Introduction of New Large Tow Carbon Fiber Products and PCM* Technology

* Prepreg Compression Molding
Mitsubishi Rayon

Carbon Fiber Business
for Industrial applications

Specialty Products

The Mitsubishi Rayon Group optimally leverages its proprietary materials and wide-ranging technological know-how to swiftly and precisely meet market needs.
MCHC Group Organization

Mitsubishi Chemical Holdings Corporation (MCHC)*

The KAITEKI Institute, Inc.

Mitsubishi Chemical Corporation (MCC)
Paid-in capital: ¥50.0 billion
Consolidated net sales: ¥1,874.8 billion

Mitsubishi Tanabe Pharma Corporation (MTPC)*
Paid-in capital: ¥50.0 billion
Consolidated net sales: ¥404.7 billion

Mitsubishi Plastics, Inc. (MPI)
Paid-in capital: ¥21.5 billion
Consolidated net sales: ¥313.2 billion

Mitsubishi Rayon Co., Ltd. (MRC)*
Paid-in capital: ¥53.2 billion
Consolidated net sales: ¥365.0 billion

MCC Group
Mitsubishi Chemical Corporation
14-1 Shiba 4-chome, Minato-ku, Tokyo
Tel: +81-3-6414-3000

MTPC Group
Mitsubishi Tanabe Pharma Corporation
6-18 Kitahama 2-chome, Chuo-ku, Osaka
Tel: +81-6-6205-5085

MPI Group
Mitsubishi Plastics, Inc.
2-2 Nihombashihoongokuchou 1-chome, Chuo-ku, Tokyo
Tel: +81-3-3279-3700

MRC Group
Mitsubishi Rayon Co., Ltd.
8-41 Konan 1-chome, Minato-ku, Tokyo
Tel: +81-3-5495-3100

Figures for consolidated net sales and paid-in capital are for the year ended March 2010.
Chemical Industries Global Ranking

Sales (million $)

80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000

BASF
Dow
Bayer
MCHC
Lyondell Basell
Sabic
DuPont
Akzo Nobel
Evonik
Sumitomo Chemical

* A total sales of MCHC and MRC as of March 2010
Source: Latest data for each company from Thomson Reuters FORTUNE Global 500 (as of September 2010)

€1.00=¥106

€75.5 billion
€56.6 billion
€37.7 billion
€29.9 billion
€18.9 billion
MRC Company Profile

Foundation Year 1933
Capital €502 Million
Employee 8,203
Consolidated Sales Amount €4.51 Billion
(€1.00=¥106)

Main Business
1. Specialty Resin and Chemicals
2. Acrylic Fiber, AN
3. Carbon Fibers, Composites
4. Synthetic Fibers, Membrane

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MITSUBISHI RAYON CO., LTD.
MRC Sales Breakdown

The 3rd Largest Carbon Fiber Manufacturer

Sales Amount €4.51 Billion

- Synthetic Fibers: 14%
- Carbon Fibers, Composites: 6%
- Acrylic Fiber, AN: 7%
- Membrane etc.: 14%
- Specialty Resins and Polymers: 64%

As of Mar 2011
Features of MRC carbon fiber business

Vertical integration

CFRP
Intermediate materials
Carbon Fiber
Precursor
Acrylonitrile

Application technologies
CFRP design technologies
Pre-forming technologies
Matrics resin technologies
Composite material technologies
Carbon fiber technologies
Acrylic fiber technologies
Monomer&Polymer technologies

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MITSUBISHI RAYON CO., LTD.
Mitsubishi Rayon

Premium Carbon Fiber
for Industrial applications

Specialty Products

The Mitsubishi Rayon Group optimally leverages its proprietary materials and wide-ranging technological know-how to swiftly and precisely meet market needs.

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New product concept

Product required for growing industrial applications
- Good process-ability, high performance (small tow like)
- Tightly controlled quality (small tow like)
- Large tow for high productivity at sites
- Good availability and affordability

Our new product will change conventional large-tow perception in the market.

