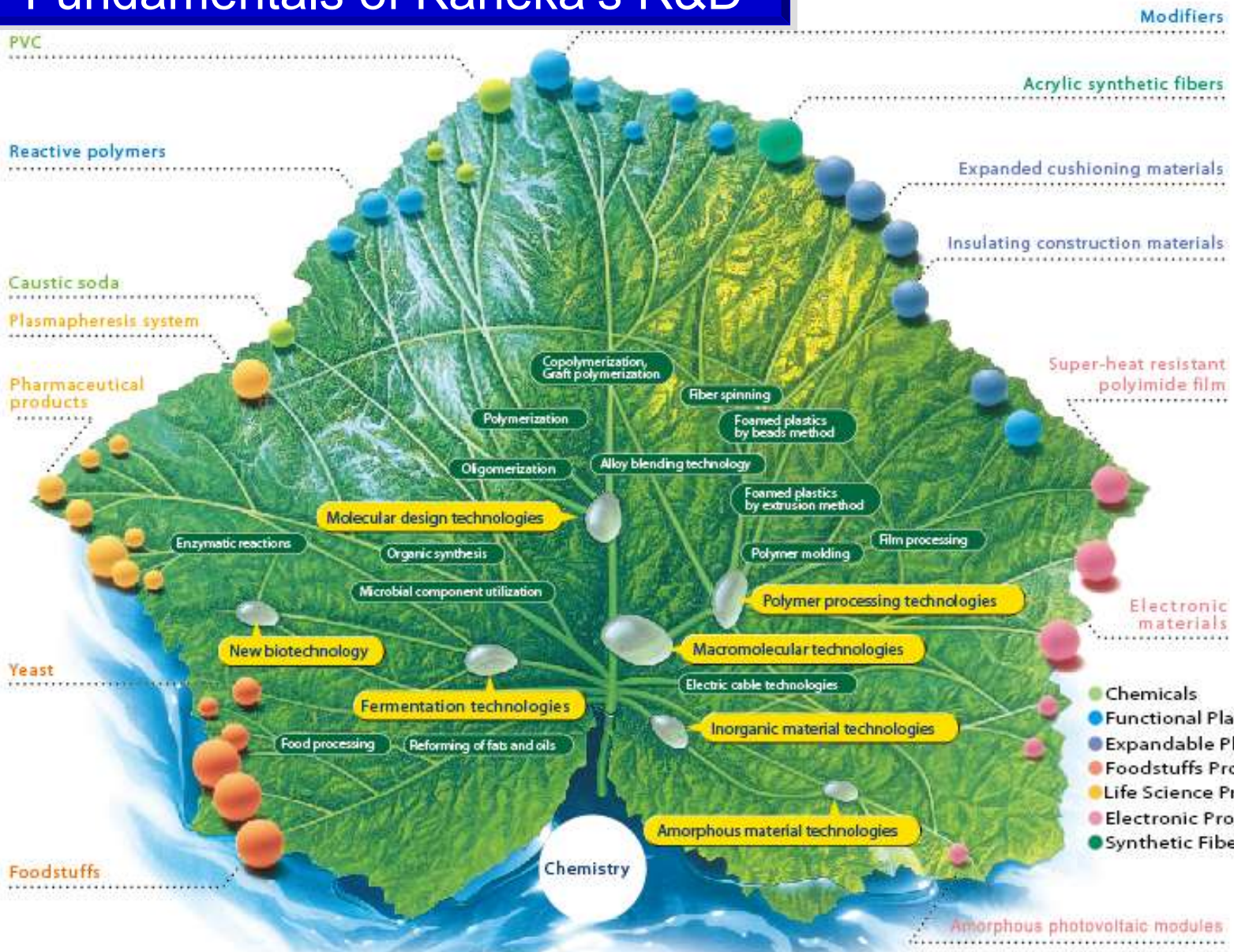
Advanced Materials and Technologies for Aerospace Applications

Masaya Kotaki

Kaneka US Materials Research Center
Kaneka Americas Holding, Inc.

kaneka
Toward an Even More Impressive and Productive Future

Fundamentals of Kaneka's R&D



Current Business Fields

Chemicals	Functional Plastics	Expandable Plastics
Foodstuffs	Synthetic Fibers	Electronics
Life Science	QOL	Solar Cell

Business Fields & Products ①

Chemicals


Caustic Soda


Kanevinyl™


Kanevinyl™Paste


Kaneka™CPVC


Vinyl Chloride-Vinyl Acetate Copolymers


Crosslinked PVC

Functional Plastics


Kane Ace™ B


Kaneka™ MS Polymer


Kaneka Silyl™


Kanevilack™


Kaneka Hyperite™


Sunduren™

Expandable Plastics and Products


Eperan- PP™


Eperan™


Kanepearl™


Kanepearl™ Soil Block


Kanelite Foam™


Kanelite ™ Inser

Business Fields & Products ②

Foodstuffs Products


Kaneka™ Margarine
Kaneka™ Shortening


PAPRÈ


Kaneka™ Yeast


LACHENTE,FRANJE


Belco


Spices

Life Science Products


Kaneka Plasmapheresis System


Intervention catheters

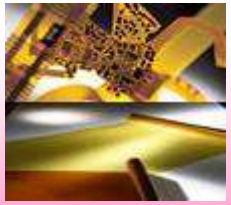

Pharmaceutical Intermediates

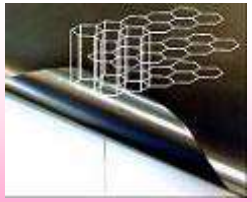

Kaneka Q10™


Kaneka QH™


Kaneka Glavonoid™

Electronics Products


Apical™


Graphinity™


Elmech™


Kaneka Flux™


Photovoltaic solar power generation system


Photovoltaic power generation systems for public and industrial installation


Solar Circuit ™

Business Fields & Products ③

●Synthetic Fibers


Kanekalon™, Kanecaron™


Protex ™

ULTIMA™

●Business Development

"KANEKA Biopolymer AONILEX ™"
(a polyester biopolymer comprised primarily of plant oil)

Thermal solution materials for use in electronic device components

New heat-resistant materials for use in optical device components
"ILLUMIKA™"

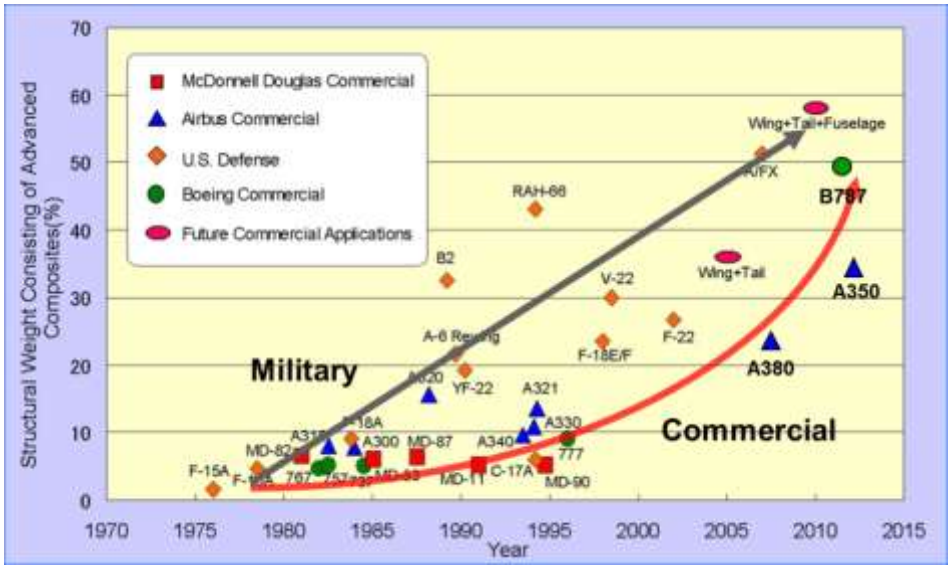
OLED Lighting Devices

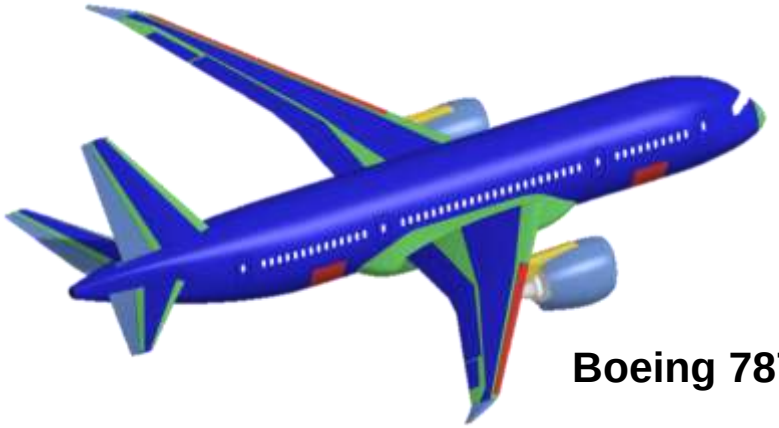
Contents

- Polyimide
- Toughening Agent (CSR)
- Graphite Sheet
- Nanocomposites

CFRPs in aircrafts

- Epoxy(EP)/CFRPs and EP/GFRPs : approximately 50 % of structural weight of aircrafts
- Long-term service temp. of EP/CFRPs : up to 120°C due to thermal stability.
- Polyimides : Excellent environmental, thermal (>200°C) and mechanical properties
- Polyimide CFRPs : Replacement of titanium parts in jet engine



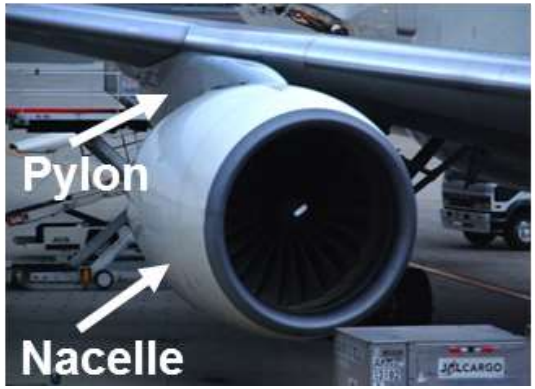


CFRP GFRP

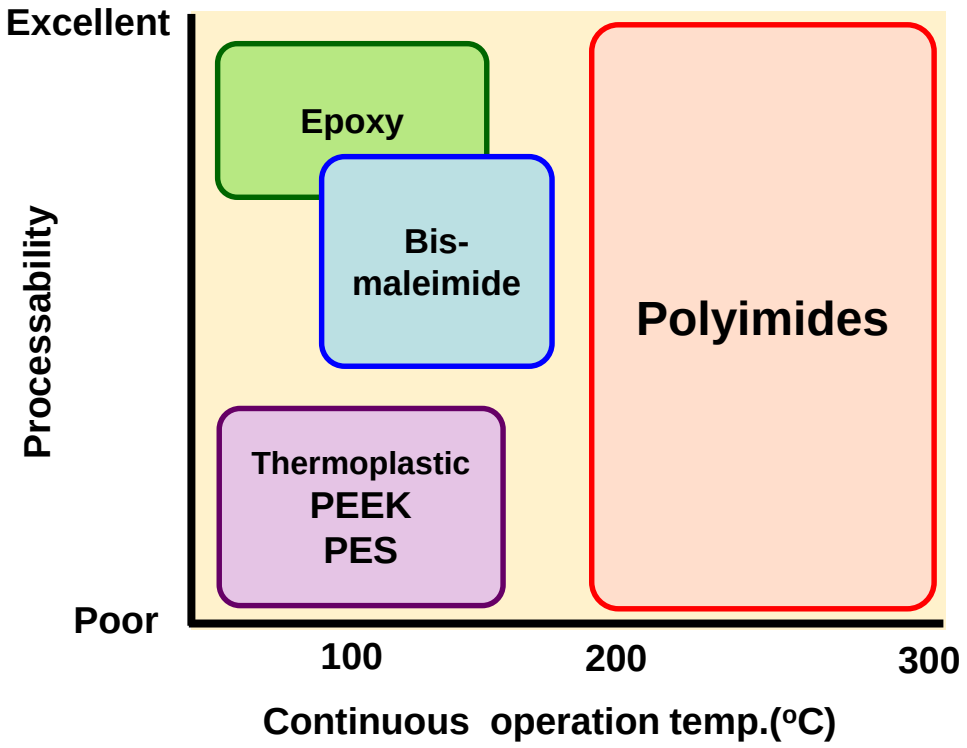
GFRP Steel, Titanium(>200°C)

Source: Advanced composites engineering (2005) Baifukan

◆ Application examples of PI/CFRPs



Matrix resins for CFRPs



＜Epoxy＞
- Excellent processability
- Lower price

＜Thermoplastic resin＞
- Secondary molding
- High impact strength
- Inferior processability

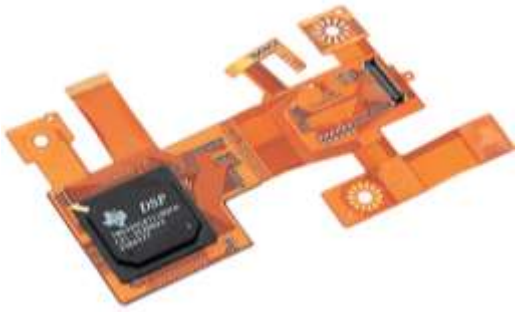
＜Bis-maleimide＞
- Good processability
- Low toughness
- Low thermal oxidation stability

＜Polyimide＞
- High thermal and environmental stability
- Lower processability
- Higher price

Kaneka moldable imide resin for high temperature CFRPs

◆ Kaneka polyimide film APICAL®

APICAL® Polyimide film



Flexible Printed Circuitry

Wire and Cable coating

◆ Thermal and mechanical properties of Kaneka thermosetting “MOLDABLE” imide resin

		PMR-15	PETI-5	AFRPE	Kaneka	
Mn		1500	5000	1600	2500	4000
Uncured Imide oligomer	Min. melt viscosity (poise)	5000	60000	10	1500	5000
Cured Imide resin	Tg (°C)	343	270	370	372	340
	Modulus (GPa)	3.0	3.1	3.4	3.2	2.8
	Elongation at break(%)	1	32	2	17	19

