Toray IR Seminar
Toray Group’s Initiatives Toward Realization of a Hydrogen Society

Initiatives at Torayca & Advanced Composites Division

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Keisuke Ishii
General Manager, Torayca Division
Toray Industries, Inc.
I. Initiatives to Realize a Hydrogen Society

II. Carbon Fiber for High-pressure Hydrogen Gas Tanks

III. Gas Diffusion Layer Base Materials for Fuel Cells
Initiatives to Realize a Hydrogen Society
Initiatives to Realize a Hydrogen Society

Developing a wide range of core materials for production, transport, storage, and utilization of hydrogen

- Carbon Paper (CP)
- Electrolyte Membranes, CCM

- Carbon Fiber for high-pressure gas tanks
- Plastic Liner

• Carbon fiber for high-pressure gas tanks
• Carbon Paper, Gas Diffusion Layer
• Plastic Liner • Electrolyte Membranes, CCM, MEA

Production ➔ Transportation, Storage ➔ Use

Renewable energy from wind, solar etc. ➔ Water Electrolyzer ➔ Hydrogen ➔ Hydrogen Compressor ➔ Hydrogen Gas Station ➔ Hydrogen Transport Trailer ➔ Hydrogen ➔ Fuel cell (FC) vehicles FC for home and Industry

Toray Group products

Carbon fiber

(Example of applications) High-pressure gas tanks

Carbon paper (CP)

Gas Diffusion Layer (GDL) = Carbon paper processed products

CCM: Catalyst Coated Membrane MEA: Membrane Electrode Assembly CP: Carbon Paper GDL: Gas Diffusion Layer

Courtesy of Toyota Motor Corp.
Carbon Fiber for High-pressure Hydrogen Gas Tanks
Carbon Fiber Demand Outlook for Gas Tanks

- Global Carbon fiber demand expanding under megatrends towards carbon neutrality
- Hydrogen tank demand to significantly expand especially or commercial vehicles (trucks, etc.) beyond 2026-2027
- High tensile carbon fibers increasingly required for higher pressure and lighter weight of gas tanks

Example of hydrogen gas tank application

- Passenger vehicle
- Truck
- Bus
- Train
- Trailers for transport
- Hydrogen station

Carbon Fiber Demand Outlook

- Natural gas (CNG) tanks, etc.
- High-pressure hydrogen tanks

Expanding at annual growth rate of 42% (2022-2025)

4-fold High-pressure hydrogen tank demand

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## Toray’s Strengths and Business Expansion Strategies (Carbon Fiber)

### Our Strengths and Value Proposition

- 30 year-experience and database on high-pressure gas tank application
- Stable supply with high performance and quality
- Global production and technical supports base
- Proposal on optimal carbon fibers, resins and tank structure analysis

### Business expansion strategies

- Proceed with production capacity increase corresponding to demand increase (U.S.A., South Korea)
- Enhance competitiveness on quality, performance and cost
- Enhance global production base and technical supports
- Strengthen partnership with major global customers
Brief History on Development and Supply of Carbon Fibers for High-pressure Gas Tanks

- Development of carbon fiber for tanks started in the 1980s
- Industrial scale adoption for natural gas tanks in the 1990s
  → Baseline data base of T700S for the application (de-facto standard)
- Started sales of high-strength fiber T720S, which is dedicated to hydrogen tanks
- Applied to the high-pressure hydrogen tank application from the 2010s
  → Adopted to Toyota Motor Corporation’s “MIRAI”
- Developed T1100S, which is the strongest in our carbon fiber, for space applications
- Sold trusts from customers based on the above history of 30+year history

Global leader through development of new products, proven stable and high-quality production
(40-50% of share)
Characteristics of Toray’s Carbon Fiber for High-pressure Gas tank

Torayca™ Carbon Fiber

- High strength
- Consistent quality and good workability
- Database
- Stable supply

High-pressure Hydrogen Tank

- Lightweight and compact
- Improved safety
- Improved productivity, reduced cost
- Stable mass production

FCV

- Improved fuel efficiency
- Improved cabin comfort
- Improved safety
- Realization of hydrogen society

Torayca™ carbon fiber contributes to improvement of performance and expansion of production of FCV, through realization of mass production for safe and high-performance hydrogen tanks.
Further Strengthening of Competitiveness

- **Further high performance and stable supply** by utilizing up-to-date DX technologies enable to strengthening competitiveness

**Example 1: AI technology for carbon fiber development**

- Non-programming AI tool

<table>
<thead>
<tr>
<th>Process parameter 1</th>
<th>Process parameter 2</th>
<th>Process parameter 3</th>
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<tbody>
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</table>

  Process conditions determination and prediction of carbon fiber properties → Cut development time by half

**Example 2: Atomic level defect control**

- Introduction of atomic resolution electron microscope

  Analysis by Toray Research Center

  Observation on individual carbon atoms by electron microscopic
  (The first success in the world) → Atomic-scale microstructure control

Collective strengths of Toray Group’s R&D

- Improved performance
- Enhancing product quality competitiveness
Global production and technical supports

- **Consistent quality from the four production sites** in Japan, the U.S., Europe, and South Korea.
- **Global technical supports** to immediately respond to customers’ request
- **Further enhancement of SCM** corresponding to location of customers

- Toray Carbon Fibers Europe
- Toray Advanced Materials Korea
- Toray (Ehime Plant)
- Toray Composite Materials America

- : Production base for T700S, carbon fiber for tanks
- : Technical Supports Base
Expansion to meet rapidly increasing demand

- Expansion of production capacity for regular tow carbon fiber
  Establishment of a stable supply in the U.S.A. and South Korea, where demand for tank applications is growing.