“Larger Filament Count, but performs as small tow or even better”
**Property Chart**

- **Tensile Modulus, GPa**
  - Pyrofil TR50S 12/15K
  - Grafil 34-700
  - Grafil 34-600
  - Pyrofil TRH50 18K
  - New P330 60K
  - New WCF 50K

- **Tensile Strength, MPa**

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## Products

<table>
<thead>
<tr>
<th>Name</th>
<th>Filament Count</th>
<th>MUL (mg/m)</th>
<th>Density (g/cm³)</th>
<th>Tensile Modulus (GPa)</th>
<th>Tensile Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P330</td>
<td>60K</td>
<td>3,200</td>
<td>1.81</td>
<td>250</td>
<td>4,900</td>
</tr>
<tr>
<td>P330</td>
<td>60K</td>
<td>3,200</td>
<td>1.81</td>
<td>250</td>
<td>4,900</td>
</tr>
<tr>
<td>WCF</td>
<td>50K</td>
<td>3,750</td>
<td>1.81</td>
<td>240</td>
<td>4,100</td>
</tr>
<tr>
<td>WCF</td>
<td>50K</td>
<td>3,750</td>
<td>1.81</td>
<td>240</td>
<td>4,100</td>
</tr>
</tbody>
</table>

Spool length: 2,500m (WCF and P330)
Sizing: Epoxy based sizing

P330 series

P330 series performs as our standard small tow (i.e. High strength fiber TR50S/TRH50), however the filament count is larger (50-60k). Comparing with standard small tow fibers (less than 24K), P330 series has better process ability for large composites and performs like standard small tow. We believe that this product will push the technical envelop in carbon fiber market. This new plant will not only be the first plant to produce high performance large tow in earnest over the world, but also it will be the largest carbon fiber plant (2,700t/Y) in capacity in history.

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**MITSUBISHI RAYON CO., LTD.**
New products from Mitsubishi Rayon

- Mitsubishi 12K&15K
  - Fishing Rod
  - Bicycle
  - Golf shafts
  - Rackets
- Aerospace
- Pressure Vessel
- Civil Engineering
- Compounding
- New P330 30K&60K
- Oil and Gas
- Automotive
- Wind blade
- New WCF 50K

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MITSUBISHI RAYON CO., LTD.
## Evaluation Data (Prepreg)

<table>
<thead>
<tr>
<th></th>
<th>P 330 60K</th>
<th>TR 50S 15K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>4,906</td>
<td>4,871</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>224</td>
<td>224</td>
</tr>
<tr>
<td>0 Tensile Strength *</td>
<td>3,019</td>
<td>2,681</td>
</tr>
<tr>
<td>0 Tensile Modulus *</td>
<td>147</td>
<td>136</td>
</tr>
<tr>
<td>0 Compression Strength *</td>
<td>1,488</td>
<td>1,315</td>
</tr>
<tr>
<td>0 Compression Modulus *</td>
<td>131</td>
<td>123</td>
</tr>
<tr>
<td>90 Flexural Strength</td>
<td>153</td>
<td>136</td>
</tr>
<tr>
<td>ILSS</td>
<td>93</td>
<td>94</td>
</tr>
</tbody>
</table>

Strand Test: Resin: MRC #350

*Vf 60% basis calculation

**Good process-ability and less fuzz**

WCF 50K data to be available, initial result shows slightly higher compression properties comparing with P330 60K

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[MITSUBISHI RAYON CO., LTD.](#)
Evaluation Data (Filament Winding)

P330 60K has similar properties to the ones of TRH50 18K which has been selected/applied for various projects (mainly pressure vessels from small to large)

P330 60K helps improve productivity at customer's site (e.g. the number of spools can be minimized)

MRC internal evaluation result:
- Consistent resin pick-up
- Good tow spreadability
- Less fuzz
  (comparing with conventional large tow)
Evaluation Data (UD Fabric)

