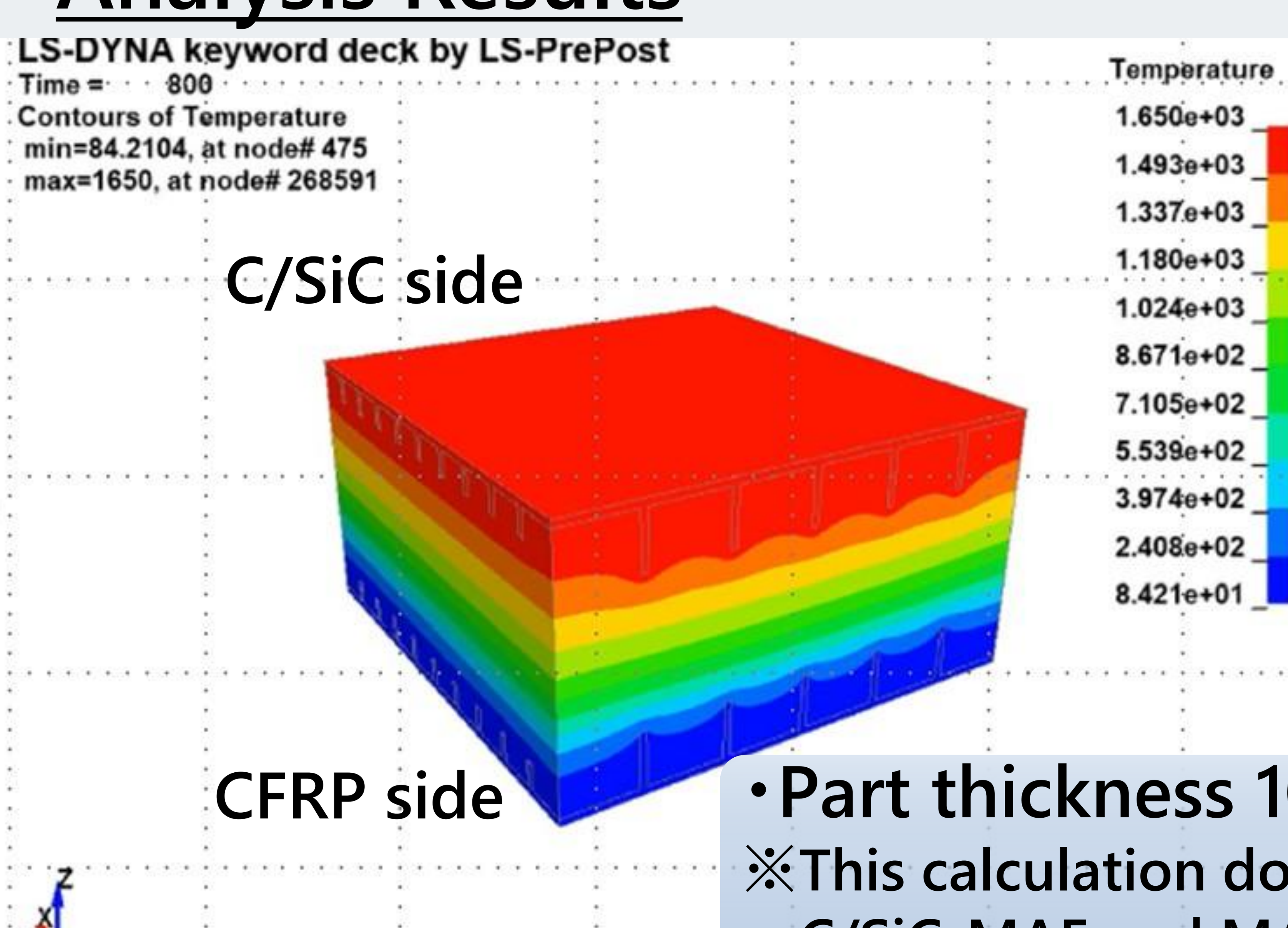
・Assuming that each part is in close contact
・Unsteady heat conduction analysis

Physical property

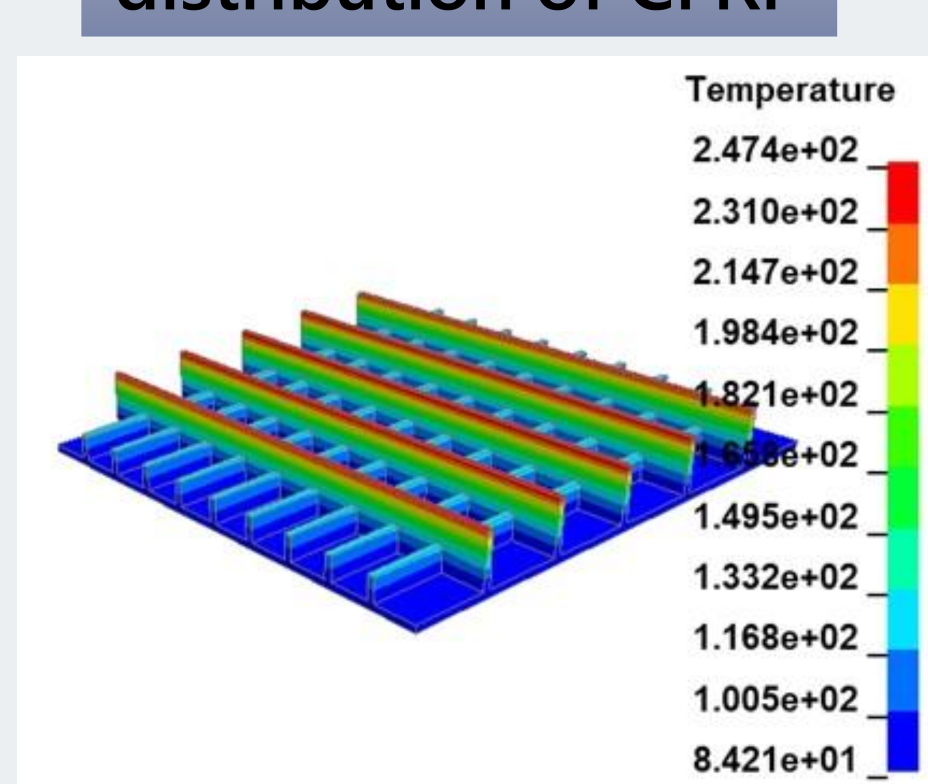
Properties	Unit	Phenolic CFRP	C/SiC	MAF
Thermal Conductivity（In-plane）	W/mK	55	Depends on temp.（Right table）	Depends on temp.（Right table）
Thermal Conductivity（Out-of-plane）	W/mK	1.5	Depends on temp.（Right table）	Depends on temp.（Right table）
Density	kg/m^3	1,600	2,400	130(Bulk)
specific heat	J/kgK	900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

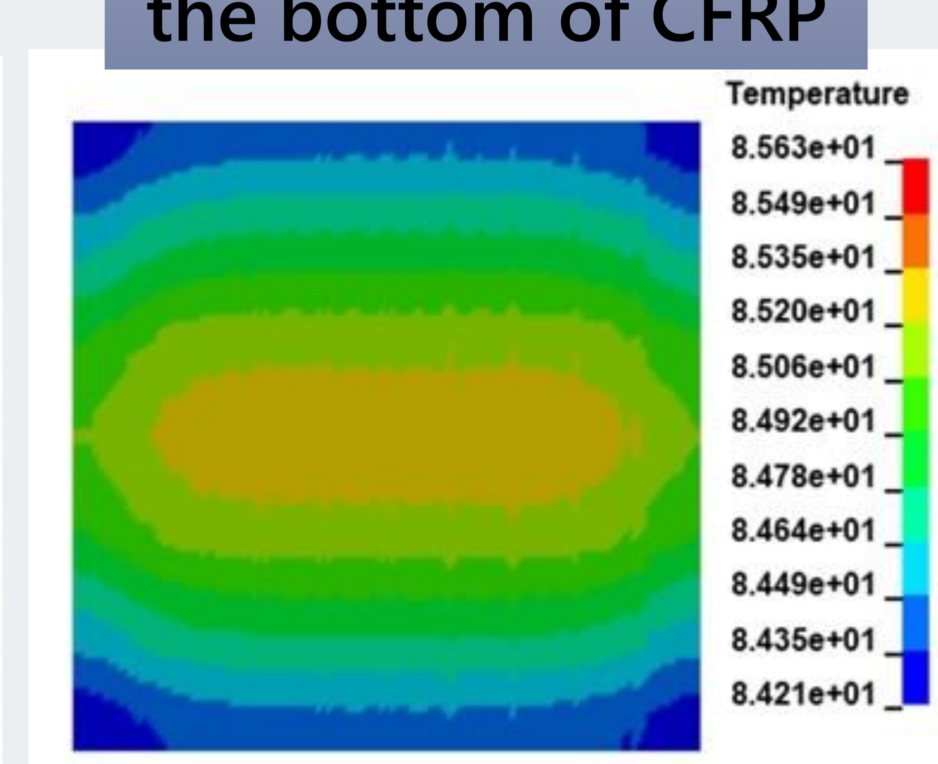
Analysis Results



Temperature distribution of CFRP



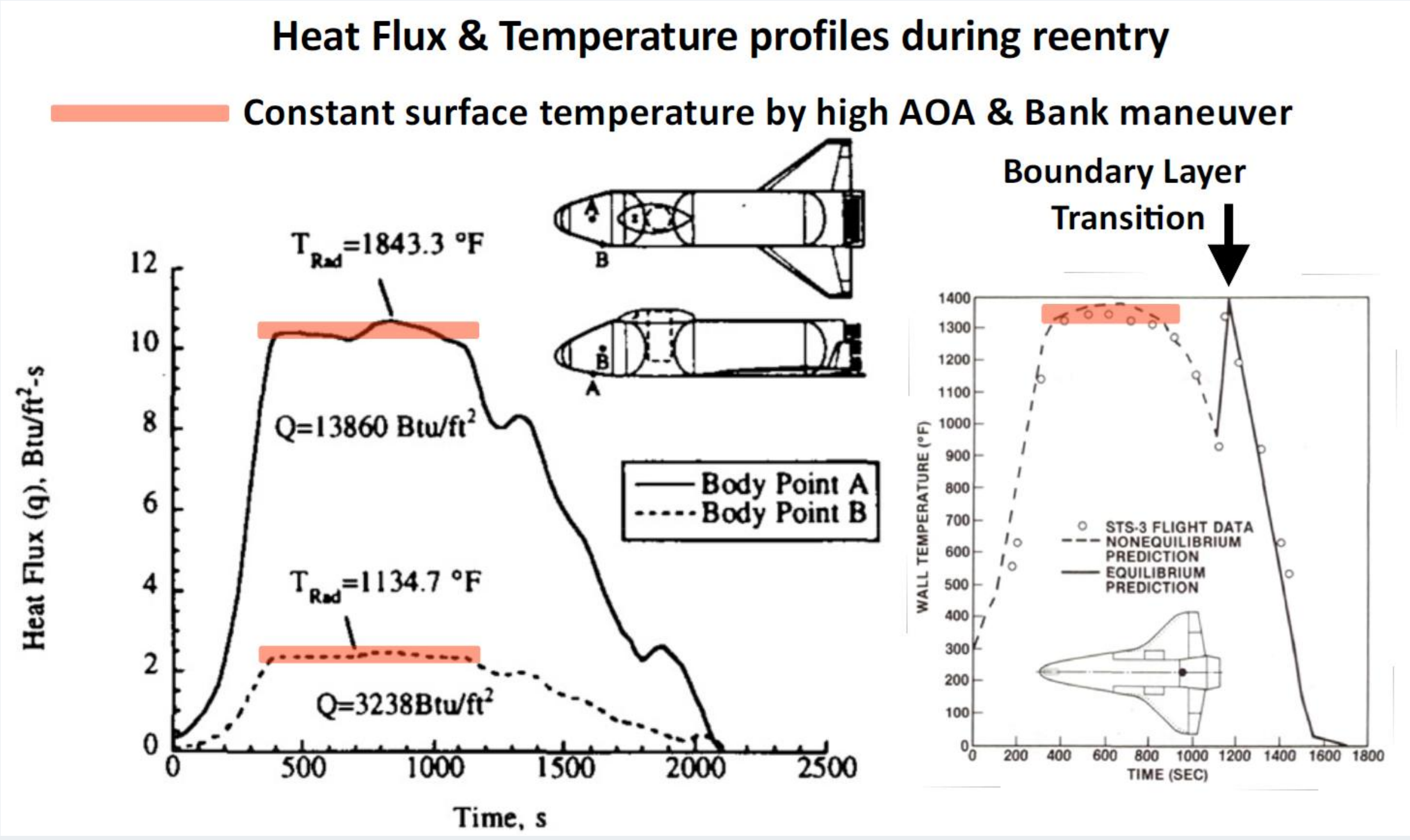
Temperature distribution on the contact surface with the bottom of CFRP



・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.