Imide oligomer solution

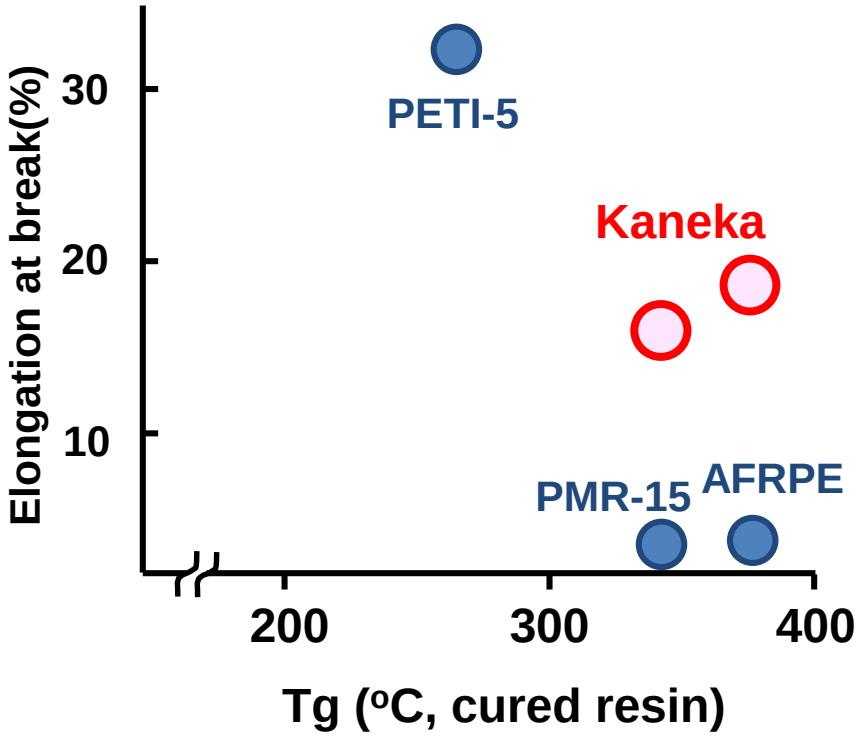
Imide oligomer powder

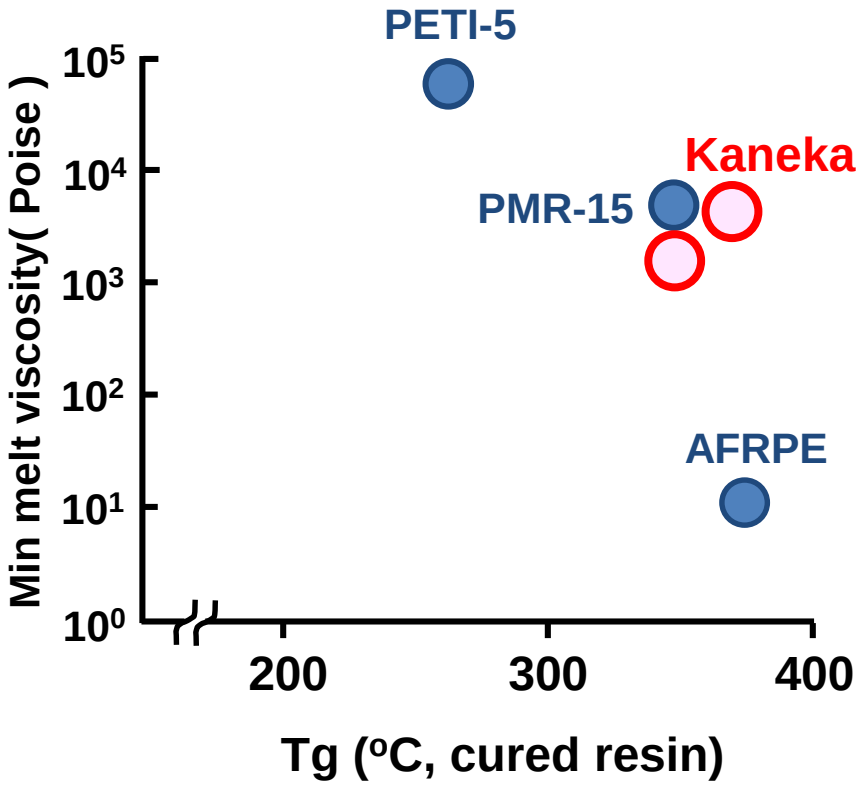
Cured resin film

Molding

These data are not guaranteed values and may be varied by the future tests.

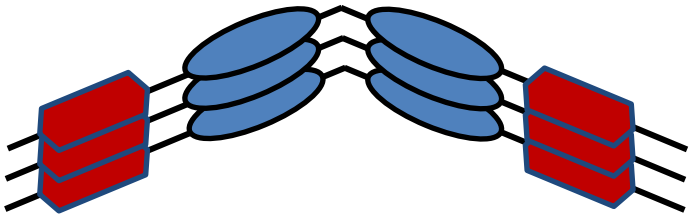
Thermosetting polyimides for composites





Our Strategy of Molecular Design

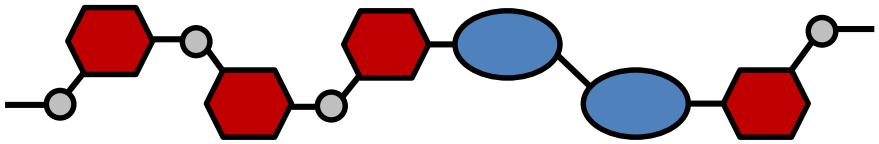
PMR-15



- Symmetric, planer rigid units
- Aggregation between rigid units
- Low molecular weight

⇒ High Tg and brittle

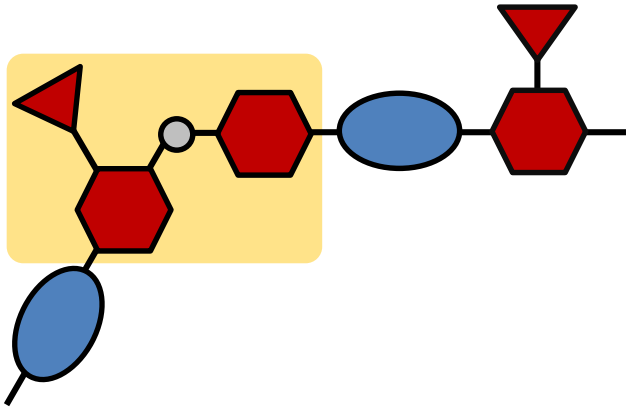
PETI-5



- *meta*-Linkage and multi-flexible ether bonds
- Disturbed regularity by copolymerization
- High molecular weight

⇒ Mid. high Tg and high elongation

Kaneka

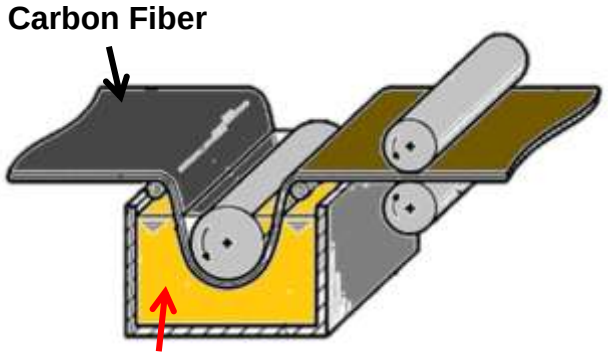


- Asymmetric monomers with pendant group
  - Prevention of the molecular aggregation
  - Disturbed regularity of repeated units
- Mid and high molecular weight

⇒ High Tg and excellent processability

Polyimide Composites

◆ Wet prepreg (solvent wet-type)

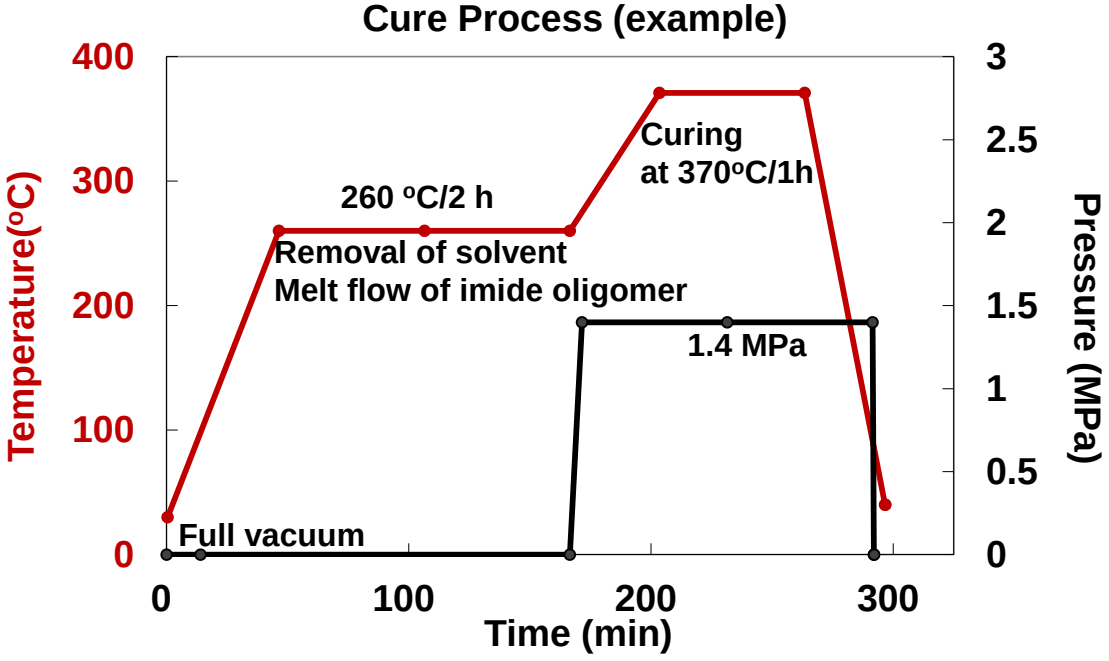


Impregnation

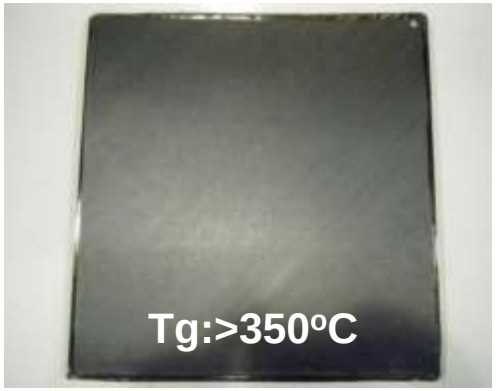
Continuous PI/CF prepreg

- Imide oligomer/ NMP solution
- Monomers/alcohol solution

◆ Molding of PI CFRPs

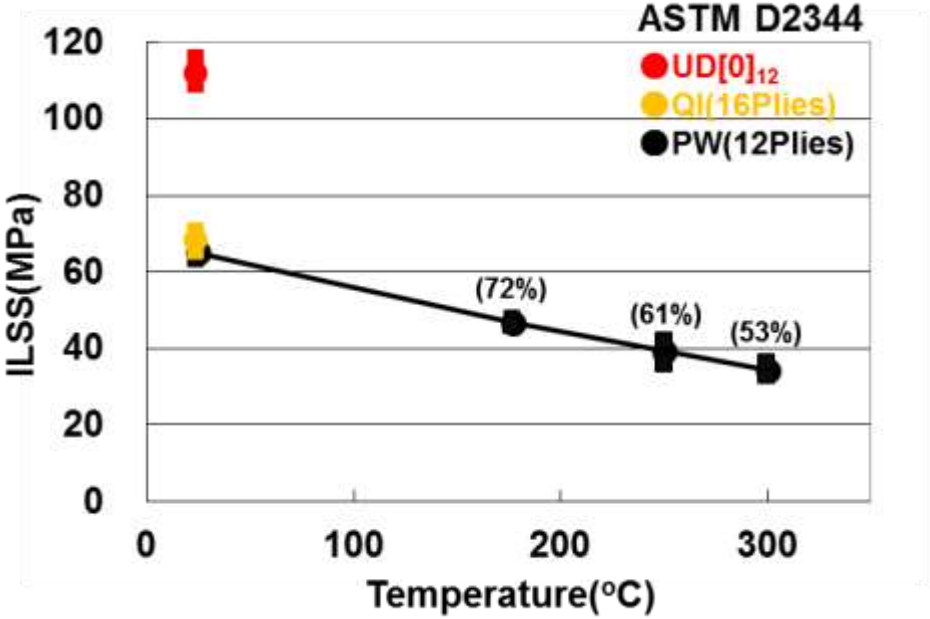


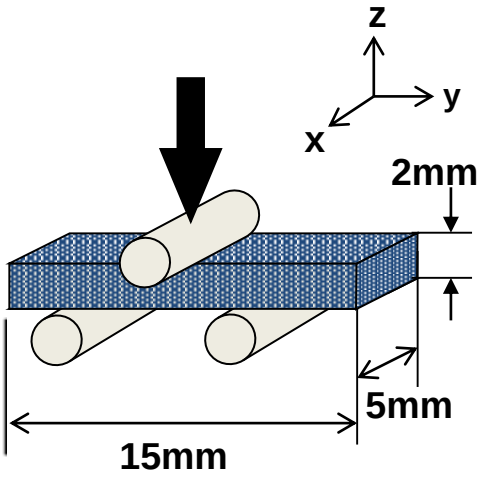
Autoclave



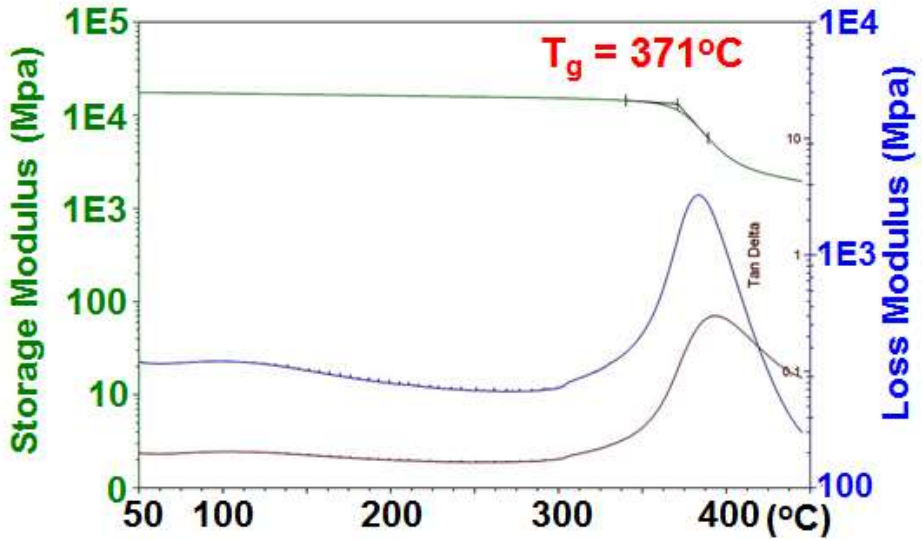
Short beam share and dynamic mechanical analysis test

Short beam share





DMA data

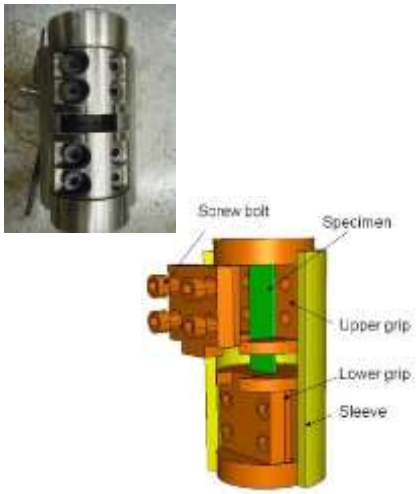


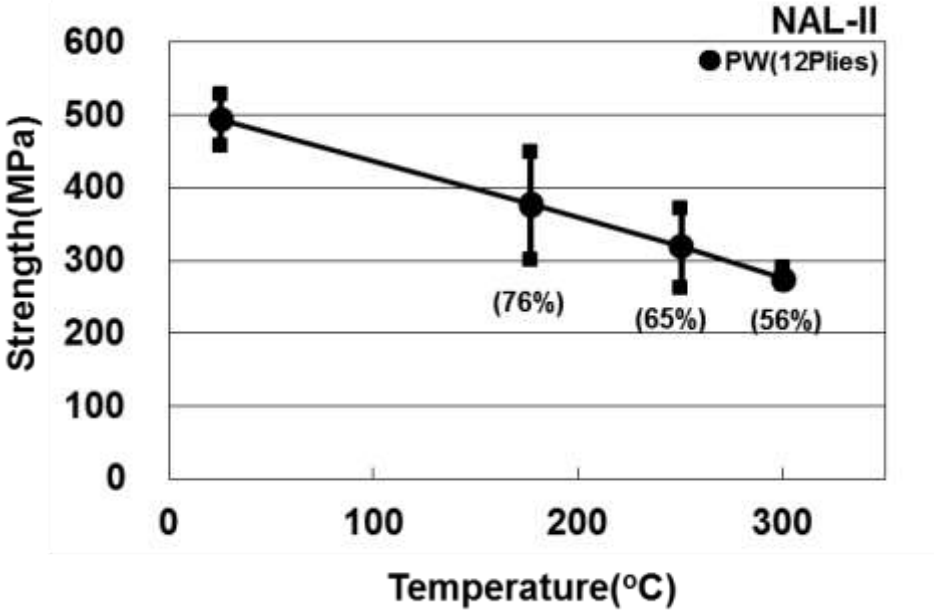
In air
10°C/min

These data are not guaranteed values and may be varied by the future tests.