Evaluation at MRC

Weaving pattern: UD fabric
Weaving Machine: Tsudakoma Rapier
Target FAW: 600g/m2
Warp Yarn (CF): 4.5 ends/inch
Fill Yarn (GF): 8 ends/inch
Warp Yarn Tension: 17kg
Fabric Width: 300mm

Result

- No Fuzz
- Good spredability
Evaluation Data (BIAXIAL +/-45° CF FABRIC)

- Non-crimped Biaxial Fabric based on 60K. 2 layers of carbon fibre fabric stitched with polyester. Carbon fibre orientation is +45/-45 degree.
- TRH50 60M exhibits good spread-ability, required for light weight fabric

<table>
<thead>
<tr>
<th>Material</th>
<th>Fiber Type</th>
<th>Fiber Orientation</th>
<th>Nominal Weight (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Fiber</td>
<td>TRH50 60M</td>
<td>+45°</td>
<td>150</td>
</tr>
<tr>
<td>Carbon Fiber</td>
<td>TRH50 60M</td>
<td>-45°</td>
<td>150</td>
</tr>
<tr>
<td>Polyester knitting yarns</td>
<td></td>
<td>-</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>-</td>
<td>304</td>
</tr>
</tbody>
</table>
PREMIUM LARGE TOW CARBON FIBRE FOR INDUSTRIAL APPLICATIONS
LARGE FILAMENT COUNT WITH PROCESSABILITY AND PROPERTIES OF REGULAR TOW

PRODUCT CONCEPT:
• Excellent Processability and High Performance
• Consistent Quality
• High Productivity in Producing Large Components
• Commercial Availability and Affordability

TARGET MARKETS:
• Filament Winding for Pressure Vessels
• Multi-axial Fabric for Automotive Applications
• UD and Multi-Axial Fabrics for Wind Energy Applications
• Large Scale Components Parts where Property to Price Ratio is Critical

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Development of PCM* technology

* Prepreg Compression Molding

Specialty Products

The Mitsubishi Rayon Group optimally leverages its proprietary materials and wide-ranging technological know-how to swiftly and precisely meet market needs.
High cycle CFRP molding process

- PCM has a potential for CFRP mass production.

**PCM (Prepreg Compression Molding)**

Newly developed fast curing prepreg is preformed, and then cured in heated steel tool. Short mold cycle times.

**Advanced RTM**

Dry fabric is charged in heated tool, then resin is injected into the mold. Cycle time can be shortened with fast curing resin system.
# Prepreg for PCM

<table>
<thead>
<tr>
<th>Properties</th>
<th>Developed prepreg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R 02</td>
</tr>
<tr>
<td>Resin type</td>
<td>Bisphenol A type</td>
</tr>
<tr>
<td></td>
<td>Epoxy resin</td>
</tr>
<tr>
<td>Gel time @ 140 C, min.</td>
<td>2.0</td>
</tr>
<tr>
<td>Minimum cure time @140 C, min.</td>
<td>5.0</td>
</tr>
<tr>
<td>CF reinforcement(^1)</td>
<td>Typical grade</td>
</tr>
<tr>
<td>FAW g/m²</td>
<td>250 or 125</td>
</tr>
<tr>
<td>Resin Content, wt%</td>
<td>30</td>
</tr>
<tr>
<td>CF Vf vol%</td>
<td>59</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>1.54</td>
</tr>
<tr>
<td>Other advantage</td>
<td>Good Surface</td>
</tr>
</tbody>
</table>

1) TR50S carbon fiber from Mitsubishi Rayon Co., Ltd. is used for all prepregs
   Tensile strength: 4900 MPa, Modulus: 240 GPa, Elongation: 2.0%

2) Plain, twill and Satin fabric can be used.
Fast curing formulation

- Resin formulation has been optimized for fast curing
  - Optimized combination of resins and curing agents
  - Curing behavior are evaluated by Curelastometer
    - Curelastometer can measure/monitor resin behavior under conditions similar to actual molding.