Thermal analysis applying Space Shuttle heating energy

Space Shuttle Heating Energy



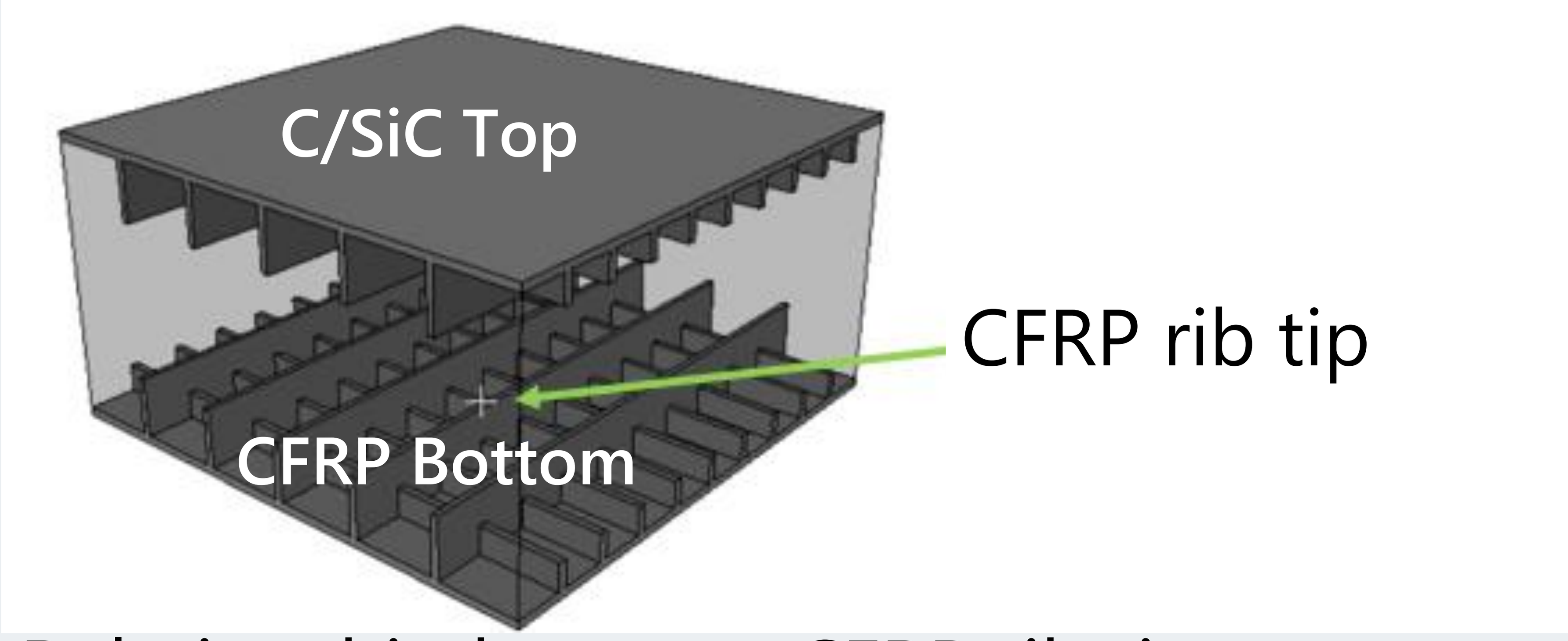
Reference

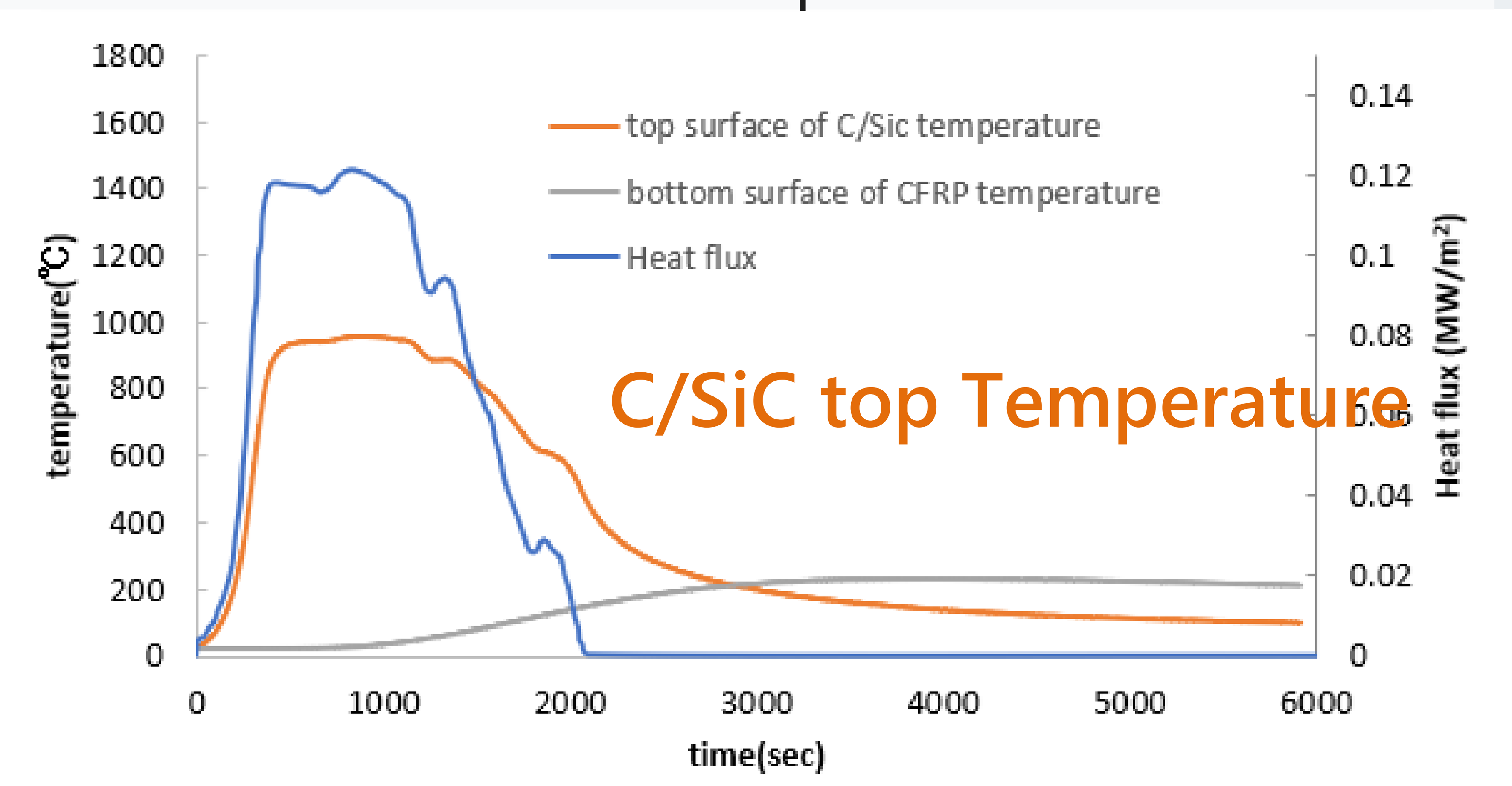
・AIAA-99-3459 Parametric Weight Comparison of Current and Proposed Thermal Protection System (TPS) Concepts
David E. Myers, Carl J. Martin, Max L. Blosser NASA Langley Research Center Hampton, VA 23681-2199
33rd Thermo physics Conference 28 June - 1 July, 1999 / Norfolk, VA
・NASA CP2283 "Shuttle performance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

from Dr. Yoshifumi Inatani

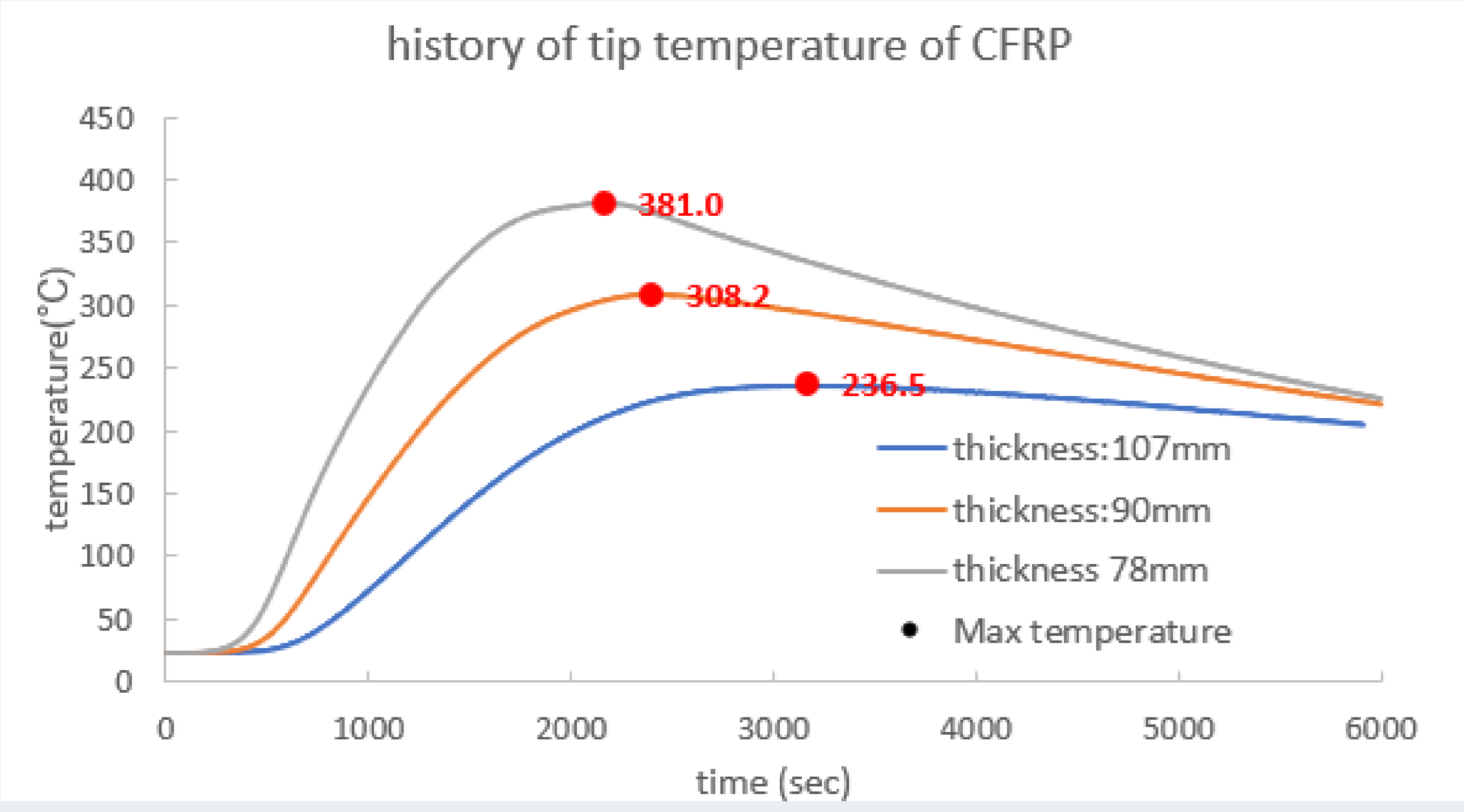
TPS thermal analysis results

Analyzing the conditions under which the CFRP rib tip temperature is 300°C 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.