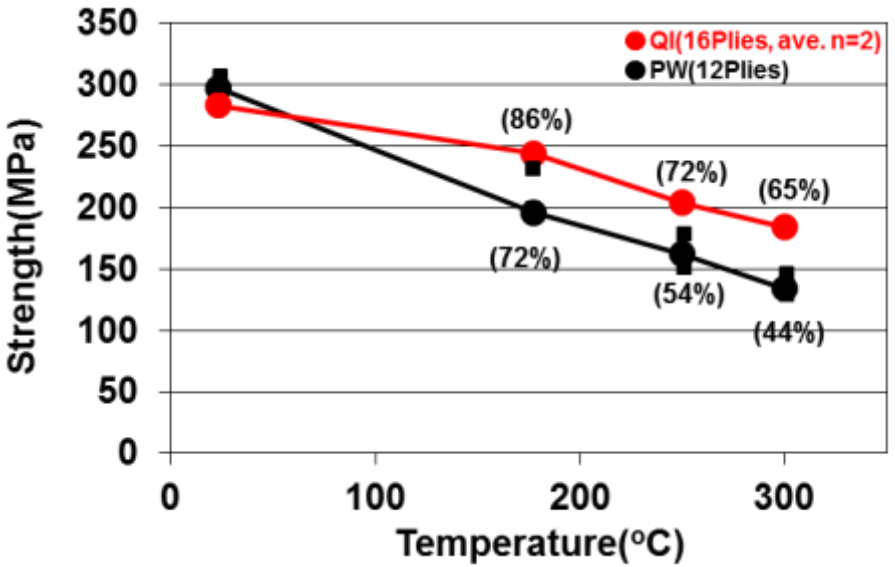
Non- and Open-hole compression tests

Non-hole compression





Open-hole compression



These data are not guaranteed values and may be varied by the future tests.

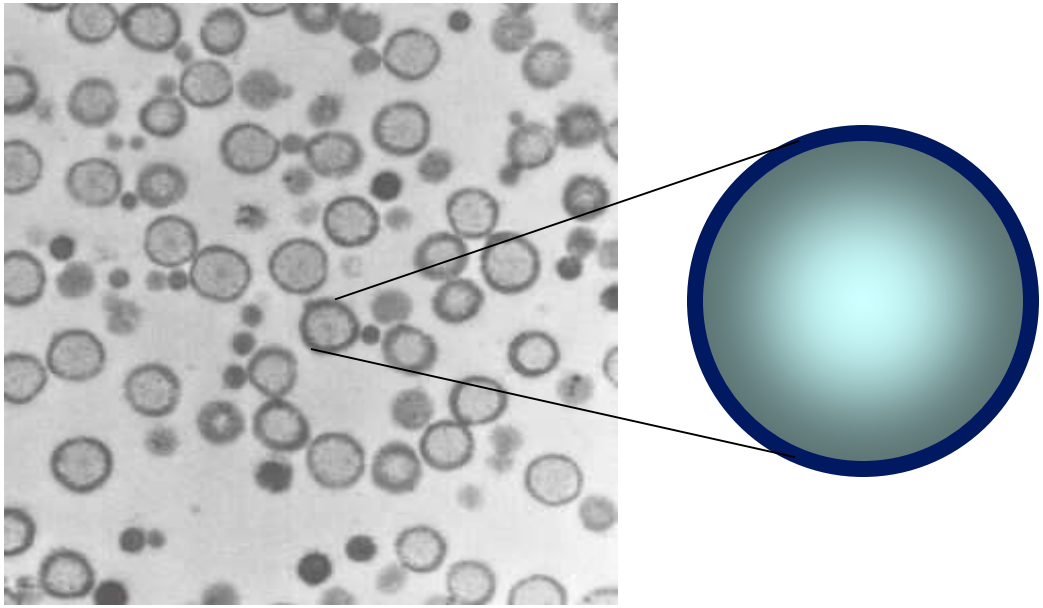
Kane Ace MX®

Core-Shell Rubber (CSR) Toughener for Thermosetting Resin Systems

KANEKA SOUTH AMERICA Ltda
Al. Min. Rocha Azevedo, 38 cj 1101
São Paulo, SP
(11) 3286-0081

What is Core-Shell Rubber (CSR)?

The structure of a core-shell rubber particle consists of a cross-linked rubber core encased by a hard "glassy" shell.



Performance can be optimized by tailoring the structure, chemistry, particle size and distribution, as well as shell functionality.

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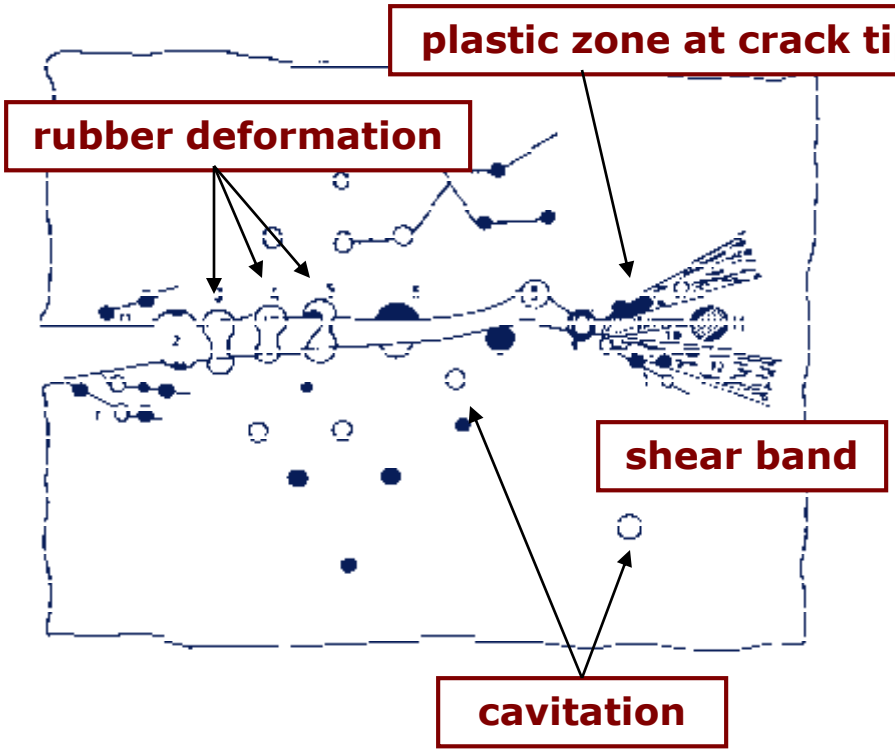
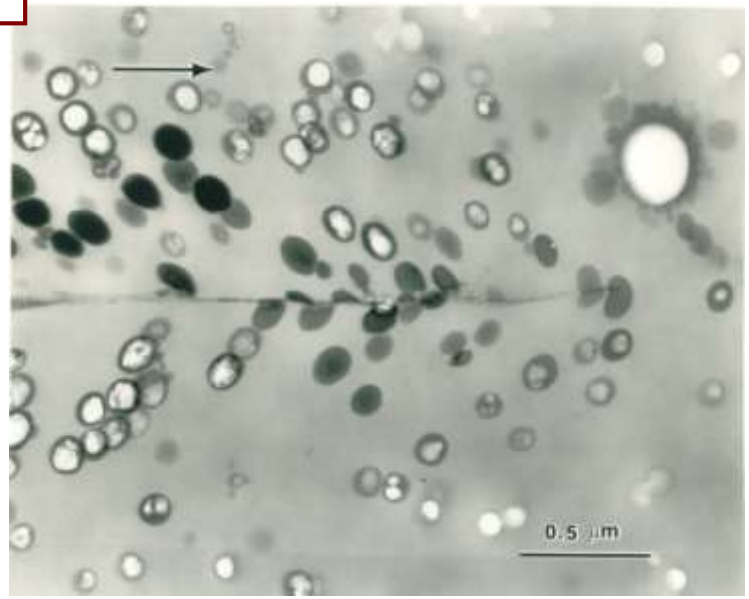
(11) 3286-0081

How Does CSR Toughen?





Rubber Cavitation and Shear Yielding
(epoxy resin/CSR)

KANEKA NORTH AMERICA LLC
6161 Underwood Road
Pasadena, Texas 77507
800-526-3223

What is Kane Ace® MX?

Kane Ace® MX is a family of user-friendly concentrates comprised of proprietary core-shell rubber (CSR) particles pre-dispersed into thermosetting resins or other liquid media.

KANEKA SOUTH AMERICA Ltda
Al. Min. Rocha Azevedo, 38 cj 1101
São Paulo, SP
(11) 3286-0081

Formulating With Kane Ace™ MX

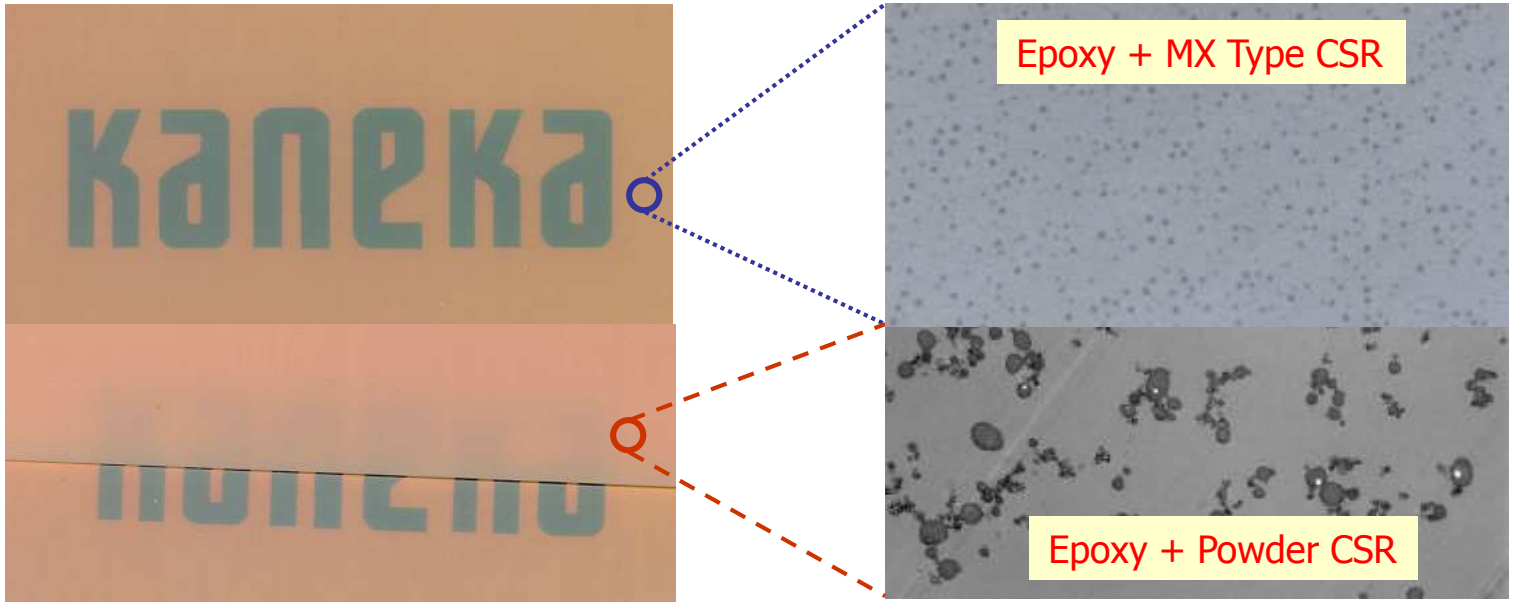
Standard Recipe	MX Modified Recipe
Part A: 70 parts liquid Bis A resin 20 parts epoxy resin Bis-F 10 parts reactive diluent	**Part A:** 52 parts liquid Bis A resin 20 parts epoxy resin B 10 parts reactive diluent 24 parts MX 125
Part B: 30 parts Part B- Curative	**Part B:** 30 parts Part B-Curative
Mix Ratio Part A to B: 100/30	**Mix Ratio Part A to B:** 106:30
Core Shell Concentration: 0%	**Core Shell Concentration:** 4.4%

Replacing 18 parts of epoxy with 24 parts of MX-125 is an easy way to add a modest amount of CSR without affecting the ratio of epoxy to curing agent

KANEKA NORTH AMERICA LLC
6161 Underwood Road
Pasadena, Texas 77507
800-526-3223

Benefits of Kane Ace® MX

DISPERSION is the key to improvement of mechanical properties!



TEM analysis shows complete dispersion of CSR particles via MX while conventional tougheners suffer from agglomeration issues.

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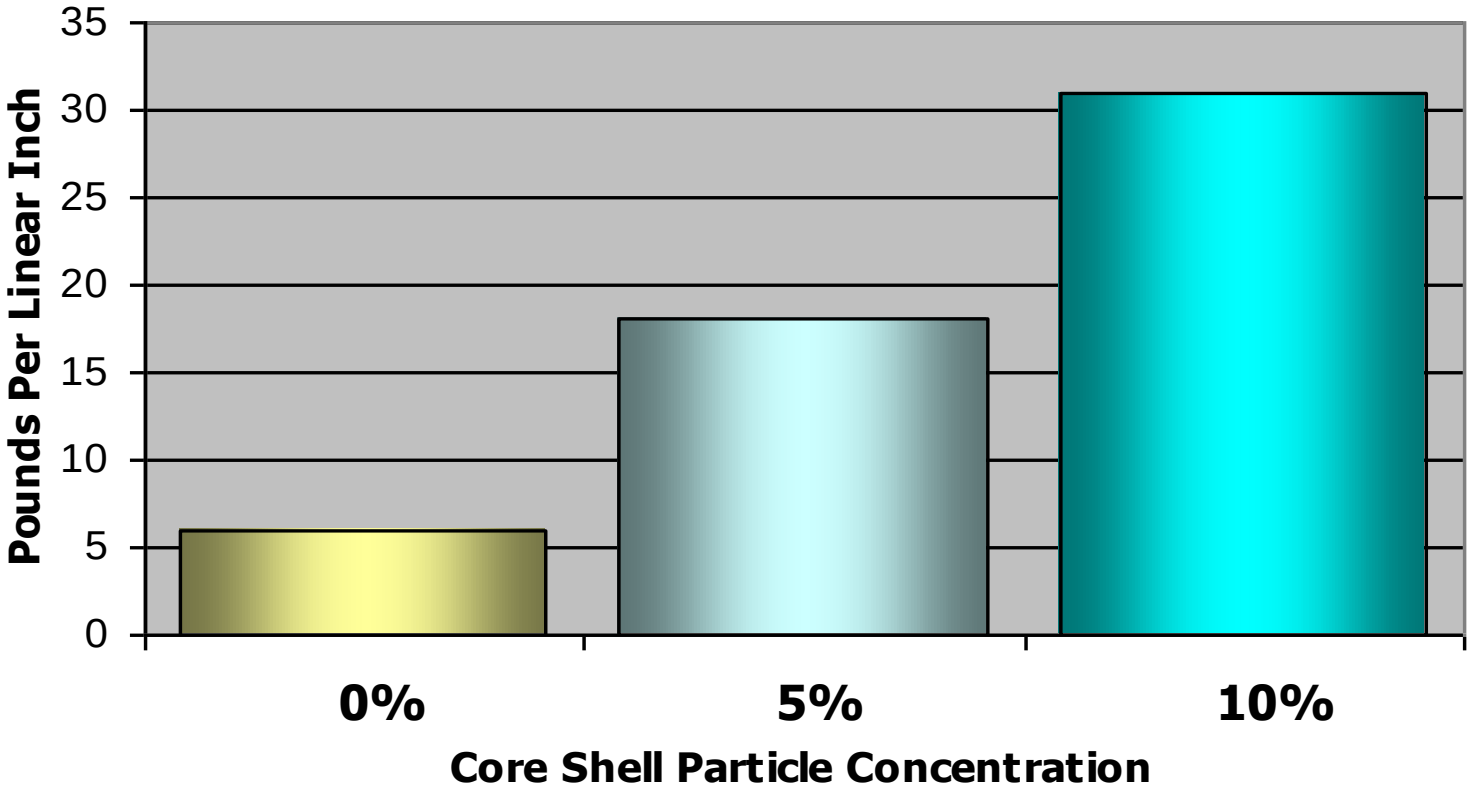
Al. Min. Rocha Azevedo, 38 cj 1101
São Paulo, SP
(11) 3286-0081