![Curelastometer test diagram](image)

![Graph showing torque vs time for R 03 and R 02](image)

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**MITSUBISHI RAYON CO., LTD.**
Viscosity control

Resin viscosity at elevated temperature was optimized for compression molding.

- Low viscosity of conventional materials at elevated temperature results in excessive resin flow

![Viscosity at elevated temperature graph]

Problem caused by low resin viscosity
- Bleed out of cavity
- Inconsistent mechanical results
- Fiber distortion
- Poor thickness uniformity
- Poor cosmetics
- Demolding issue
0 degree Flexural strength/modulus

- Strength (MPa)
- Modulus (GPa)

Comparison between Control, R02, and R03:
- Strength: Control > R02 > R03
- Modulus: Control = R02 = R03
Thermal Analysis

- **E’ Tg of R 03 is over 160° C**
  - R 03 can be used for high temperature applications

**DMA**

![DMA Graph]

Prepreg Control R 02 R 03

<table>
<thead>
<tr>
<th>Prepreg</th>
<th>Control</th>
<th>R 02</th>
<th>R 03</th>
</tr>
</thead>
<tbody>
<tr>
<td>G’-Tg (℃)</td>
<td>127</td>
<td>125</td>
<td>165</td>
</tr>
<tr>
<td>tan δ (℃)</td>
<td>148</td>
<td>154</td>
<td>186</td>
</tr>
</tbody>
</table>

Molding Condition: 140 ℃×5min  8MPa
Control prepreg is cured by autoclave
A quarter part of engine hood was developed to demonstrate feasibility of PCM body panels.

- PCM outer and CF-SMC inner panels were bonded to produce a body panel structure consisting of two parts.
- CFRP engine hood is 63% lighter than steel hood.

SUBURU Impreza
Steel hood;  14.5 kg
CFRP hood;  5.3 kg
(Whole hood)
Surface Quality of PCM parts

- R 02 UD Prepreg can achieve Class A surface.
- Wave scan index of parts molded by PCM is similar to that of typical class A SMC parts.

Wave scan index was measured by Wave Scan-T from BYK-Chemie.
PCM Molding Process

- PCM
  - UD and/or Fabric
  - Prepreg

- Hybrid Molding
  - UD and/or Fabric
  - Prepreg
  - + SMC

- SMC

100% mold coverage, preform recommended

Molds complex shape with SMC

Charge → Press → De-mold
Structural model parts development

- Structural floor model parts was developed by PCM
  - Hybrid molding of Prepreg and CF-SMC

**Structural floor model**
Size: 500X500mm

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**Vertical integration for Automotive applications**

PREMIUM LARGE TOW CARBON FIBRE FOR AUTOMOTIVE APPLICATIONS
- High Performance and Consistent Quality (unlike conventional large tow)
- High Productivity in intermediates material production
- Commercial Availability and Affordability

**Fast Cure Prepreg for Compression Molding**
- 3 minutes cure at 140°C
- Controlled viscosity at molding temperature
- Suitable tack at room temperature

**PCM (Prepreg Compression Molding Technology)**
- Suited for high volume automotive parts production
- Wide Range of applications can be produced by PCM technology
  - Class A finish for outer body painted panels
  - Cosmetically enhanced for superior carbon fabric appearance
  - Structural parts by PCM/CF-SMC Hybrid molding

**Multi-Axial Fabric utilizing our large tow carbon fiber optimized for RTM process**
- Light weight Non-crimped Biaxial Fabric
- Good quality in appearance and performance
To a world standard.
Mitsubishi Rayon is one of the world's leading suppliers of carbon fibre. Our driving force is our integrated production system – raw material to finished product – which enables us to respond quickly to changing market needs. Our new range of P330 carbon fibres is an example of this response in action with a fibre that offers high strength and resilience plus volume production. The standards set by Mitsubishi are endorsed by customers throughout the world.

Danke schön.