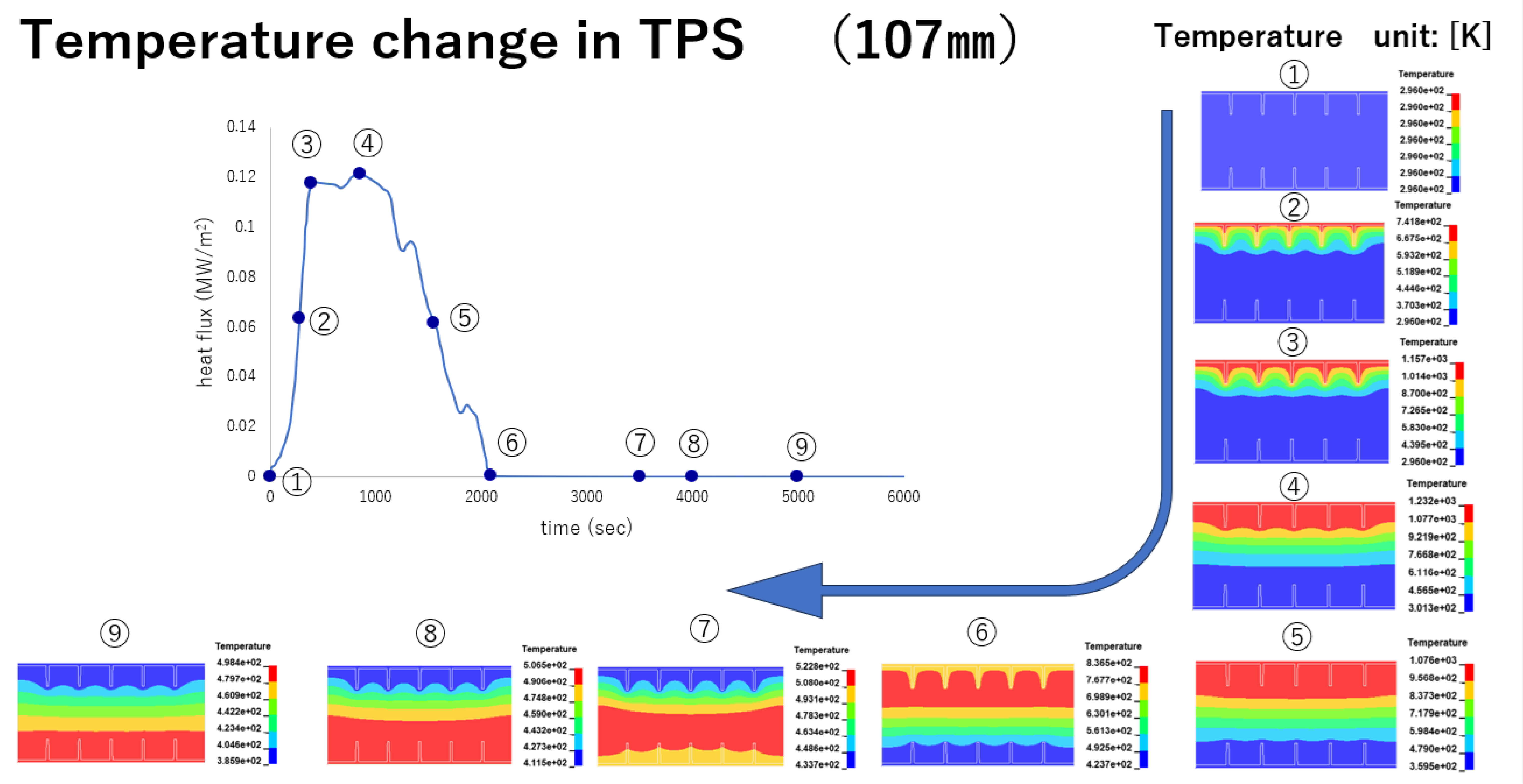




Relationship between CFRP rib tip temperature and TPS thickness



TPS internal temperature over time

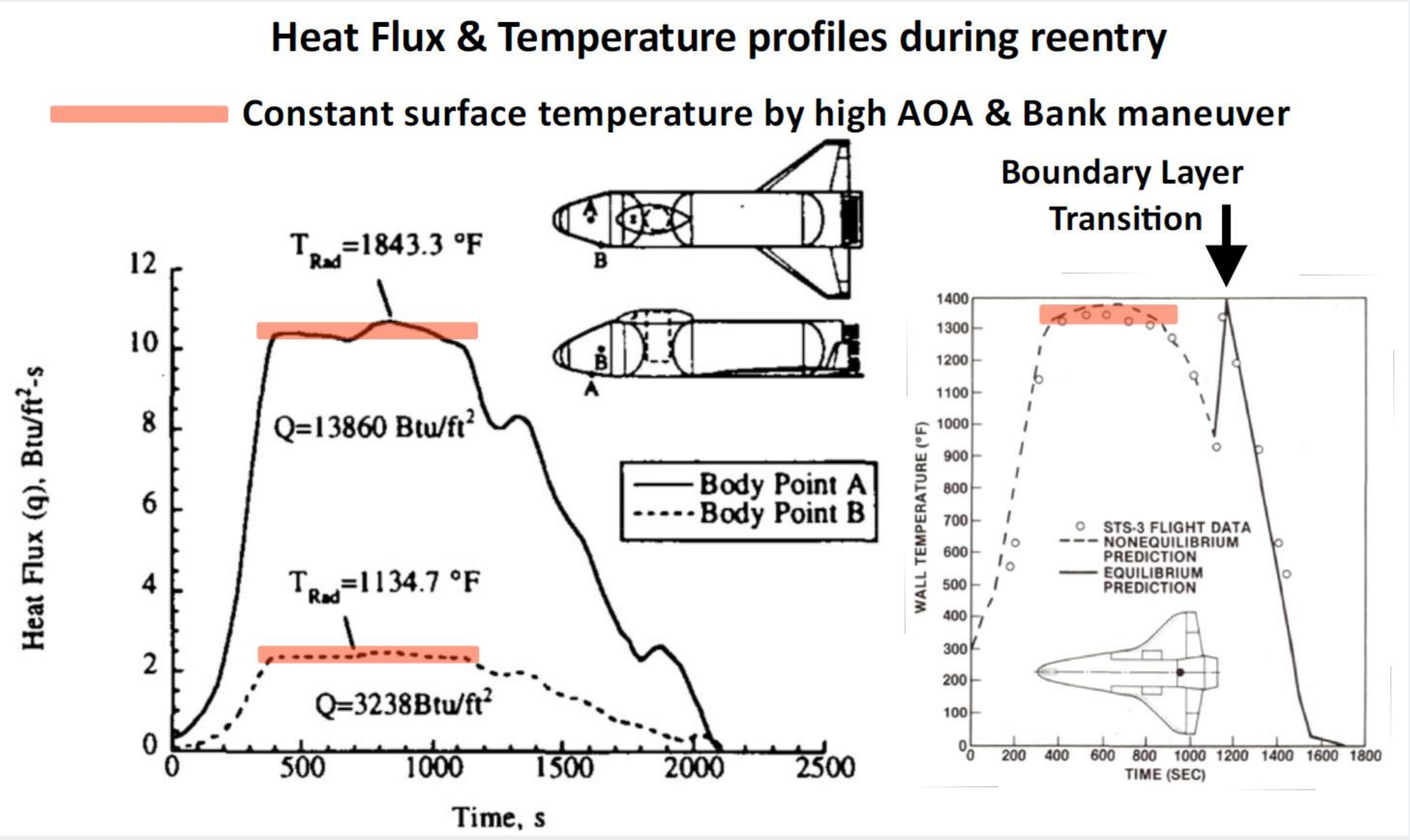


MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

Thermal analysis applying Space Shuttle heating energy

Space Shuttle Heating Energy

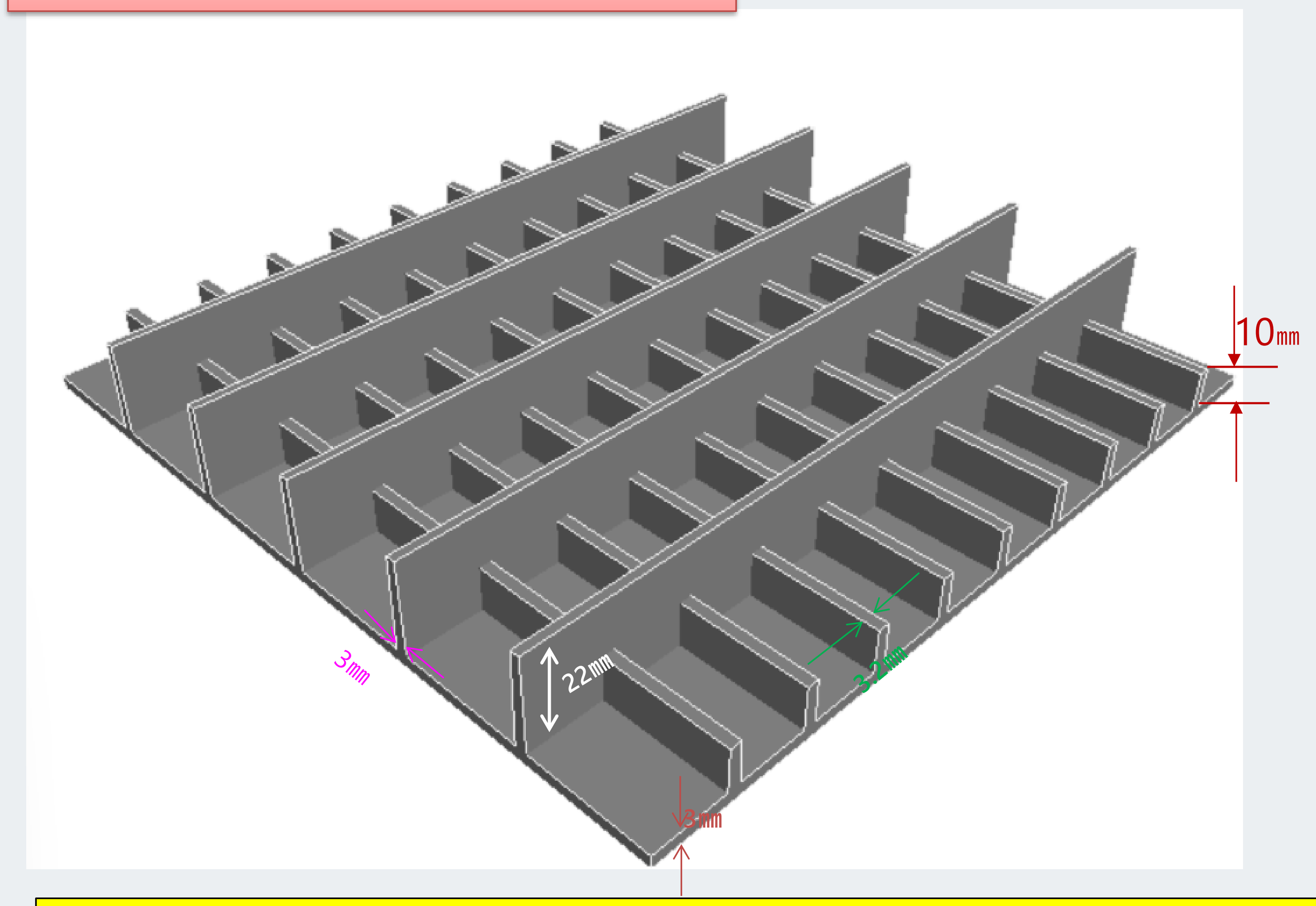


Reference