Benefits: Increased Peel Strength



(Recipe: Bis A Epoxy + Curing Agent + MX)

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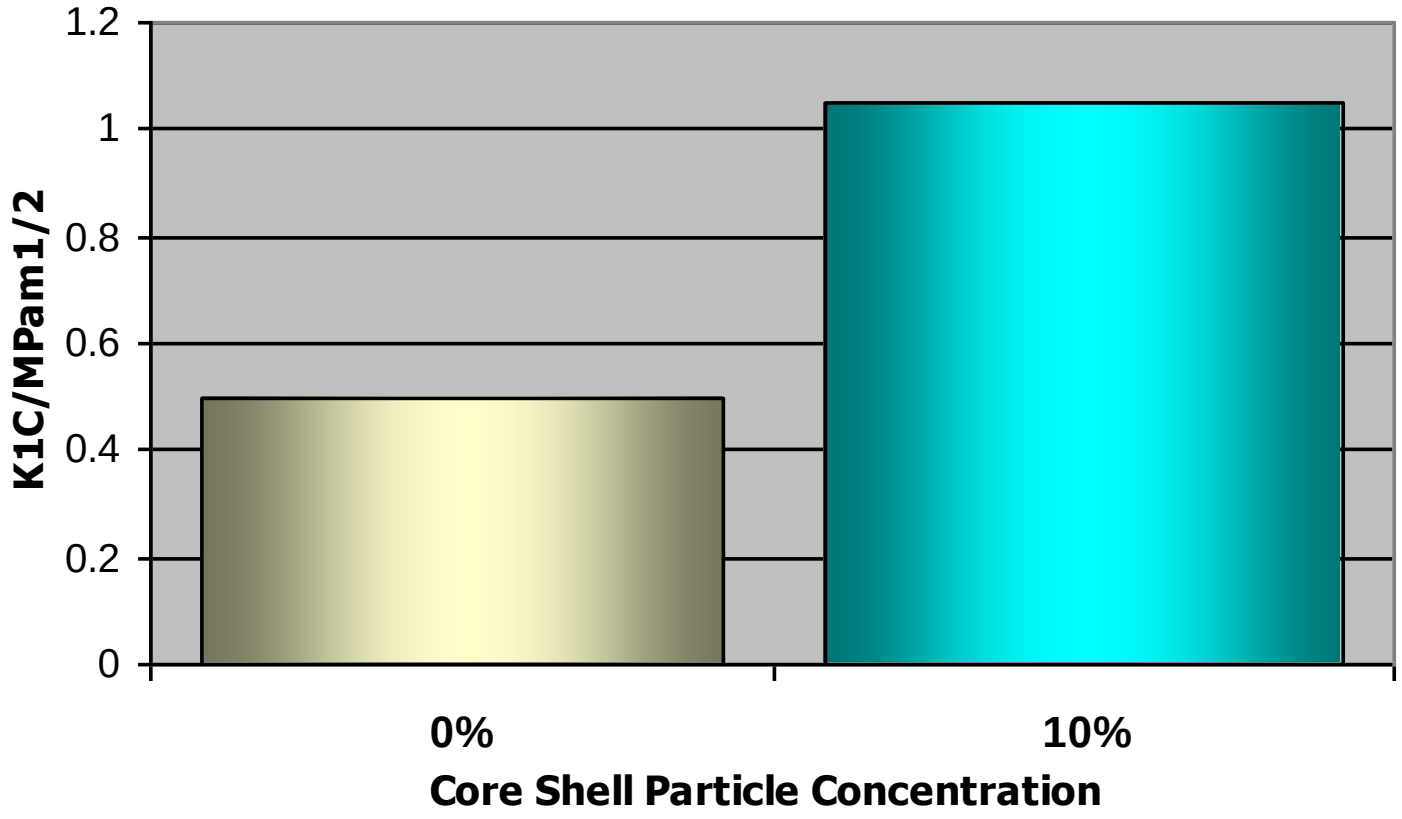
São Paulo, SP
(11) 3286-0081

Benefits: Fracture Toughness (K_{1C})



(Recipe: Bis A Epoxy + Curing Agent + MX)

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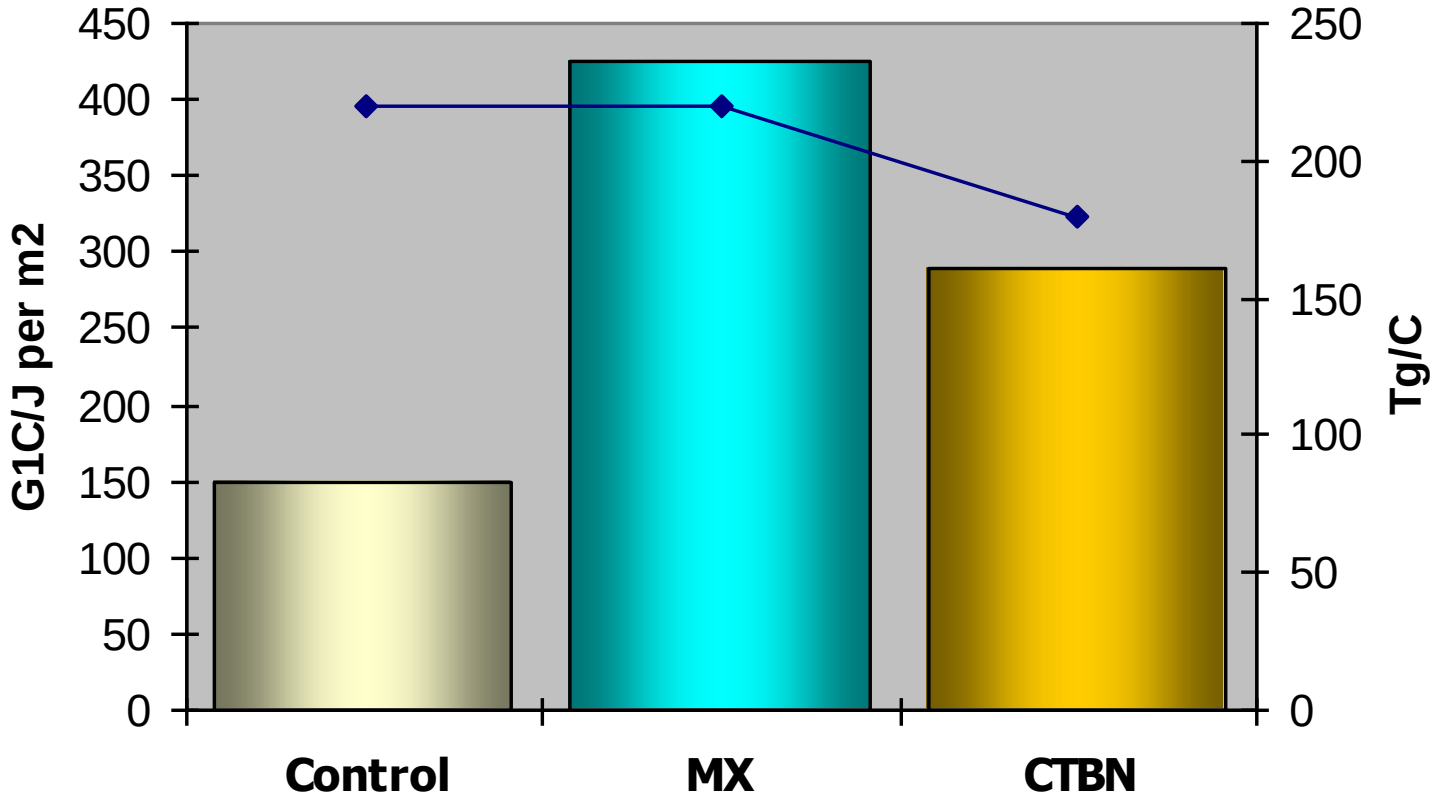
São Paulo, SP
(11) 3286-0081

Benefits: Toughness versus T_g



(Recipe: Bis A Epoxy + Curing Agent + MX)

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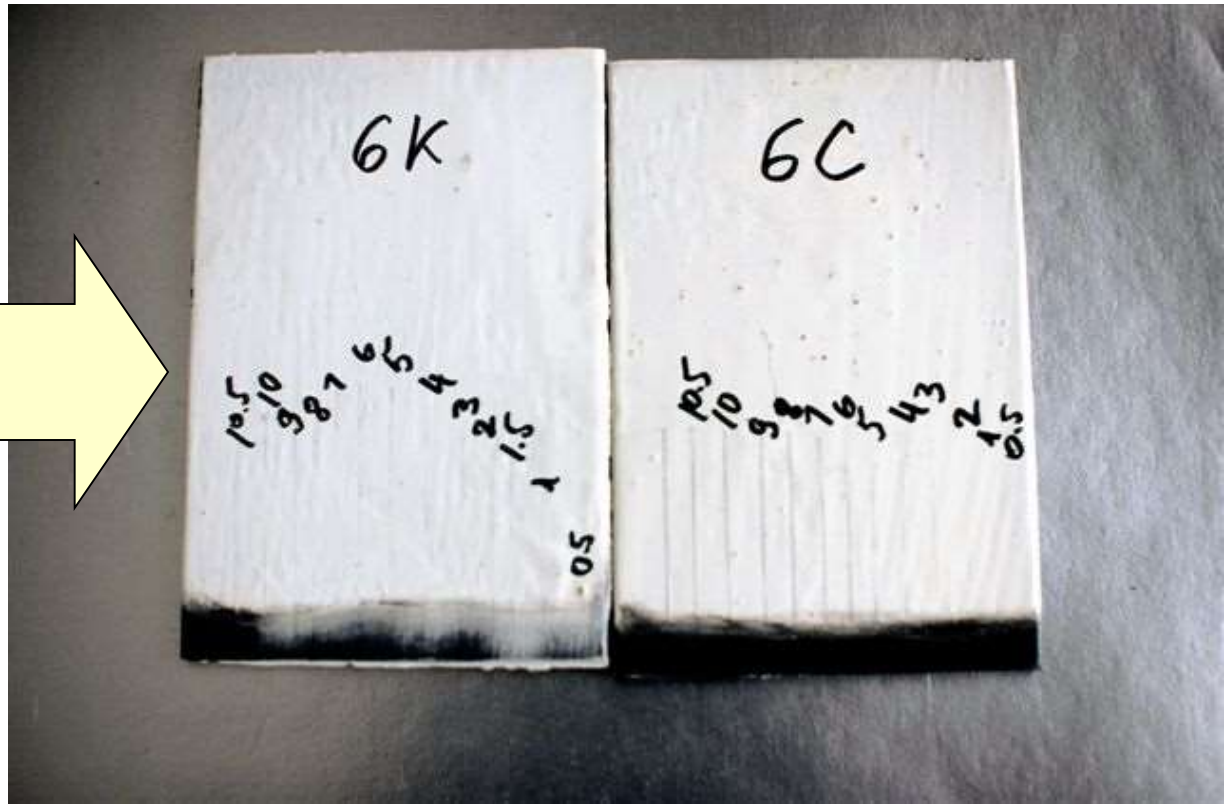
Benefits: Mar & Scratch Resistance

Kane Ace® MX can provide improvements to mar/scratch and abrasion resistance of thermosetting materals.



Huntsman "Zero VOC" White Epoxy High-Gloss topcoat (WEHGT)

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São Paulo, SP
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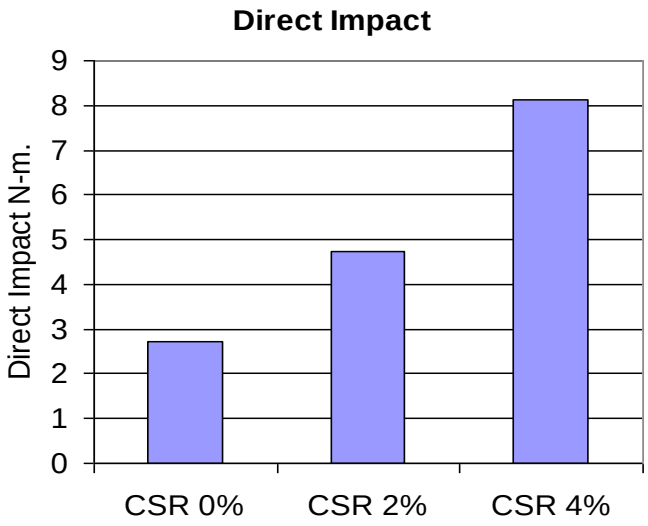
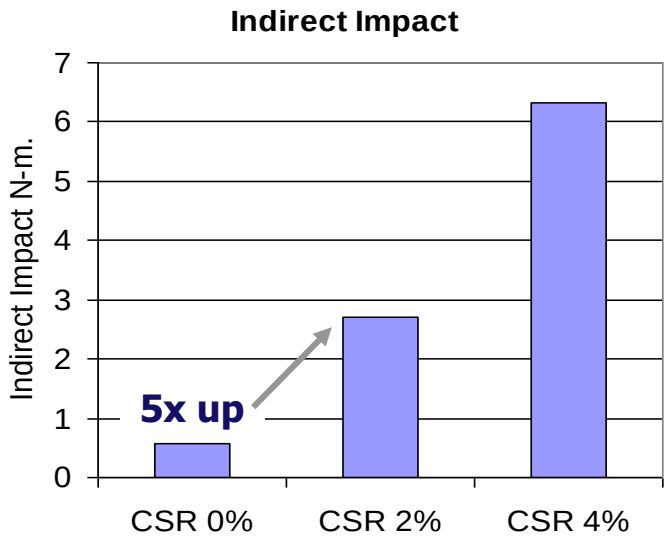
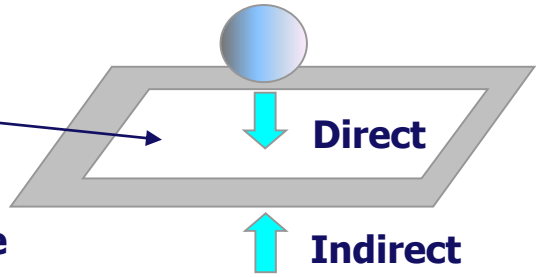
Gardner Impact