・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

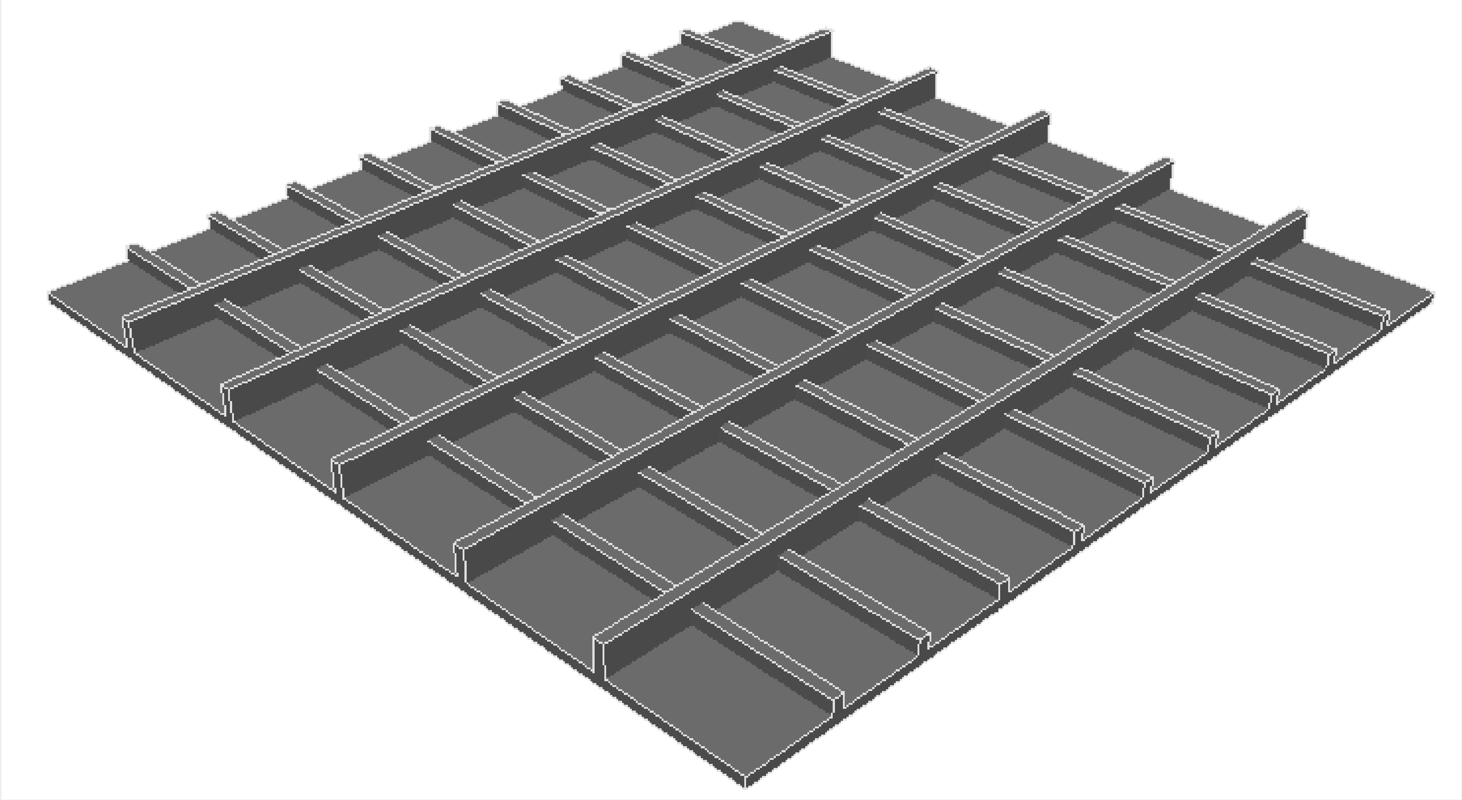
STD model



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℃

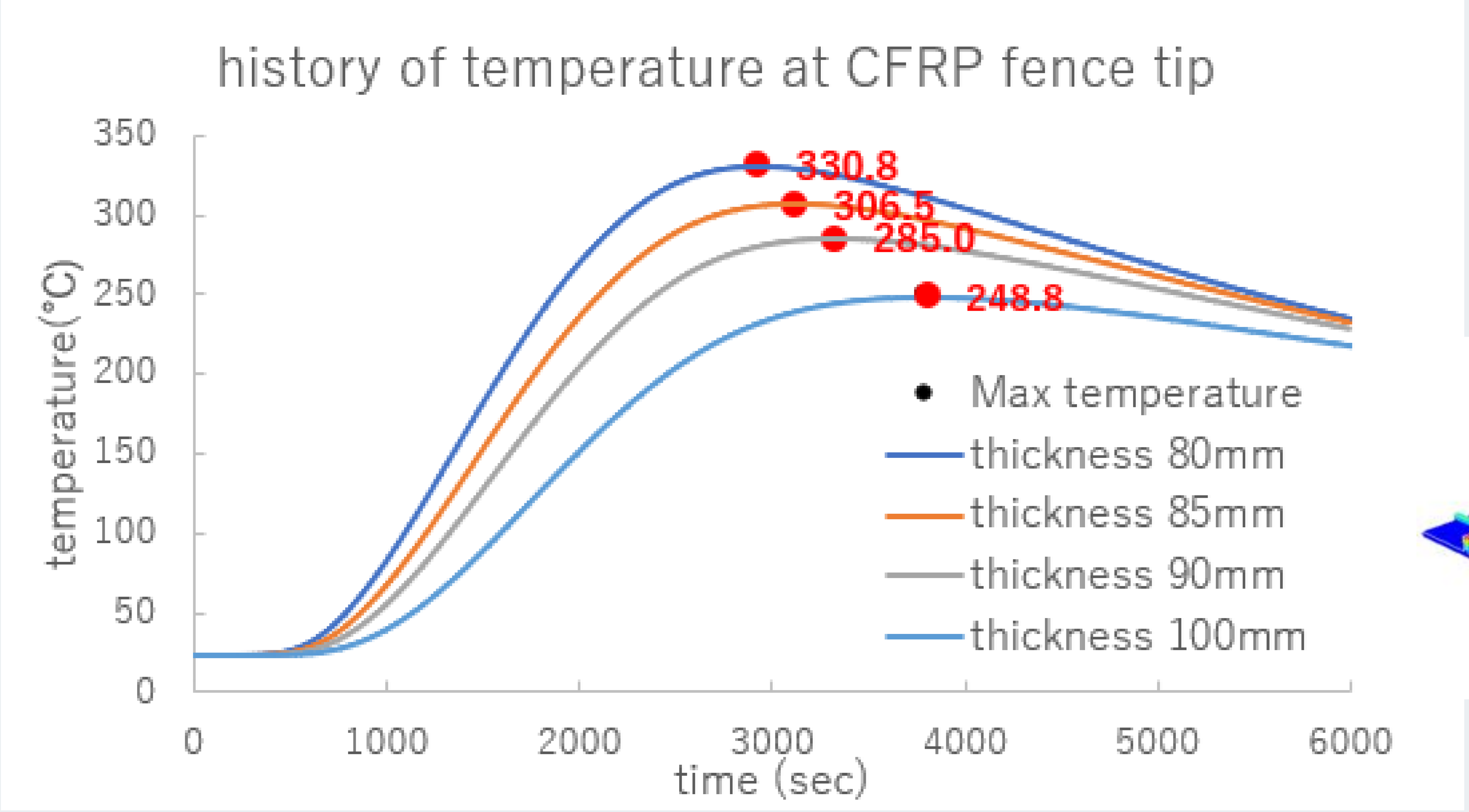
Light Weight model



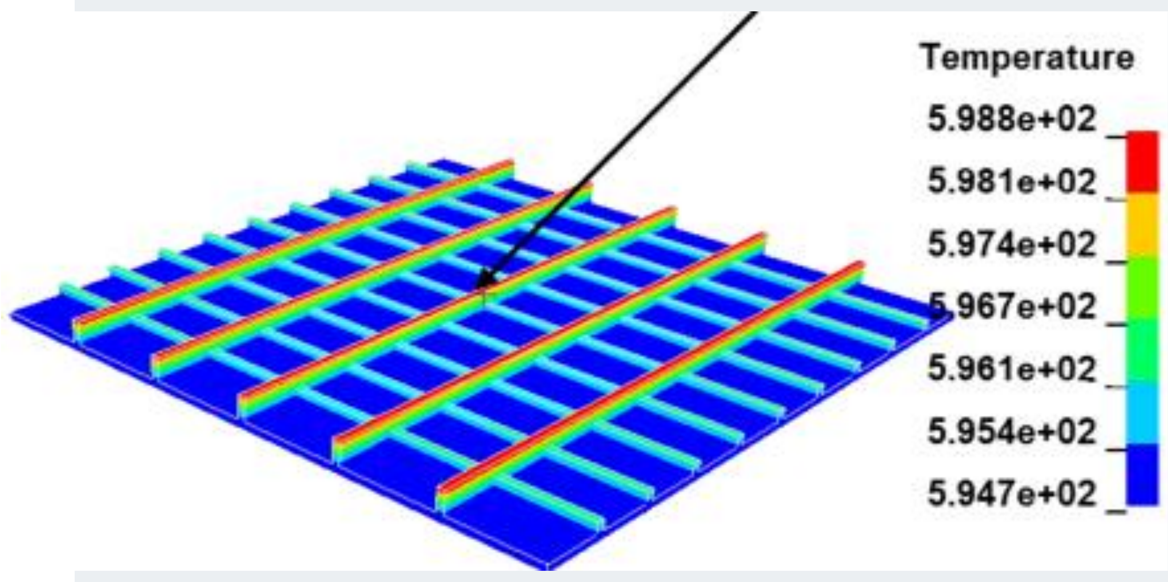
C/SiC density: 2.2　Wt　7.2Kg/m²
ＭＡＦ density：０．１３　Wt　10.8kg/m²
CFRP density：1.6　Wt　5.2Kg/m²
ＴＰＳ90mm Weight　23kg/m²

CFRP rib Tip temo：２８５℃

CFRP rib Tip temperature



CFRP rib Tip Temp



MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

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

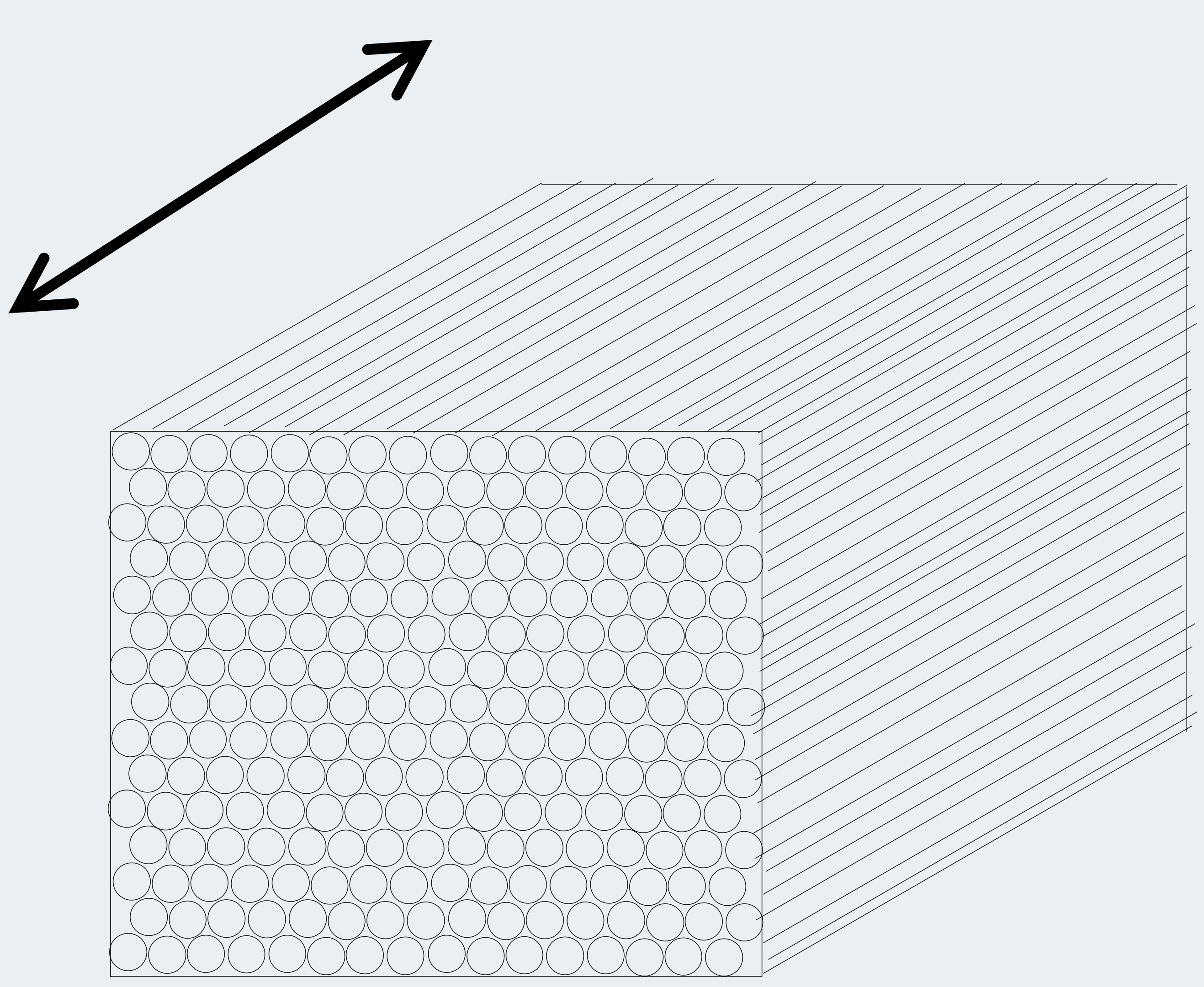
※The listed values are typical and can vary depending on the laminated structure and the amounts of substances contained.