Cold Rolled Steel Substrate

Test temperature 23°C

ASTM D-2794

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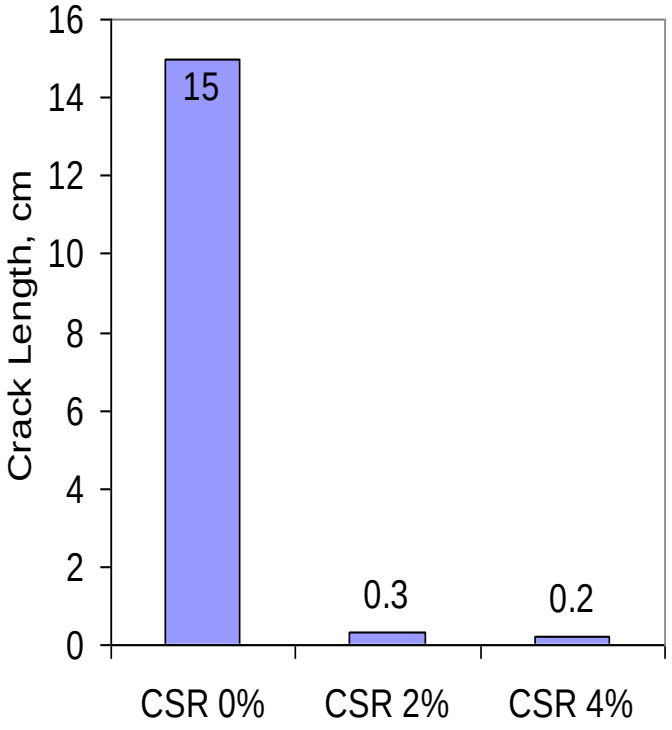
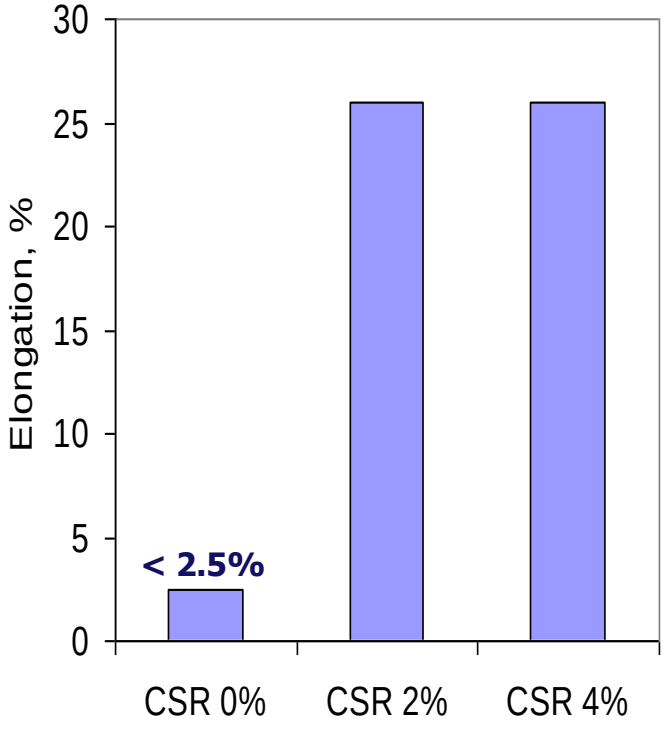
Al. Min. Rocha Azevedo, 38 cj 1101
São Paulo, SP
(11) 3286-0081

Mandrel Bend Testing

Crack Length



Estimated Elongation



ASTM D-522

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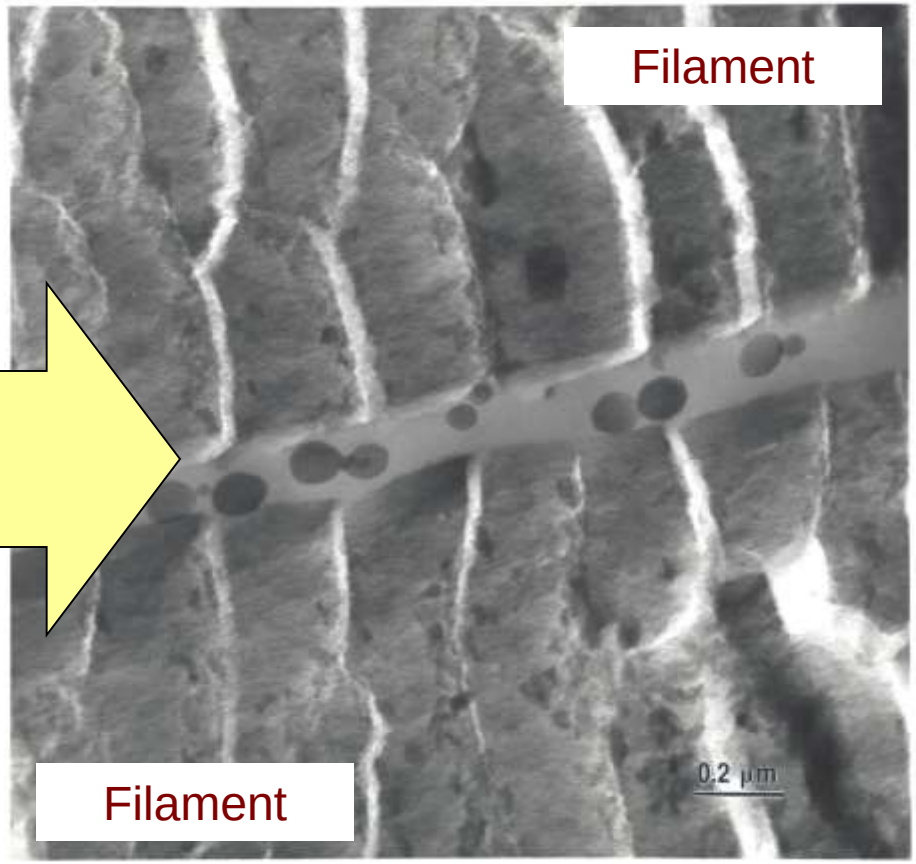
Al. Min. Rocha Azevedo, 38 cj 1101
São Paulo, SP
(11) 3286-0081

Benefits: Fiber Reinforced Systems

The technology associated with the production of Kane Ace™ MX avoids agglomeration of CSR particles. As a result fibers (such as carbon or glass) do not filter out the CSR particles, allowing them to toughen even the resin-rich area between single filaments.



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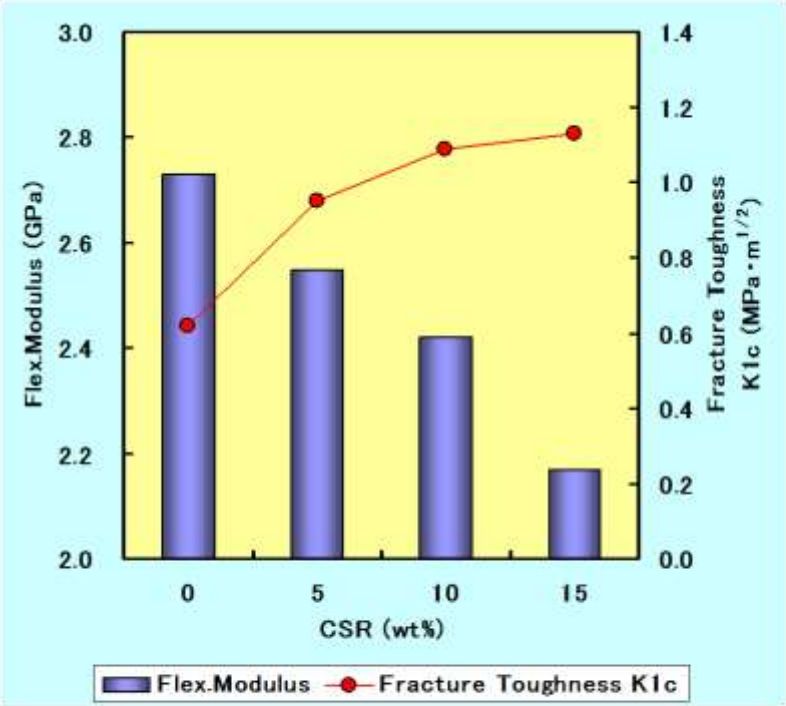
(11) 3286-0081

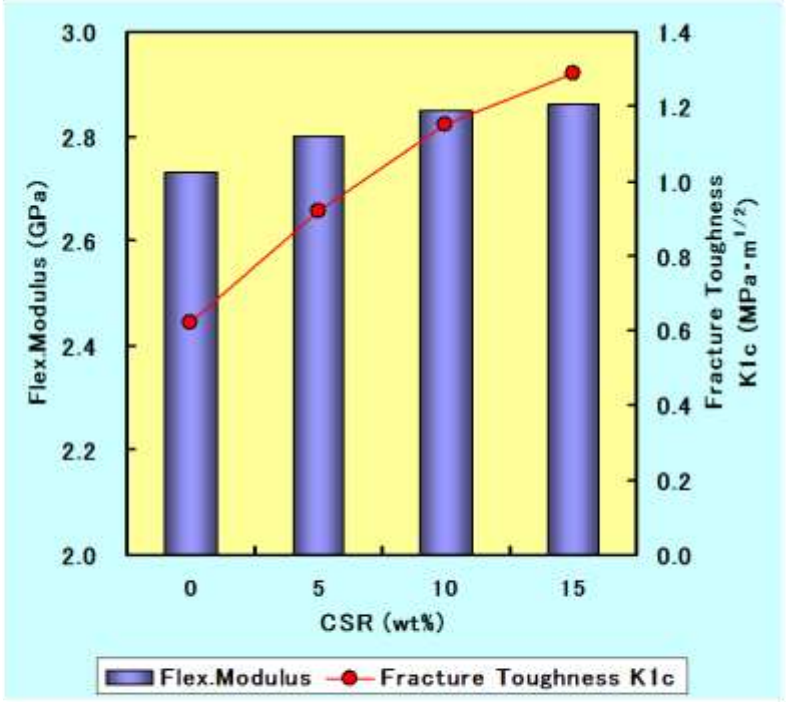
MX-170 for Composite Applications

Improves fracture toughness without sacrificing modulus

Relationship between Fracture toughness (K1c) and Flex. Modulus



Kane Ace™ MX-153 (Conventional)

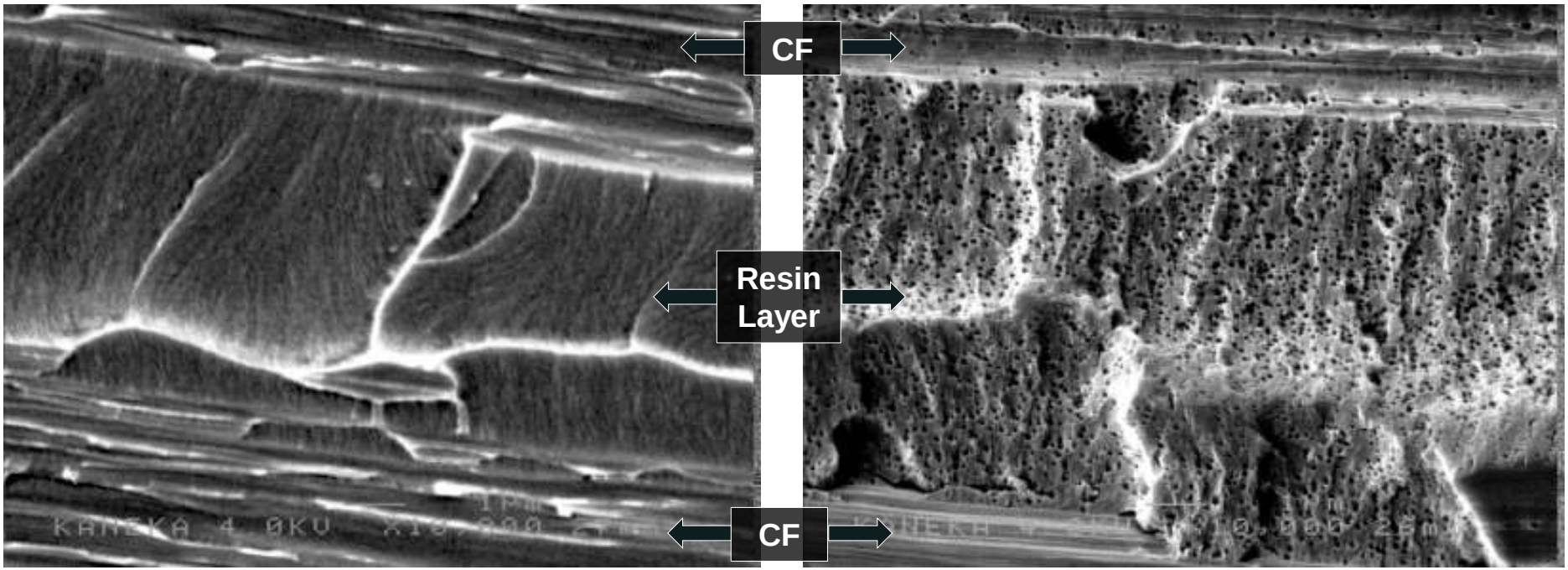


Kane Ace™ MX-170

本表の数値は測定値であり保証値ではありません。 These data are not guaranteed values but measurement values.

MX-170 for Composite Applications

Submicron-sized particles (CSR) are uniformly dispersed as primary particles in the resin layer between fibers, that means the particles are not filtered out by fibers through resin transfer molding process.



CFRP - No MX

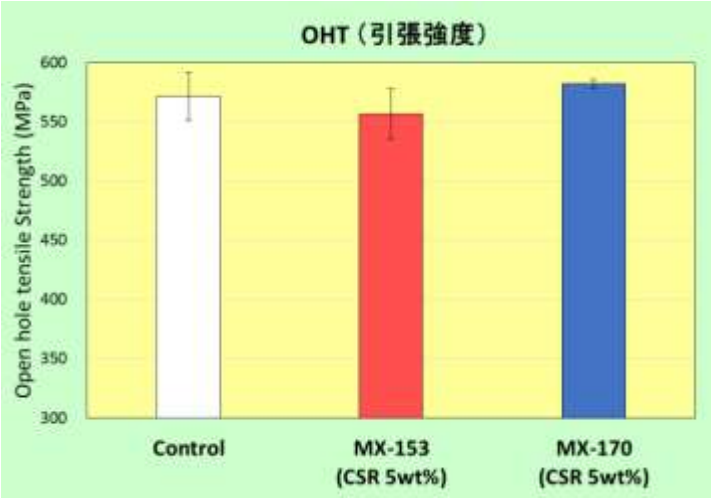
CFRP with MX（VaRTM） CSR 10wt%

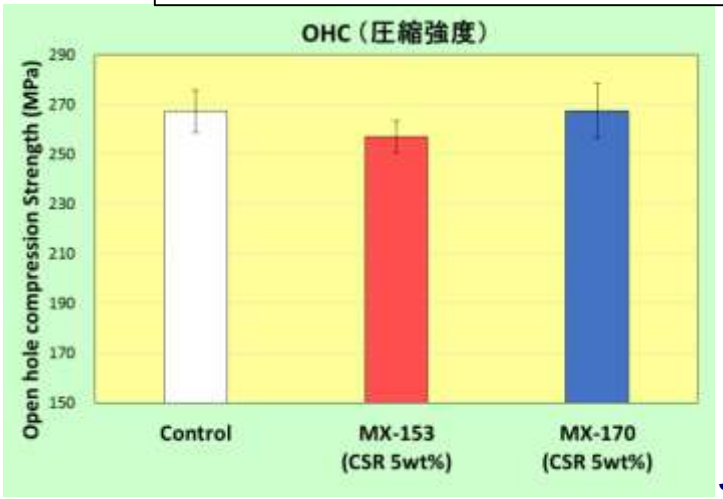
MX-170 for Composite Applications

Properties as CFRP（VaRTM)

Resin: DENATOOL XNR6809/XNH6809 = 100/95
CF: T800UD
OHT, OHC: [45/0/-45/90]2s, t=3.35mm
CAI: [45/0/-45/90]3s, t=4.8mm
Toughener: 5 wt% vs. Resin