※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

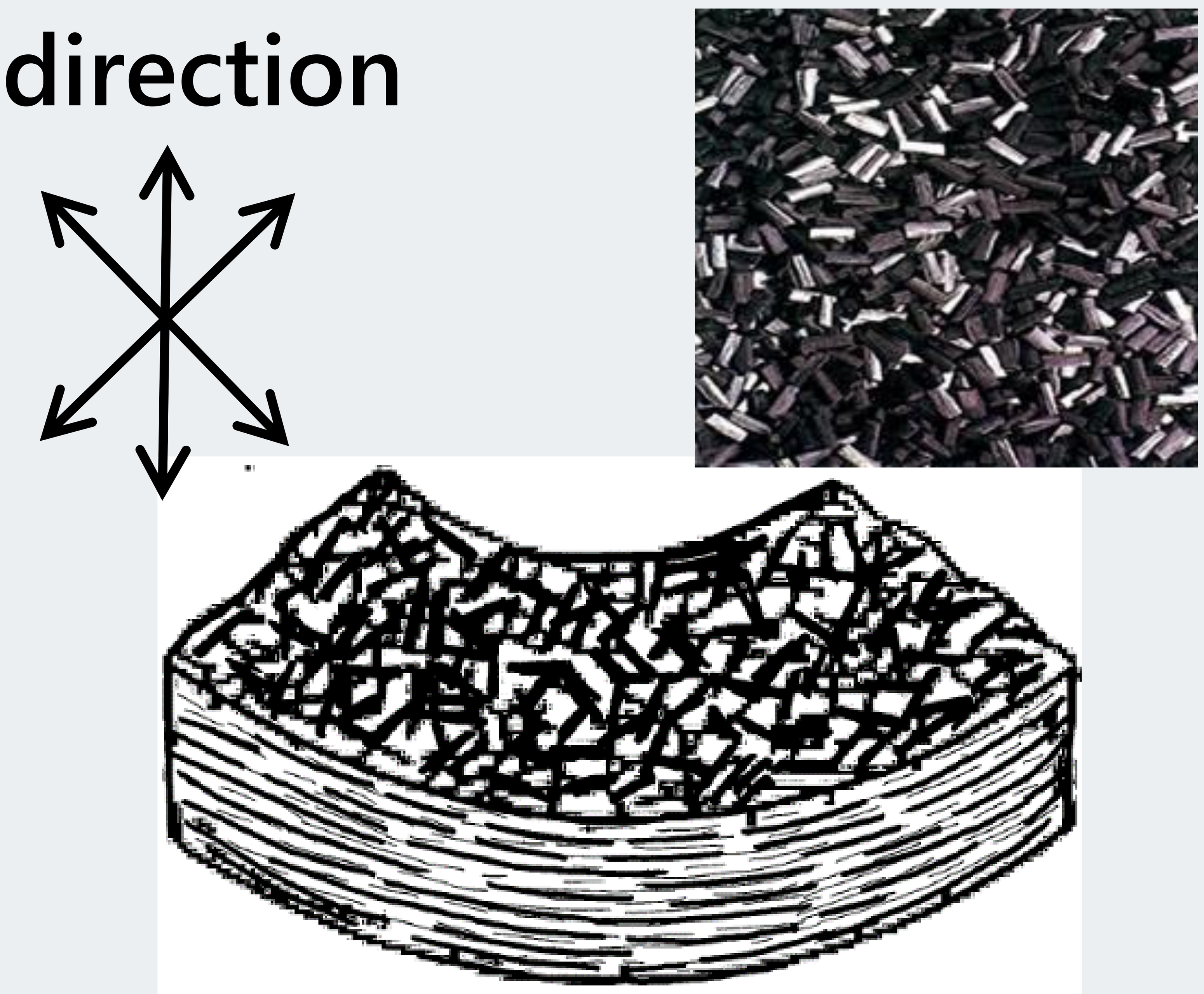
Uni Direction

CF direction



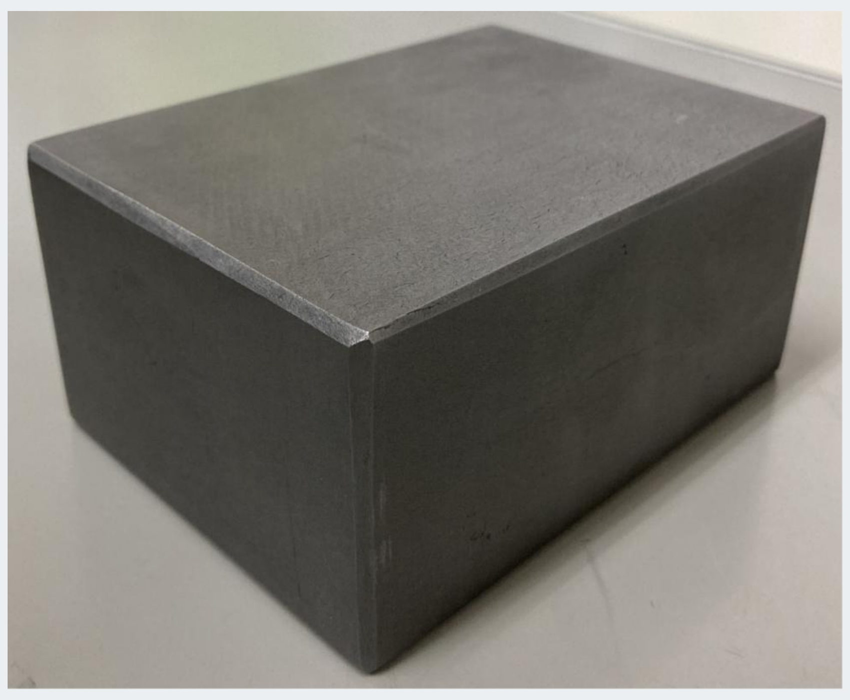
Felt

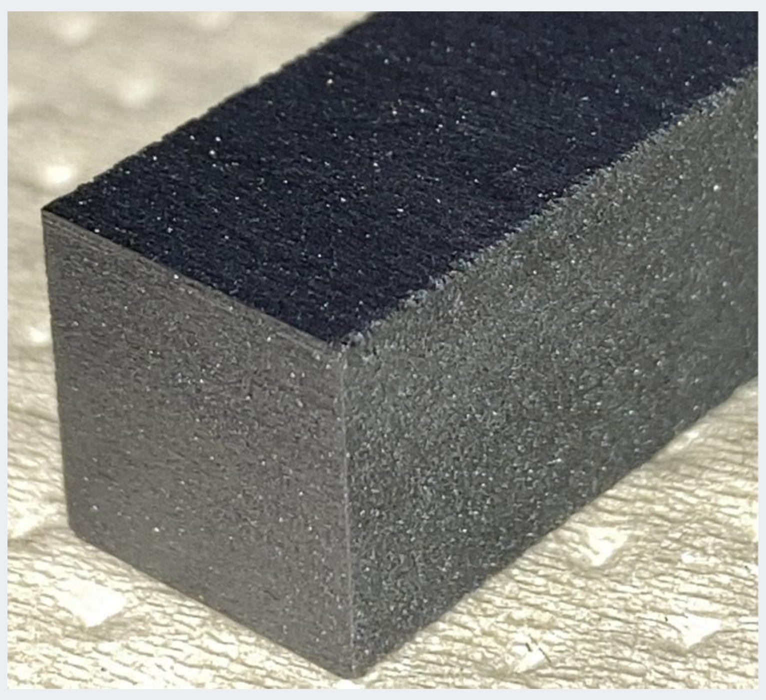
CF direction



MFC-1

MFC-1N（Development）

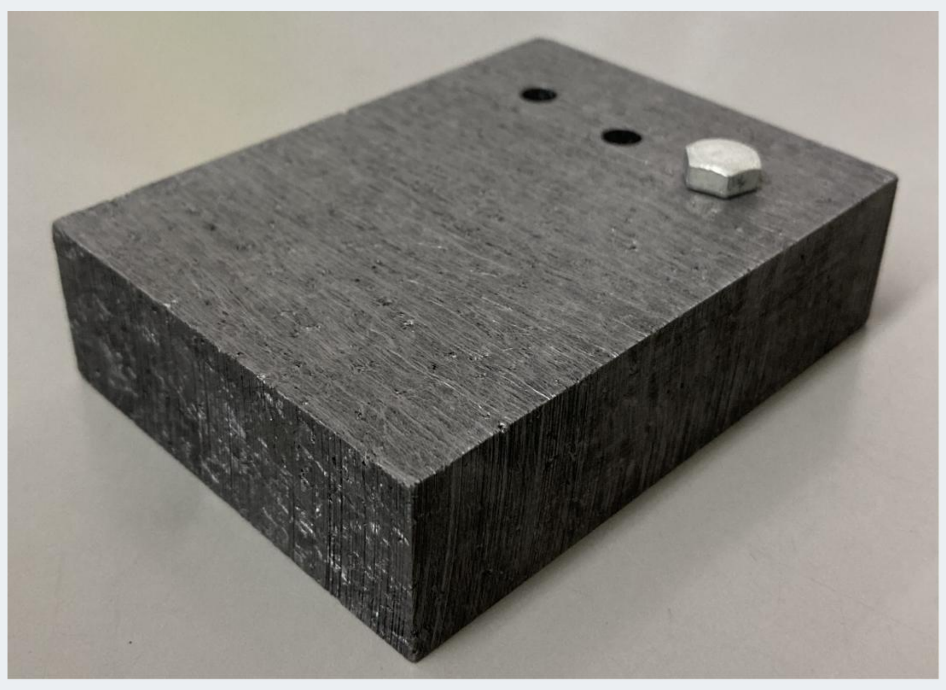


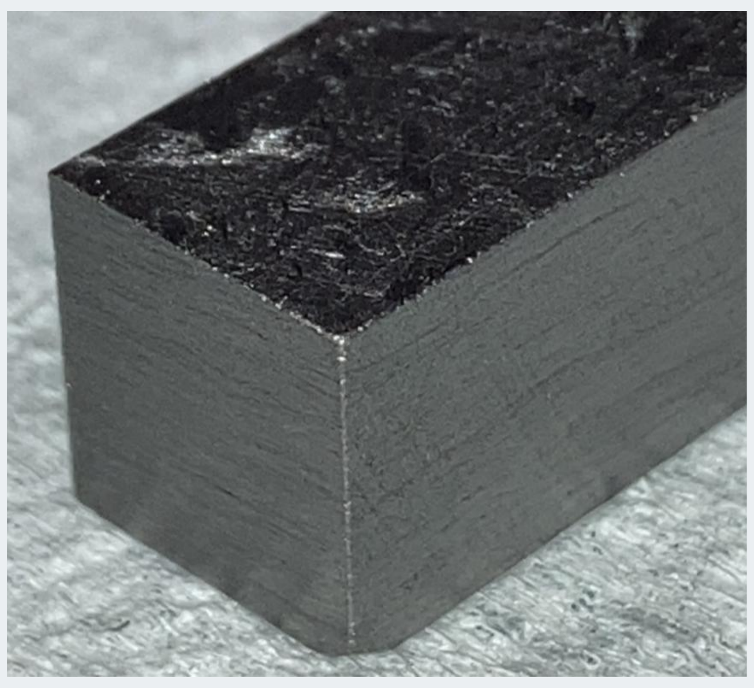


【Manufacturable size】Negotiable
210*×150×110mm *CF direction

MCI-felt type2H

MFC-2（Development）





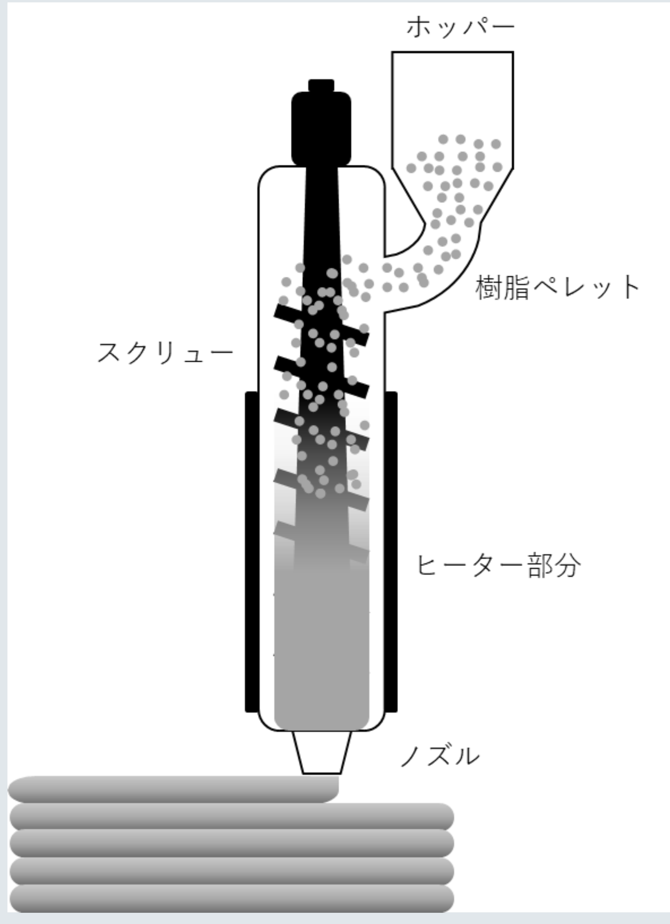
【Manufacturable size】Negotiable
210*×150*×110mm *CF direction

MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation

3D Printing materials for space

Material for Fused Granular Fabrication (FGF) printer

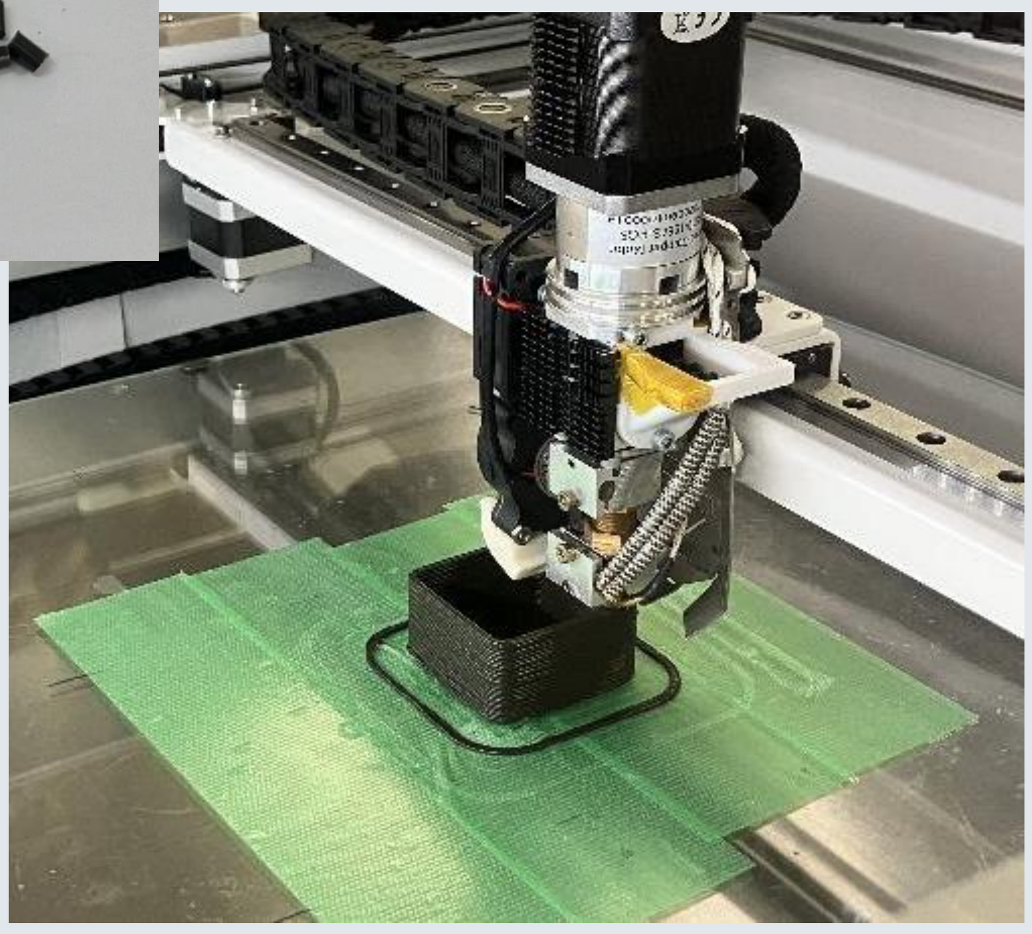


What is Fused Granular Fabrication (FGF) ?

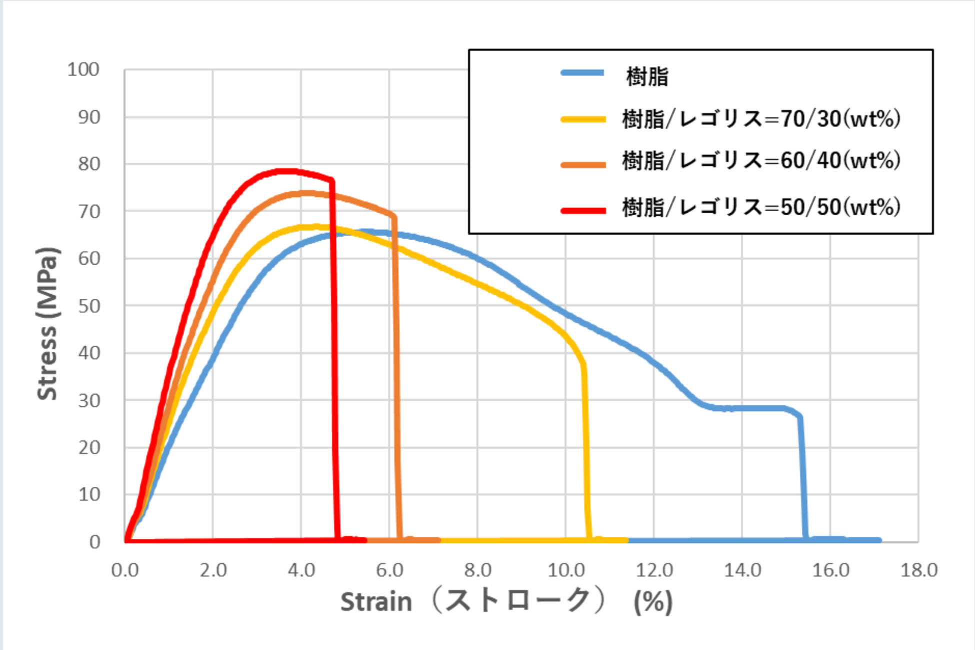
- ✓ One of the Material Extrusion type 3DP.
- ✓ Can 3D print directly from pellets.
- ✓ Can print big object with large extrusion amount.
  (Also called as LFAM / LSAM)