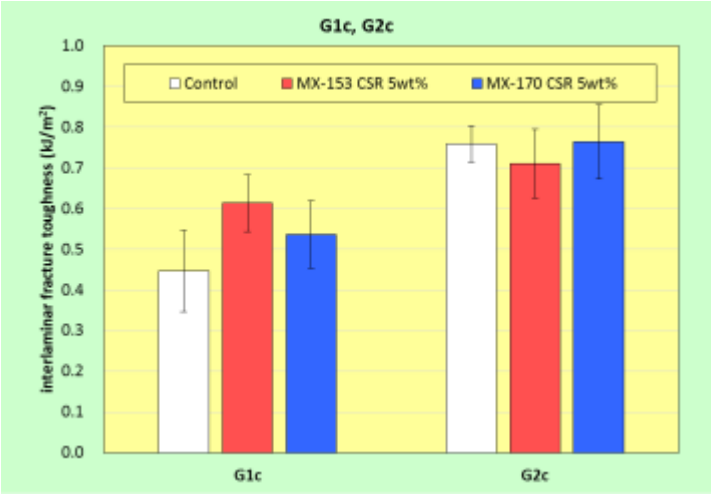
JIS K 7094

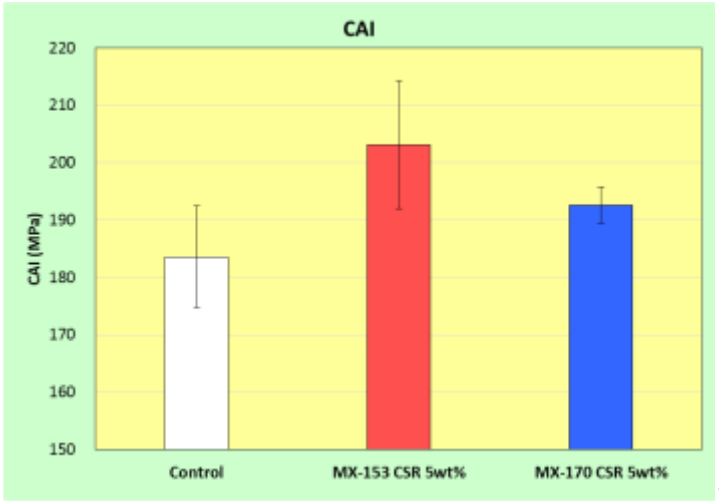




JIS K 7093

JIS K 7086





JIS K 7089

Products

Kane Ace MX products are available in a variety of carrier resins including:
Bis-A epoxy
Bis-F epoxy
Phenol Novolac epoxy
Multi-functional epoxy
Polyol for Urethane systems
Polyaspartic
Vinyl ester and UPE compatible
Acrylic system for UV curable applications

KANEKA SOUTH AMERICA Ltda
Al. Min. Rocha Azevedo, 38 cj 1101
São Paulo, SP
(11) 3286-0081

Kaneka's Graphite Materials For Air Craft

Kaneka Corporation
Electrical & Electronic Materials Division

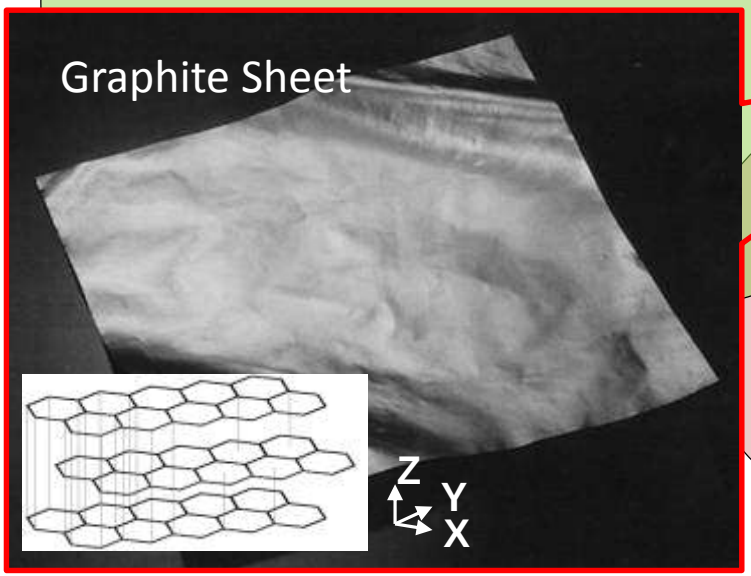
General Characteristic of Graphite Sheet

Thermal Conductivity

Good heat spreading performance
-4x's greater than copper
-6x's greater than aluminum

Carbon Material

Light weight
Lower water absorption

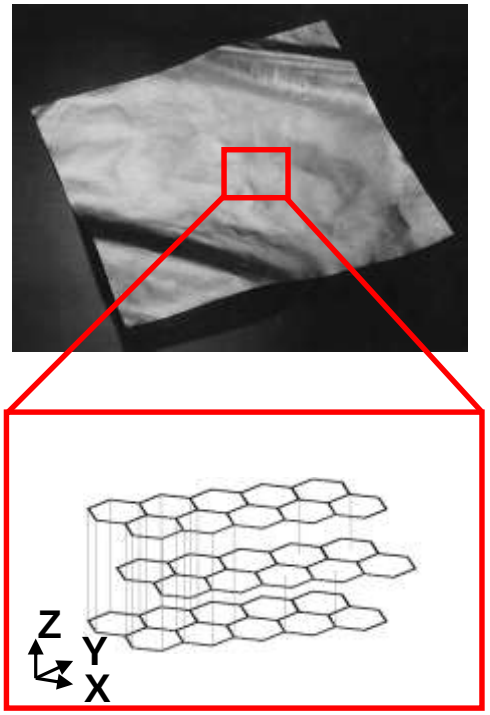


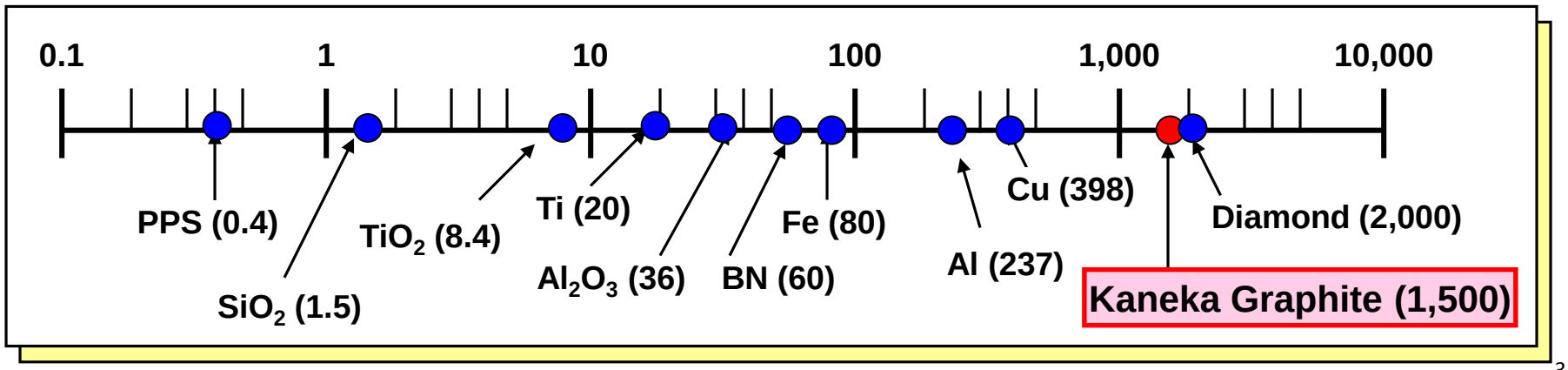
Flame resistance

Good burn-through test result
-suitable as a flame retardant sheet

General Characteristics of our Graphite material

1) High thermal conductivity in the in-plane direction
   - Graphite: 1,500 W/mK (in-plane direction)
   - about 4x's greater than Copper (398 W/mK)
   - about 6x's greater than Aluminum (237 W/mK)
2) Anisotropy of thermal conductivity
   - Graphite: 5 W/mK (thickness direction)
   - Ratio: in-plane / thickness = 300
3) Low density
   - Graphite : 2.0 g/cm^3,
   - Copper: 8.9 g/cm^3, Aluminum: 2.7 g/cm^3





General Characteristics of our Graphite material

➢ Basic Properties of our Graphite Sheet

- 10um to 40um thick Graphite Sheets are commercially available.

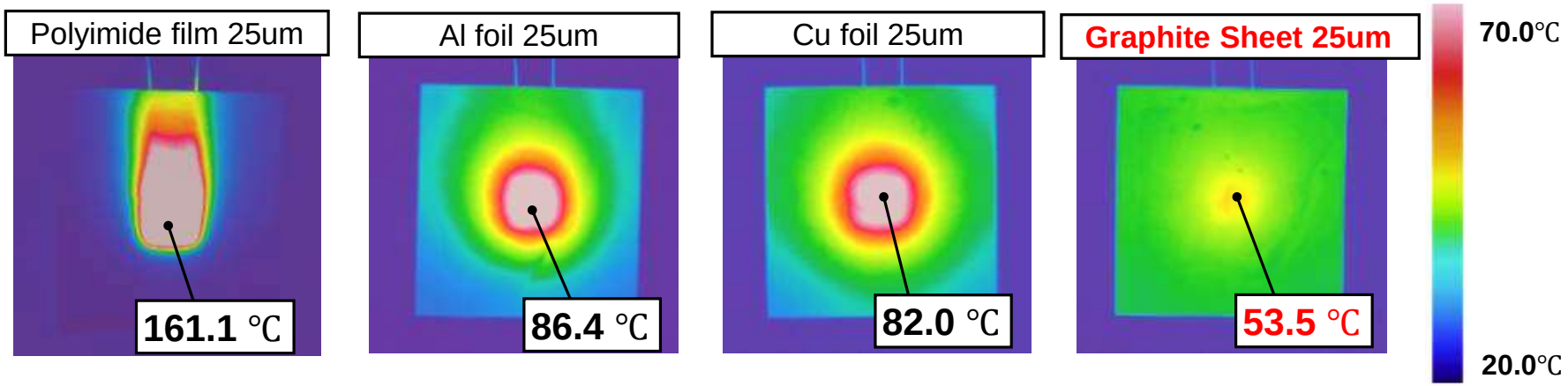
		Current grade				
Thickness (um)		10	18	25	32	40
Thermal conductivity (W/m·K)	XY axis	1600	1600	1500	1500	1500
	Z axis	5	5	5	5	5
Thermal diffusivity (cm^2/s)		9.0	9.0	9.0	9.0	9.0
Specific Density (g/cm^3)		2.1	2.1	2.0	2.0	2.0

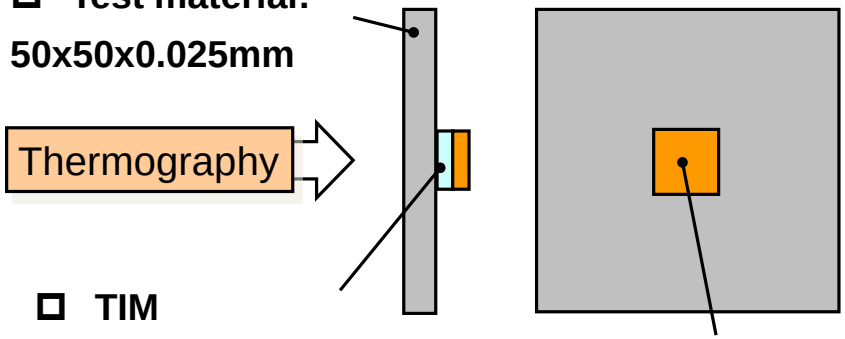
Other properties:

No Water absorption, No outgas, Electric conductivity, EMI shield, Good corrosion resistant

Heat spreading performance

- Kaneka's Graphite Sheet has a much larger heat spreading ability than copper and aluminum with the same thickness.





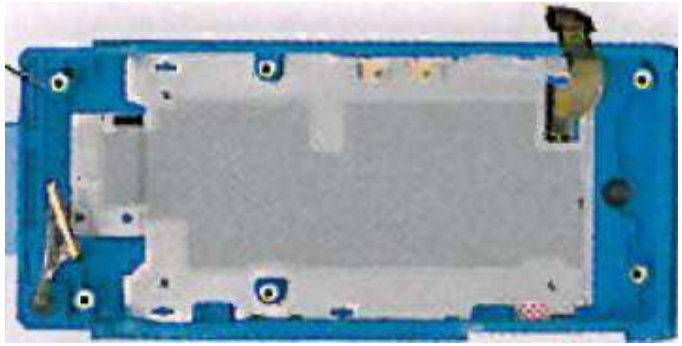
Measurement Conditions

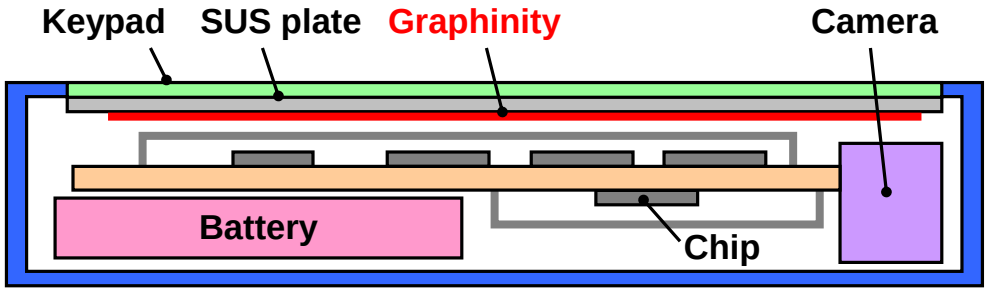
- Room Temp. : 24℃
- Heater Wattage : 2.0 W
- The emissivity was adjusted as 0.94 by black carbon spray

Application example of our Graphite Sheet

➢ Graphite Sticker

- Kaneka's Graphite Sticker is suitable as a heat spreader because of its high thermal conductivity and thinness.

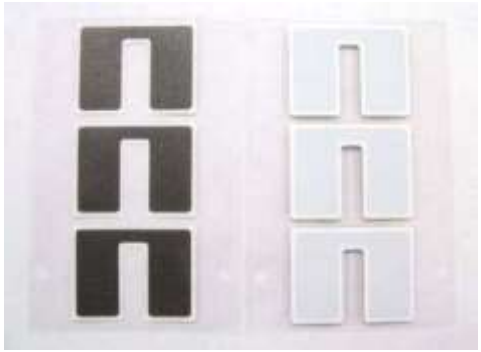




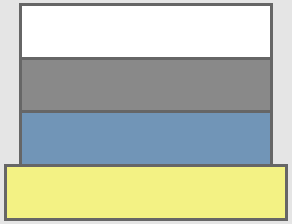
Graphite Sheet transfers the heat from the Chips, Camera and Battery.