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

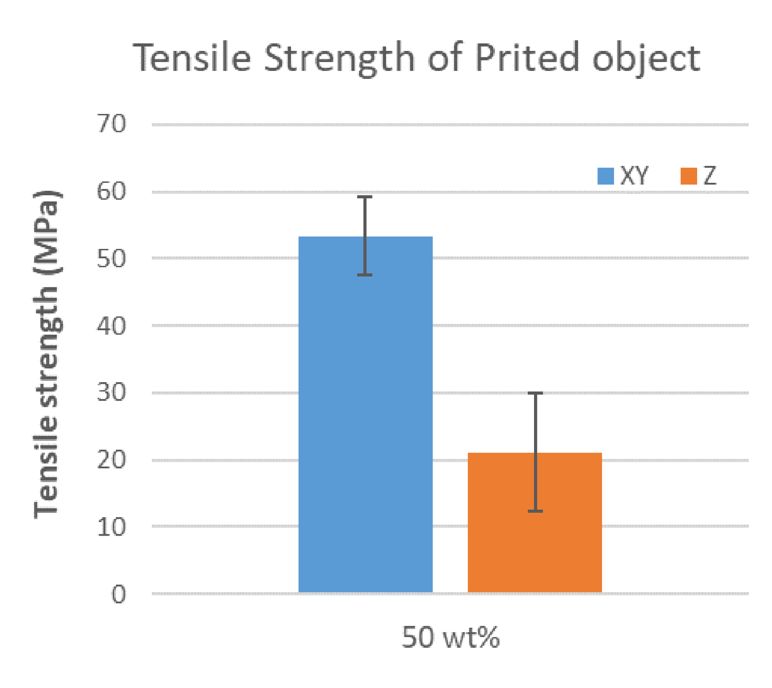
＊Using regolith simulant



<Tensile strength of injection molded specimens>

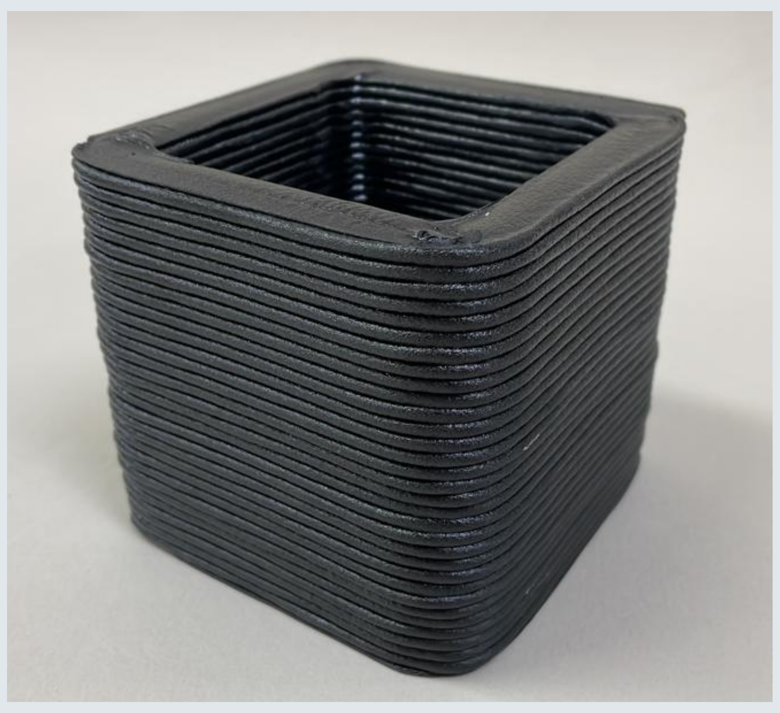


<Tensile strength of 3D-printed parts>

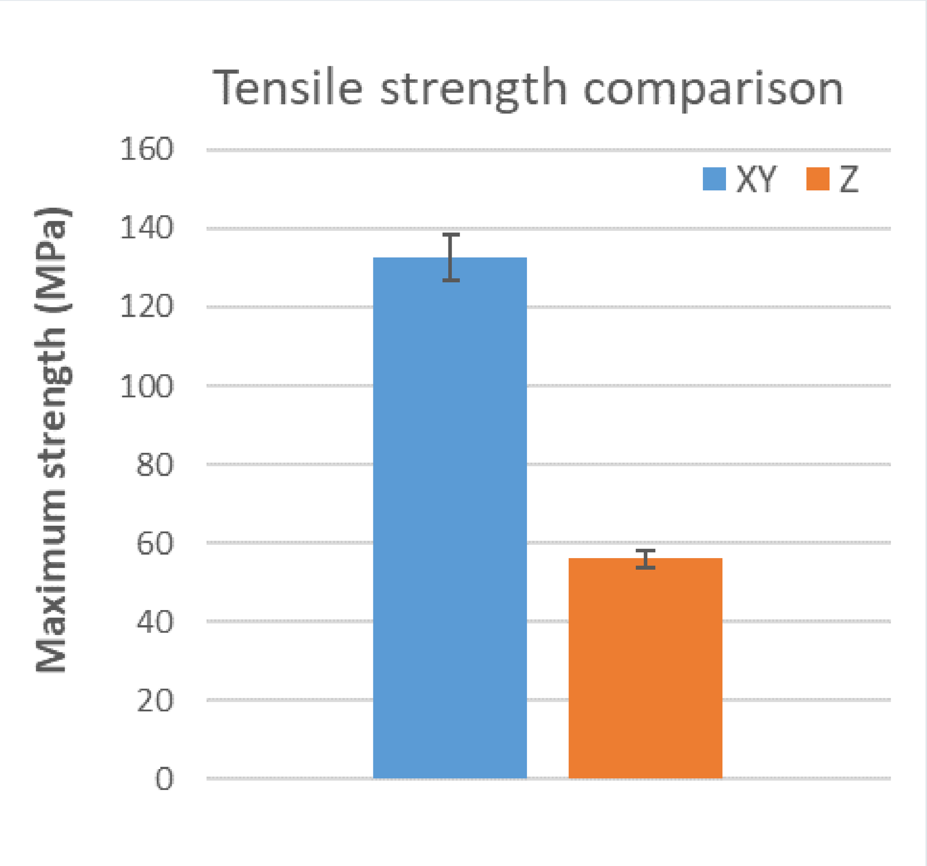


＜Print condition＞
●Nozzle：2ｍｍφ
●Temperature：～240℃

High heat-resistant (PEI/CF) material



<Tensile strength of 3D-printed parts>



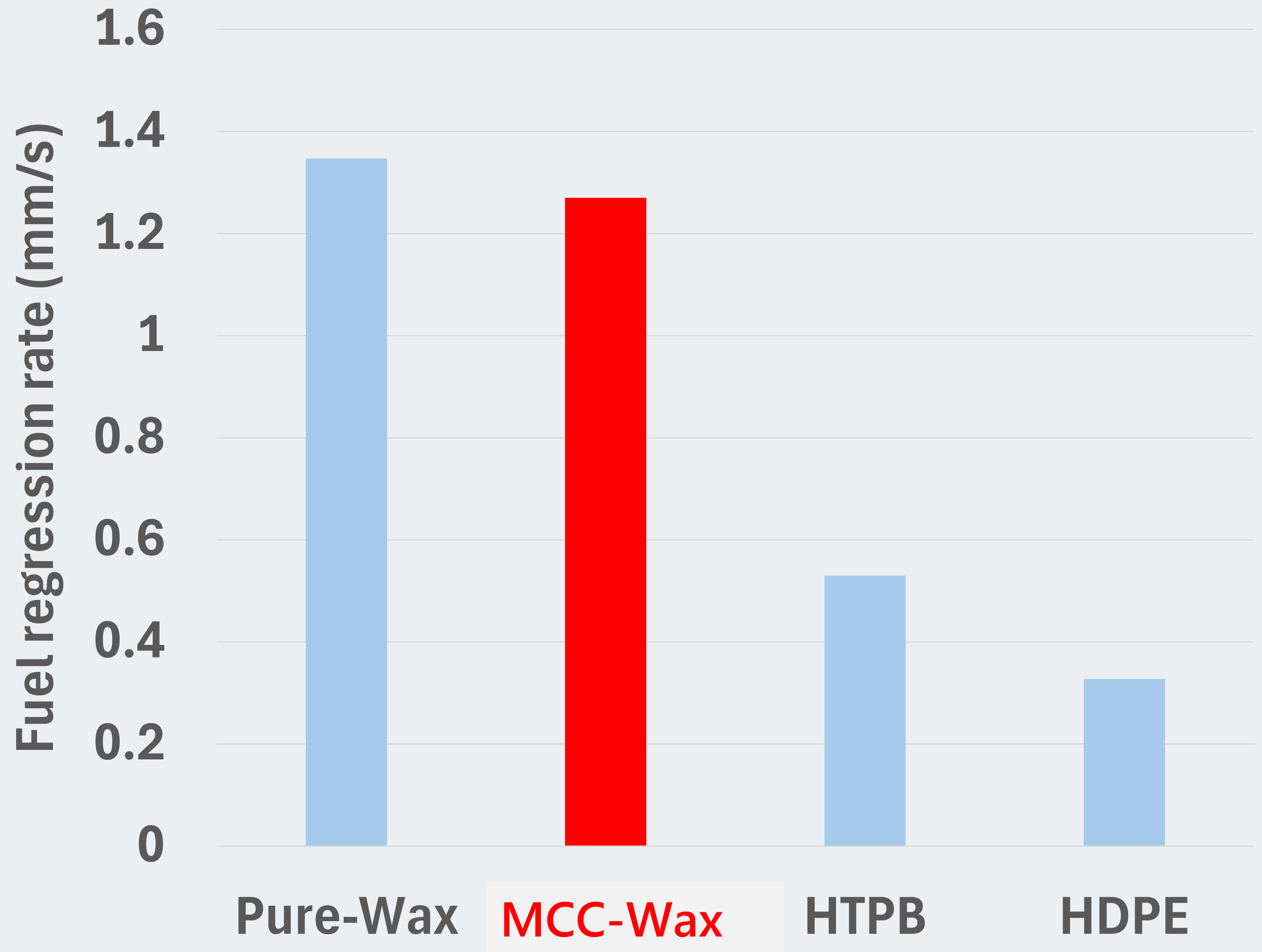
＜Print condition＞
●Nozzle：8ｍｍφ
●Temperature：～390℃