10umPET/25umGS/10umPSA, 30×80mm

PSA side　PET tape side



Protect layer/ Graphite/ Adhesive



PET tape
Graphite Sheet
Adhesive(PSA)
Release film

Burn-through Test Results

➢ Picture Fframe Test (to compare with ceramic paper)

Burn-through Test Results

➢ Flame penetration

25um

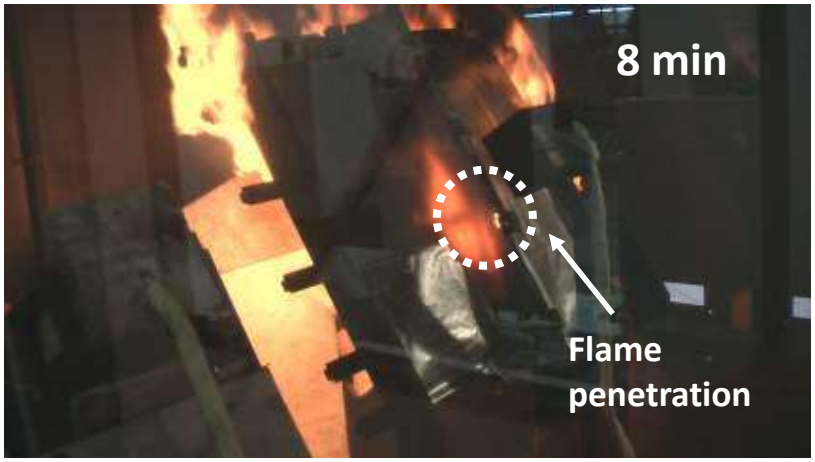
40um

Graphite sheet (25um,40um) can meet FAA requirement

Burn-through Test Results

➢ Flame penetration

25um

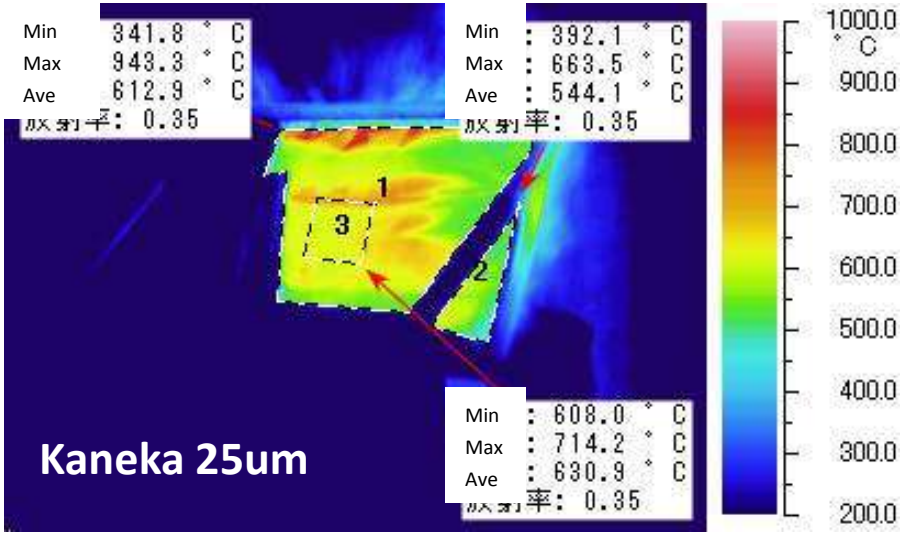


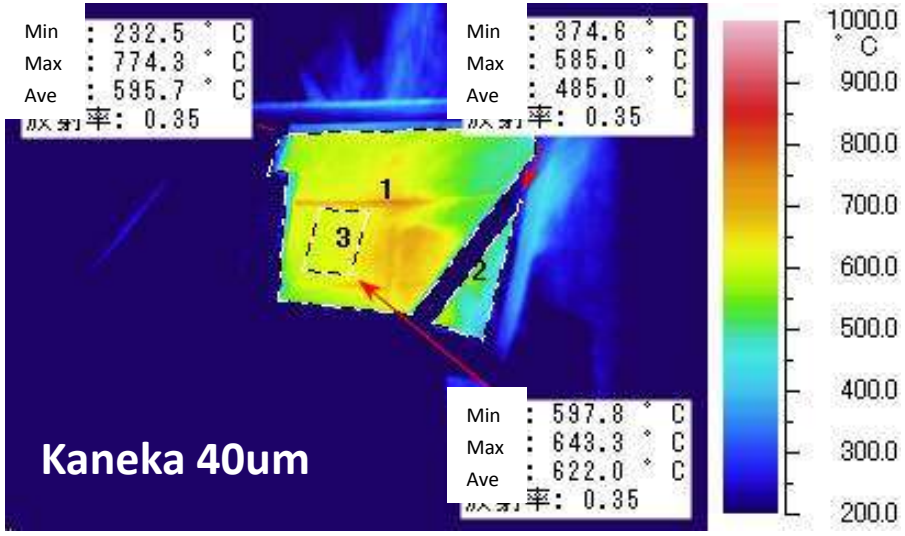
40um

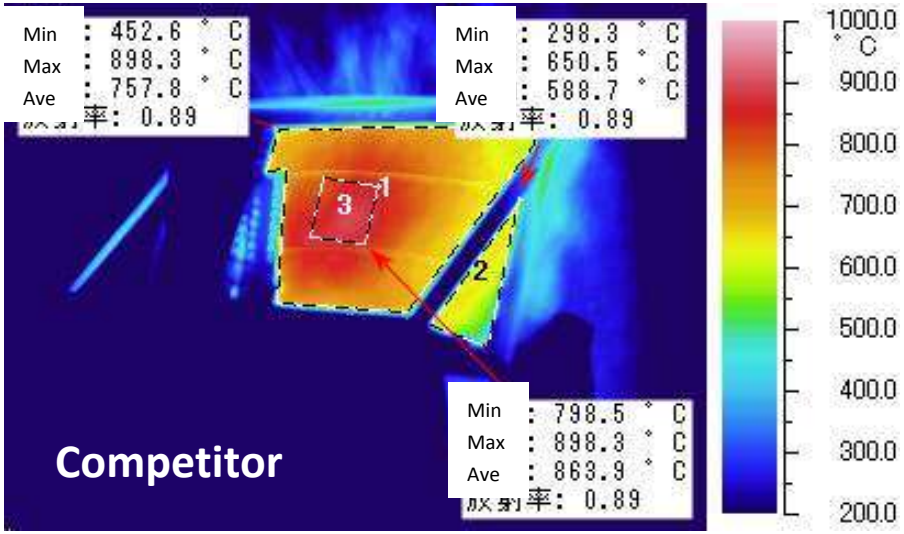
25um material can withstand 8min., and 40um material can withstand 10min.

Burn-through Test Results

After 4 min.



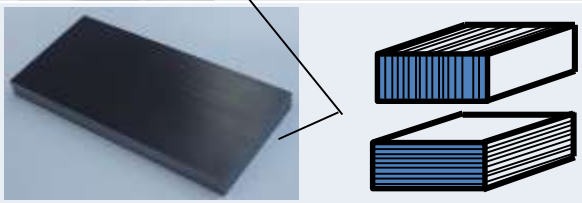
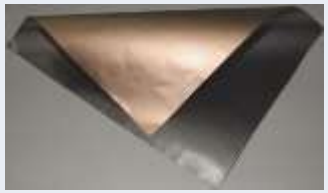




Kaneka material and competitive material are equivalent with regard to flame penetration.

However, Kaneka material has better insulative properties.

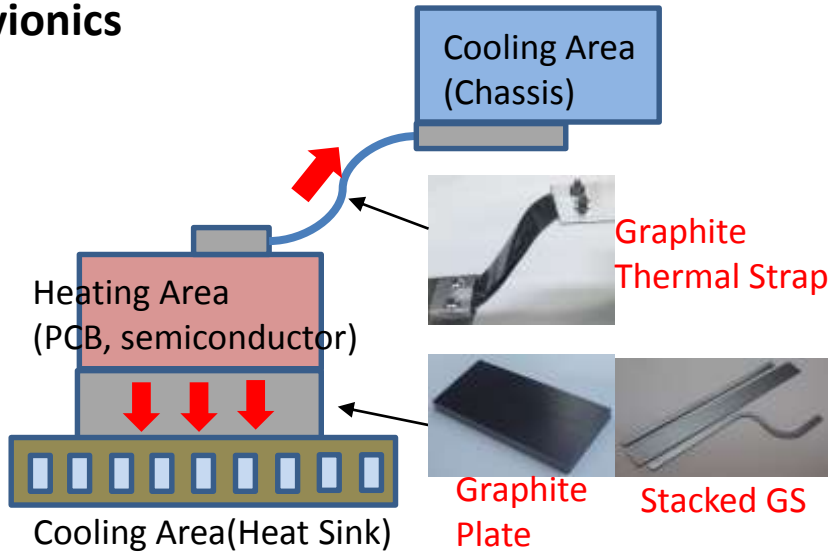
➢ New Graphite Materials (under development)

	Composition	Feature
Stacked GS		・High thermal transfer in XY or XZ axis ・Free form
Graphite Plate		・All graphite ・High thermal transfer in XY or XZ axis
Graphite Thermal Strap		・High thermal transfer ・Flexible ・Light weight (comparable to Cu)
Metalized Graphite Sheet		・High electrical conductivity ・Electromagnetic shield
GS/CFRP composite		・High Thermal conductivity (comparable to CFRP without GS) ・High Strength

Kaneka's Graphite Materials for Air Craft

➢ Potential application

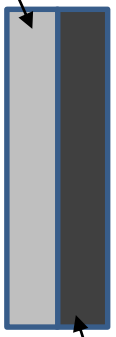
Avionics



Heat dissipation of the equipment

Body

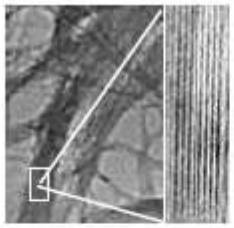
GS/CFRP Composite

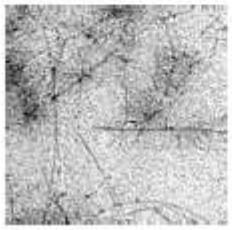


High Flame Resistance of Aircraft Body

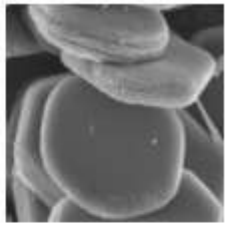
Nanomaterials

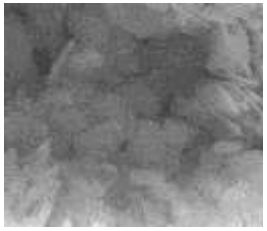
1-D
carbon nanotubes

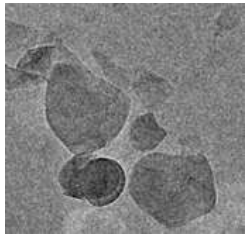


2-D
Clay, graphene, BN

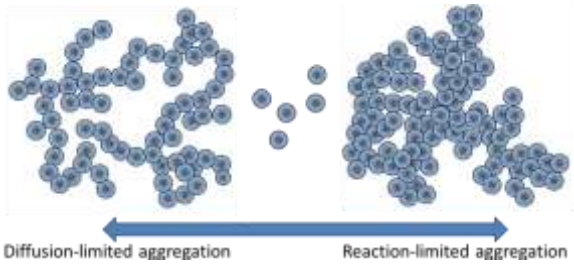






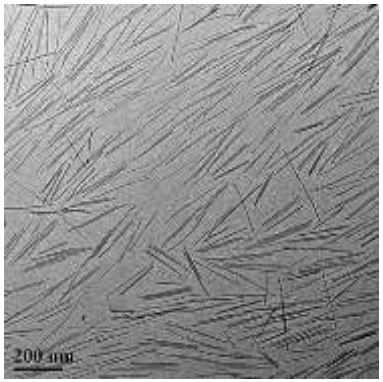
Nanocomposite/Hybrid Research at KMR

Nanocomposites

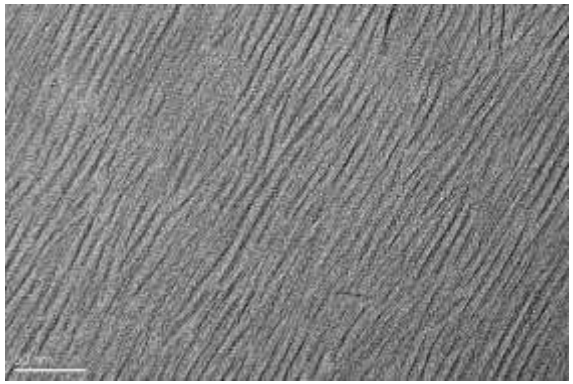


Nano-particle dispersion

Exfoliation

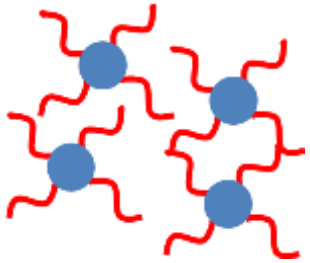


Alignment

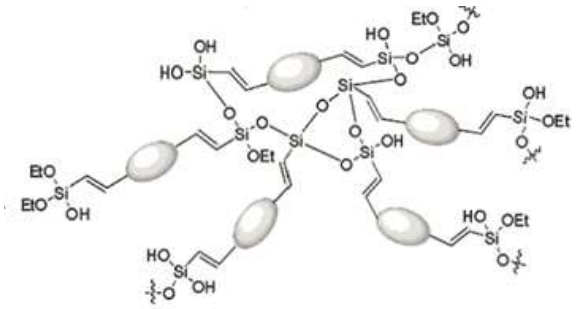


Polymer-based nanocomposites

Organic-inorganic hybrids



NP-based hybrids

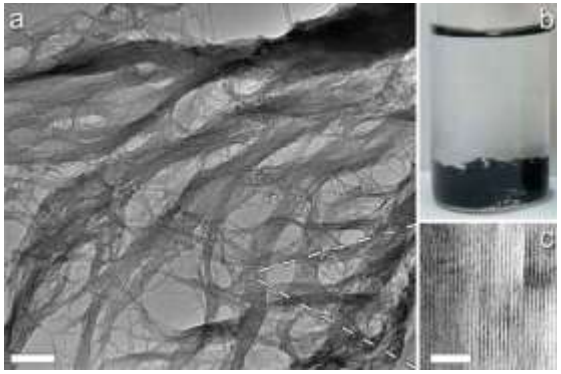


Molecular hybrids

ZrP assisted exfoliation of single-walled CNTs (SWCNTs)

SWCNT aggregates

They form bundles in microscale and cannot be dispersed in solver

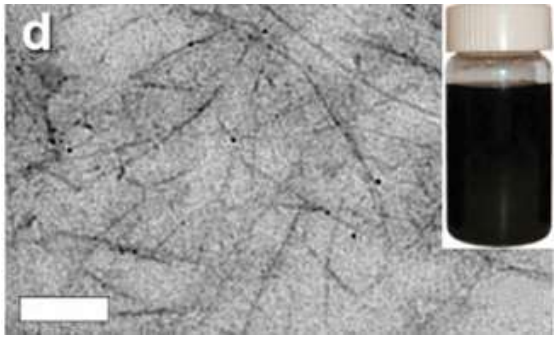


To solve this issue, we developed a method to disperse CNT by ZrP nanoplatelets

ZrP: synthetic clay, high purity, small size distribution, mature exfoliation technique
~100 nm in diameter

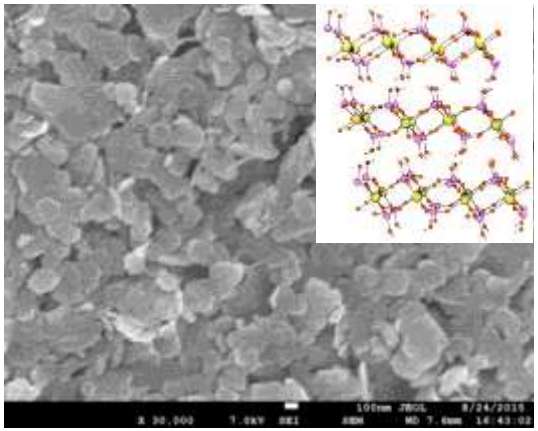
SWCNT dispersion

SWCNTs have been de-bundled and show good dispersion in water



Types of CNTs used for this process:

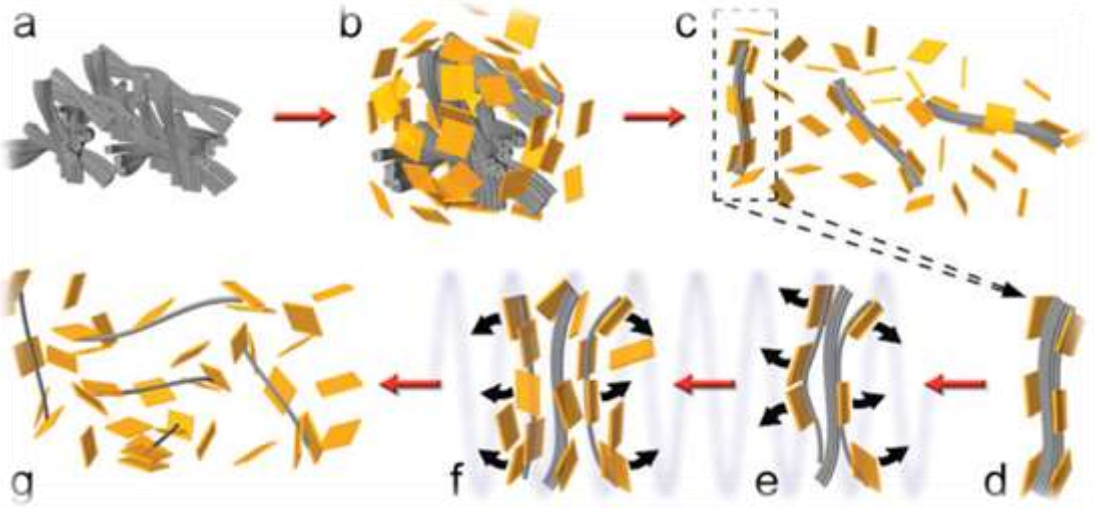
- HiPco SWCNTs
- Arkema MWCNTs
- SouthWest NanoTechnologies (SWeNT)



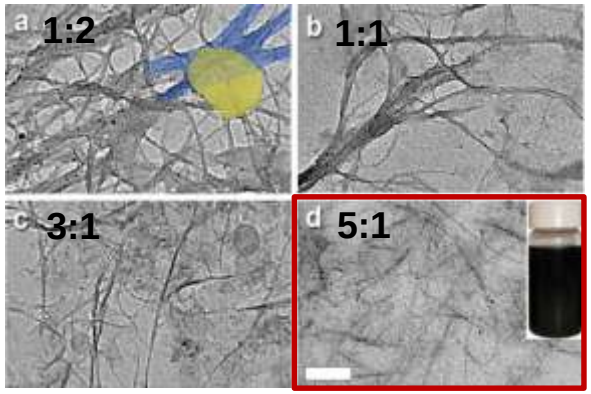
Microstructure and chemistry structure (inset)

ZrP aqueous solution

ZrP assisted exfoliation of single-walled CNTs (SWCNTs)



Different weight ratio between ZrP and SWCNTs



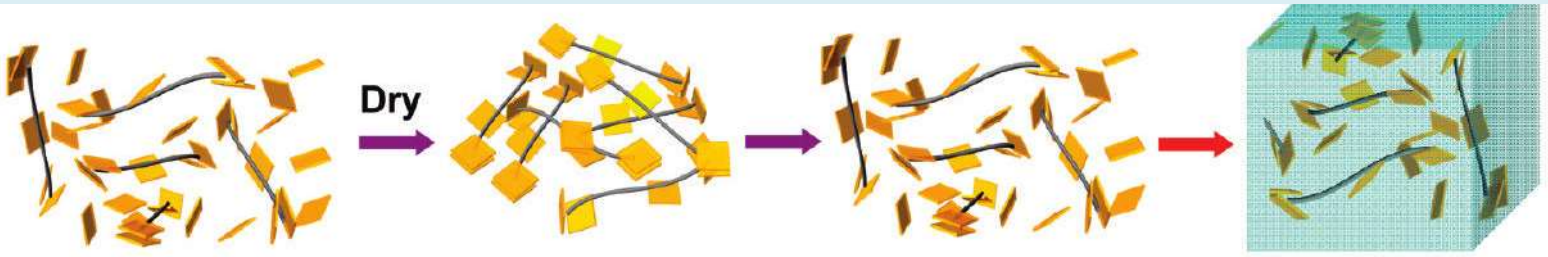
a) Large aggregates of pre-treated(oxidized) SWCNT are in an aqueous medium.
b) ZrP nanoplatelets are added and electrostatically bind to the SWCNT bundles.
c) SWCNT aggregates are then broken up into smaller bundles.
d) One specific example of the bind between ZrP and SWCNT.
e) Nanoplatelets with an ultrasonic wave progressively pull individual tubes and small bundles from bundles.
f) Nanoplatelets continue to pull small bundles from larger bundles.
g) Mechanism continues until the nanotubes are pulled into an individually dispersed state.

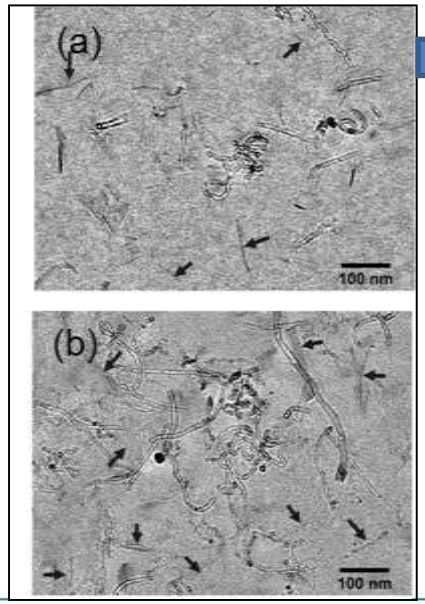
Good dispersion is achieved with a ZrP-to-CNT weight ratio of 5:1, but ZrP could be removed afterward.
More than 95% of CNT could be dispersed.
This method also applies to multi-walled carbon nanotube (MWCNT).

Small 2009, 5, No. 23, 2692–2697

Preparation of epoxy hybrid nanocomposites based on carbon nanotubes and ZrP

Transfer MWCNT/ZrP aqueous suspension into organic solvent and prepare epoxy nanocomposites





Microstructure of epoxy nanocomposites with
(A) 0.2wt% of MWNTs and 1.0 wt % of ZrP nanoplatelets and (B) 0.4wt% of MWNTs and 2.0 wt %of ZrP

Mechanical properties of epoxy nanocomposites

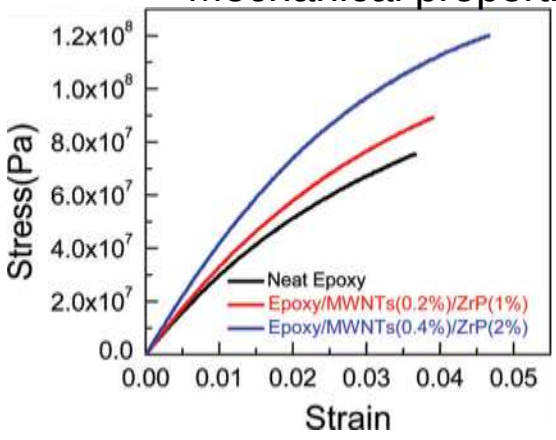
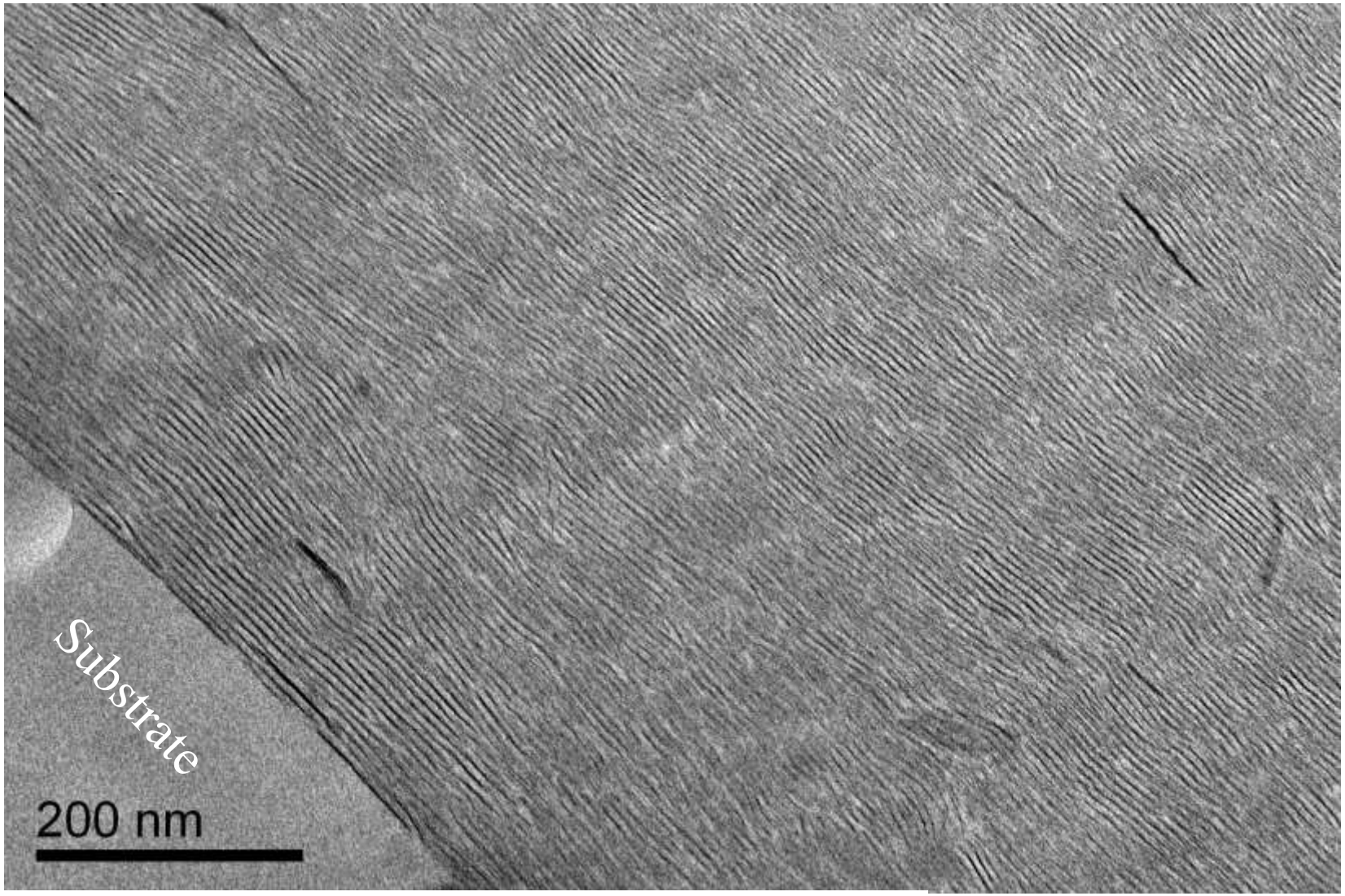


Table 1. Mechanical Properties of the Neat Epoxy and Epoxy Nanocomposites Containing Exfoliated ZrP Nanoplatelets and MWNTs

	neat epoxy	epoxy/ MWNTs(0.2%)/ ZrP(1.0%)	epoxy/ MWNTs(0.4%)/ ZrP(2.0%)	
Young's modulus (GPa)	3.04 ± 0.04	3.40 ± 0.06	4.27 ± 0.07	40%↑
tensile strength (MPa)	75.3 ± 4.2	83.1 ± 4.8	116 ± 5.5	54%↑
elongation at break (%)	3.7 ± 0.1	3.9 ± 0.3	4.3 ± 0.4	

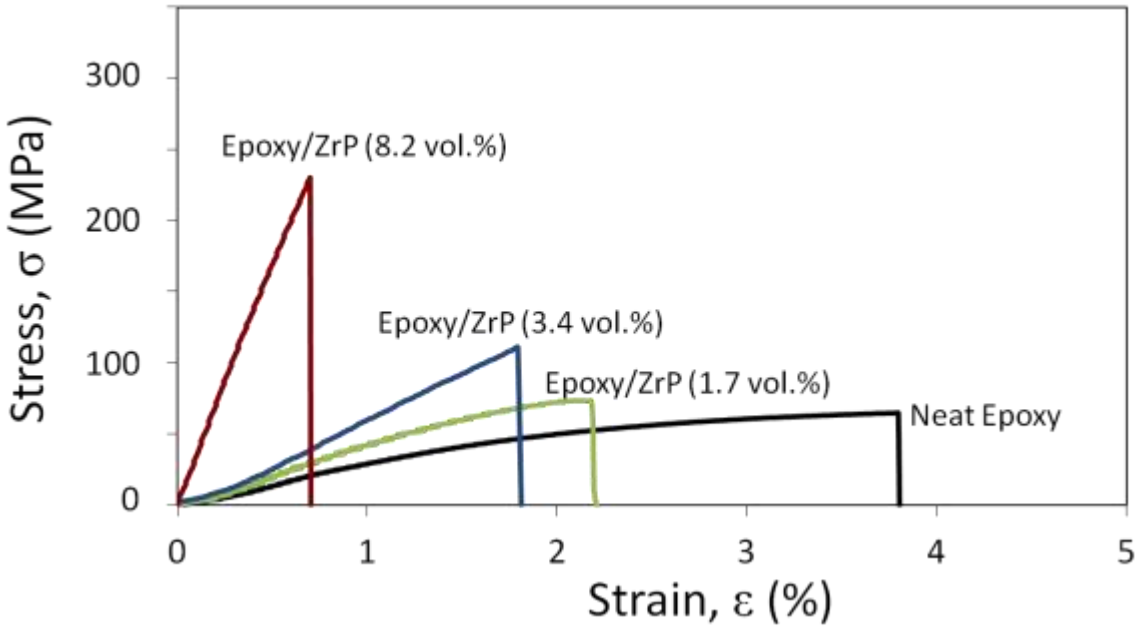
Chem. Mater. 2010, 12, 3773-3778

TEM of Epoxy/ZrP Nanocomposites (4.5 vol.%)



Highly aligned ZrP nanoplatelets in epoxy matrix

Tensile Properties of Epoxy/ZrP Films

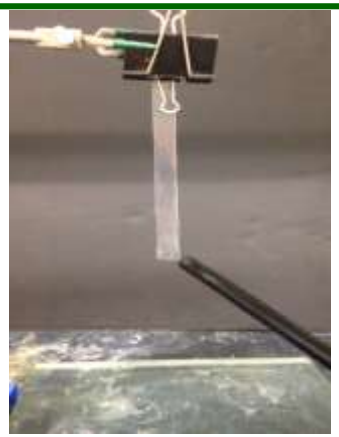


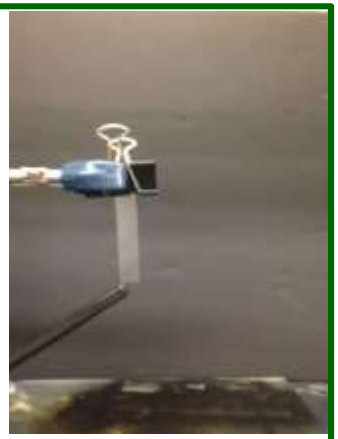
	Pure Epoxy	Epoxy/ZrP (1.7 vol. %)	Epoxy/ZrP (3.4 vol. %)	Epoxy/ZrP (8.2 vol. %)
Young's Modulus, GPa	2.7±0.4	4.4±0.9	8.1±2.3	22.0±4.0
Tensile Strength, MPa	55±5	79±9	135±25	210±40
Elongation at Break, %	3.8±0.5	2.1±0.3	1.6±0.3	0.8±0.2

Note: Tensile tests were conducted using an RSA-G2 (TA Instruments) with a tensile fixture. The tensile tests were conducted in controlled strain mode with a constant linear rate of 0.05mm/s.

Smectic epoxy/ZrP coated PET & PU


Bare PET film


Epoxy coated PET


Epoxy/ZrP coated PET


Bare PET/Epoxy coated PET


Epoxy/ZrP coated PET


Bare PU foam


Epoxy coated PU


Epoxy/ZrP coated PU


Bare PU/Epoxy coated PU


Epoxy/ZrP coated PU

Melt-dripping issue of PET film and polyurethane (PU) foam is effectively solved via application of epoxy/ZrP (4.6 vol.%) coating.

Summary

- Polyimide
- Toughening Agent (CSR)
- Graphite Sheet
- Nanocomposites


KANEKA
The Dreamology Company
—Make your dreams happen—