MITSUBISHI CHEMICAL GROUP

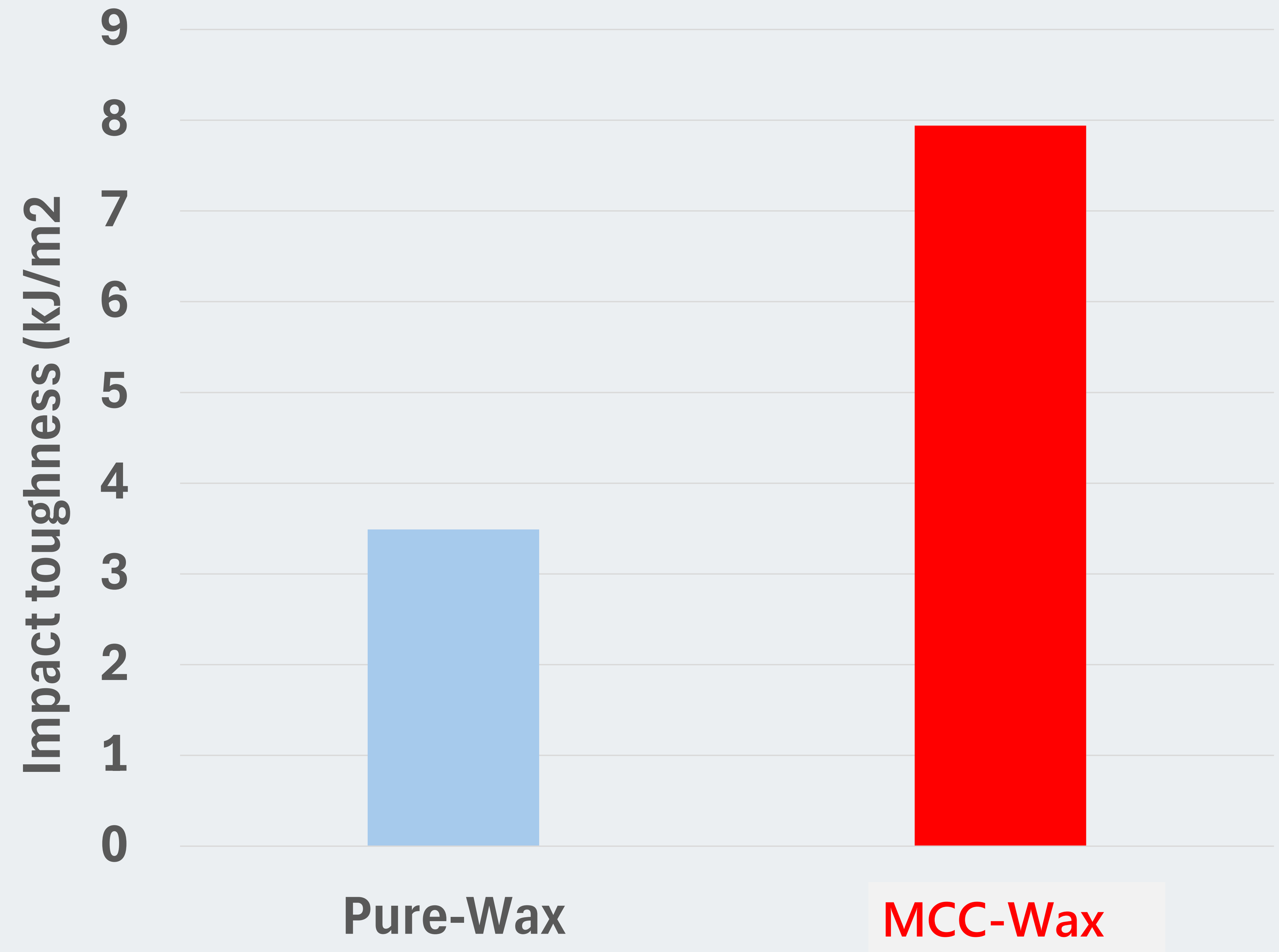
Mitsubishi Chemical Corporation

Hybrid rocket fuel
（Under Development）

Developed high-strength, high-thrust solid fuel for hybrid rockets

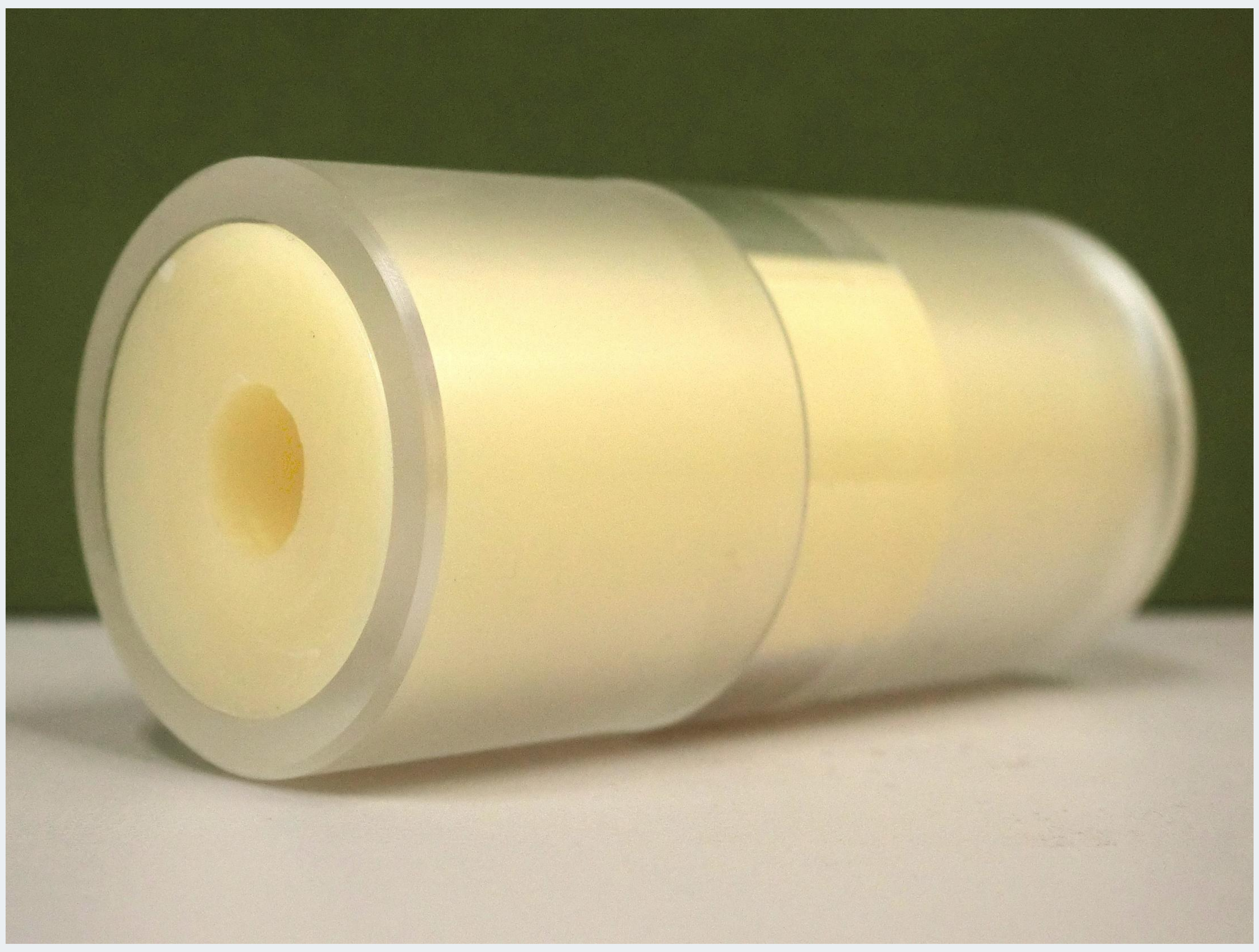


Thrust
(fuel regression rate)

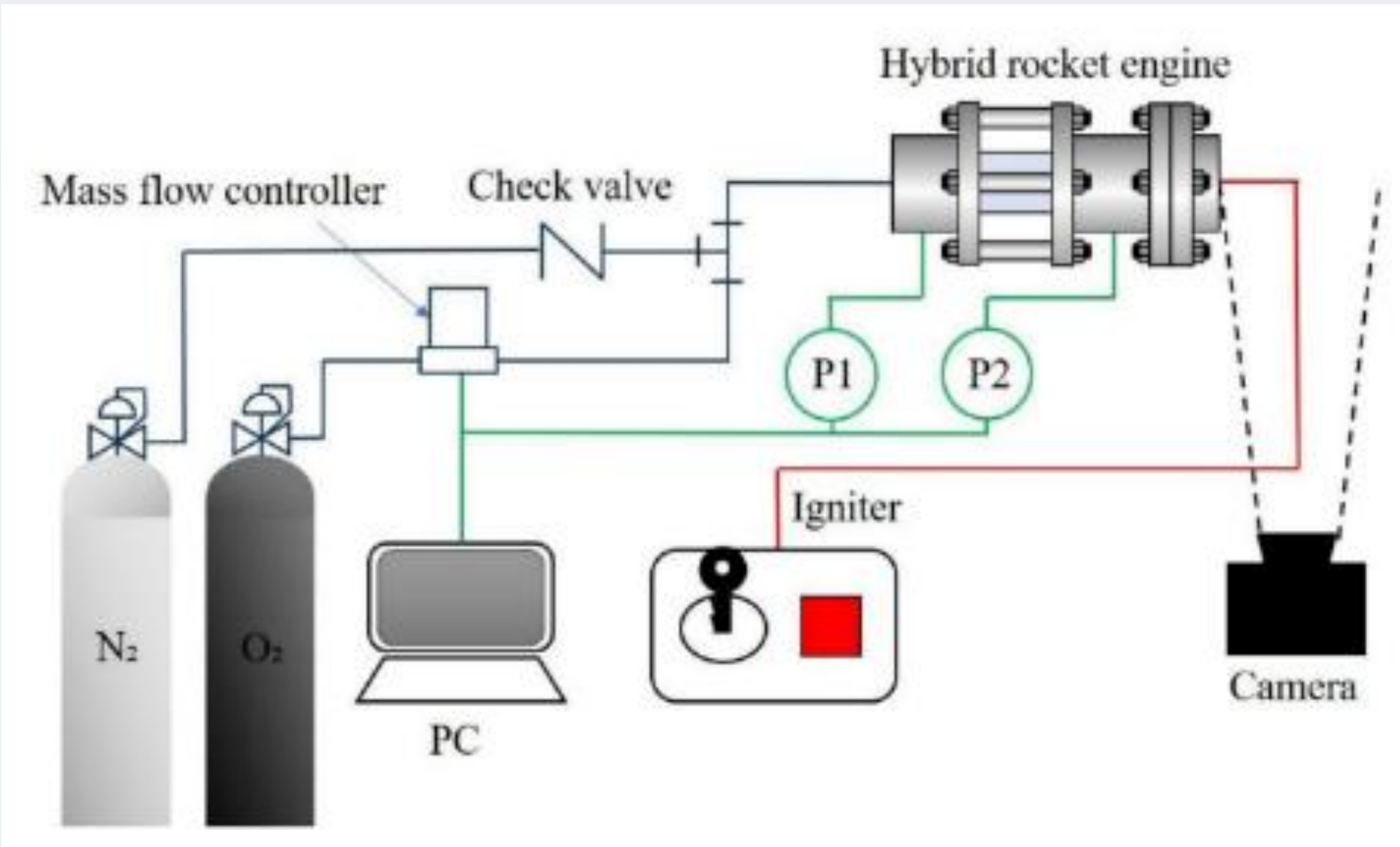


Impact properties
(average toughness value)

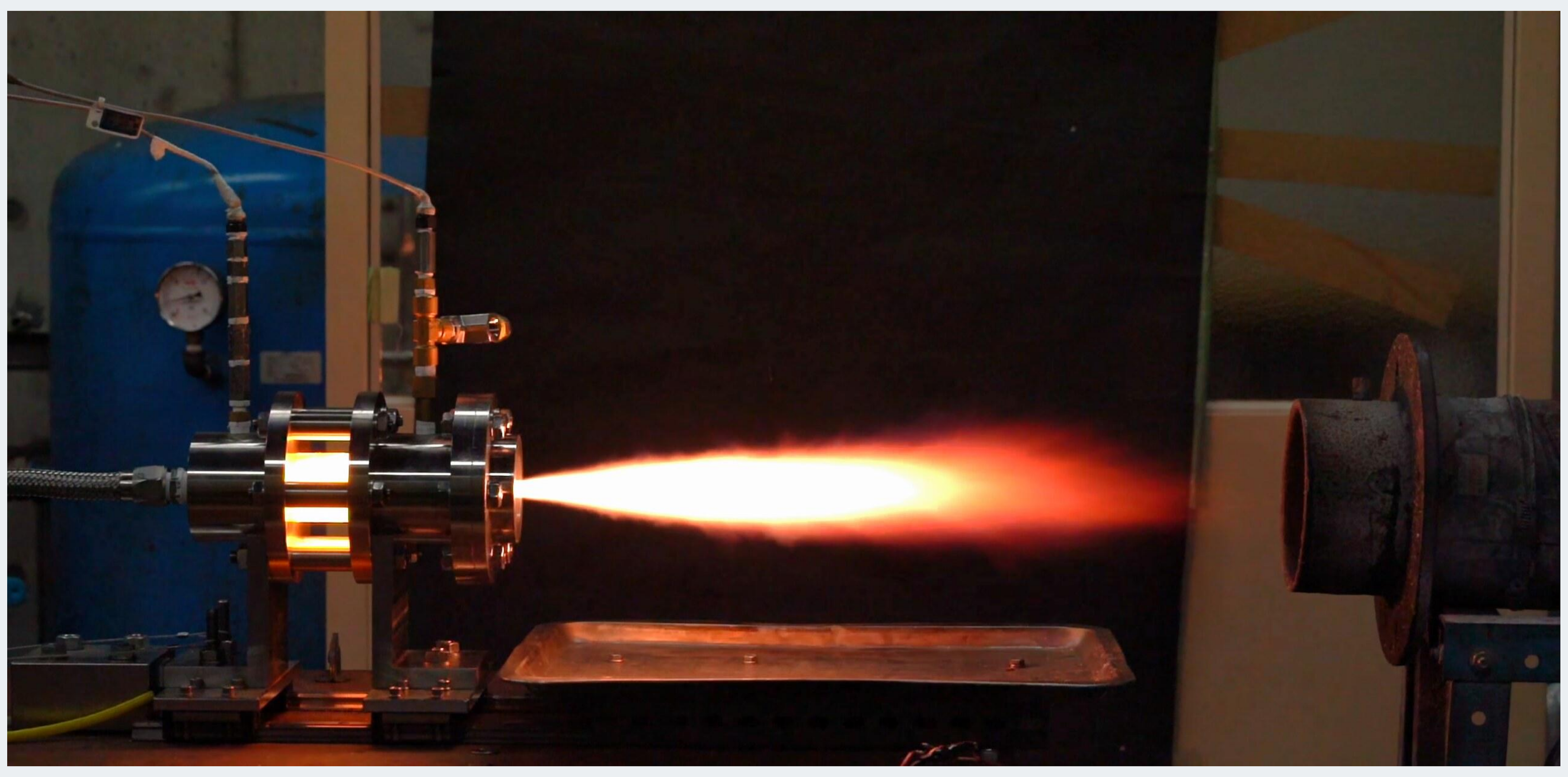
Achieved more than double the strength while retaining the high thrust of wax



Sample appearance of MCC-Wax



Combustion test overview



During the combustion test

Courtesy：Department of Aerospace Engineering, College of Science and Technology, Nihon University

MITSUBISHI CHEMICAL GROUP

Mitsubishi Chemical Corporation