**Increase production capacity 6,500 tons/year. Production scheduled to begin in 2025**

⇒ Surely meeting customers’ requests and continuous supply of products with superior performance will contribute to strengthening the business foundation over the medium- to long-term
Strengthening partnership with global major customers

- Toray Group’s development and production technology support for pressure vessels, from materials, design to production technology and facility

   - Material selection and designing pressure vessels
   - Prototyping and evaluation
   - Production technology and facility

   From supplier to a risk sharing partner
Gas Diffusion Layer Base Materials for Fuel Cells
Demand Outlook for CP/GDL Base Materials

- Demand for CP/GDL will increase for water electrolyzer (PEM-based) application and fuel cells that are promising in hydrogen society.
- Full-scale expansion is expected to be in 2026-2030 timeframe. Demand in 2030 is forecasted to grow by 3.5 times compared to 2025.

### Application of fuel cell
- Passenger vehicle
- Truck
- Bus
- Aircraft
- Electric power source for industrial/domestic use

### Demand Outlook for CP/GDL

<table>
<thead>
<tr>
<th>Year</th>
<th>Demand (t/year)</th>
<th>Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2022</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>2023</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>2025</td>
<td>400</td>
<td>35%</td>
</tr>
<tr>
<td>2030</td>
<td>1,200</td>
<td>3.5-fold</td>
</tr>
</tbody>
</table>

Increase at annual rate of 35% (2022-2025)

Passenger vehicle

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**Our Strengths and Value Proposition**

- World's largest CP/GDL production capacity (Japan and South Korea)
- Over 40 years production experience and a significant database
- Ability to propose material designs meeting customer needs
- Competitiveness from utilization of human resources and know-how deriving of its upper stream (carbon fiber)

**Business Expansion Strategies**

- **Proactive capital investment** responding to growing demand
  - Development and proposal of materials to meet customer requests
  - Increase production capacity along the global demand
  - Enhancement of global system for technical support

- Strengthen cost competitiveness by **innovative process development**
- Enhance **partnership with global major customers**
## Brief history of Carbon Paper and GDL Development

- **In 1982, Toray started development of carbon paper**
- **Over 40 years production experience, accumulated rich know-how**
- **Capability of design proposal to meet customer needs, and competitiveness by integrated production from carbon fiber**

### Development of CP / GDL at Toray

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td></td>
<td>Carbon paper sheet</td>
</tr>
<tr>
<td>1990</td>
<td>Started R&amp;D for electrode base material of phosphoric acid fuel cell in NEDO’s Moonlight Project</td>
</tr>
<tr>
<td>2005</td>
<td>Roll</td>
</tr>
<tr>
<td>2010</td>
<td>▼ Started sales of GDL (2008)</td>
</tr>
<tr>
<td>2015</td>
<td>▼ Mass production system of CP/GDL was introduced at Ehime Plant (2020)</td>
</tr>
<tr>
<td>2020</td>
<td>GDL=Gas Diffusion Layer (Carbon paper processed products)</td>
</tr>
<tr>
<td>2025</td>
<td>▼ Started R&amp;D for electrode base material of phosphoric acid fuel cell in NEDO’s Moonlight Project</td>
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### Examples of application

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Courtesy of Toyota Motor Corp.</td>
</tr>
<tr>
<td>2000</td>
<td>▼ Started supply of CP for Honda’s “CLARITY Fuel Cell” (2016)</td>
</tr>
<tr>
<td>2010</td>
<td>▼ Started supply of CP for Toyota’s “MIRAI” (2014)</td>
</tr>
<tr>
<td>2015</td>
<td>▼ Started supply of CP for Toyota’s “MIRAI” (2019)</td>
</tr>
<tr>
<td>2020</td>
<td>▼ Started supply of GDL for automobile manufacturers in Europe, the U.S. and China</td>
</tr>
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Photos are excerpted from websites of Toyota Motor Corp. and Honda Motor Company.
Characteristics of GDL for fuel cells

- Carbon paper and Gas Diffusion Layer (GDL) contribute to improving performance of FCV by realizing high performance FC

  - High conductivity
  - High gas permeability, high drainage
  - High strength
  - Impurities-less, high surface quality

  - Excellent current and voltage characteristic
  - High durability
  - Simplifying systems
  - Improvement safety
  - High output, improvement of fuel efficiency
  - Long-life, low cost

(Note) The supply chain described above is image, and it does not necessarily represent an actual supply chain.
Further Strengthening of Competitiveness

- Strengthening competitiveness by leveraging DX (material informatics and AI) to improve quality of products

Example 1: Utilized proprietary material informatics (MI) tools for complicated parameters

- Reduced the number of evaluations required to find an optimal material combination by 1/10 or less

Example 2: Automated appearance inspections from the human eye. AI is used for image processing.

- Zero overlooked defects
- Appearance inspections

Example 3: Cooperation with Greenerity

- Feedback to base materials development for fuel cells from MEA characteristics
Global Production and Technical Supports

- Established sales and technical support base in Japan, China, South Korea, Europe and the U.S., corresponding with global demand increase
- In addition to two major production bases in Japan and South Korea, considering to expand production sites in the U.S. and Europe
- Contributing to increasing value by meticulous service to advanced customer specifications

- TIUK: Toray International U.K. Ltd.
- EACC: Euro Advanced Carbon Fiber Composites GmbH
- TICH: Toray International (China) Co., Ltd.
- TAK: Toray Advanced Materials Korea Inc.
- TARC: Toray Advanced Materials Research Laboratories (China) Co., Ltd.
- TIAM: Toray International America Inc.
Road to Carbon Neutrality

Policy of Carbon Fiber Composite Materials Business

As a leading carbon fiber company, we will promote progressive approach and proactive communication

By 2030
- **Over 30% reduction** in CO₂ emissions
- Start rCF production in Europe and US

By 2040
- **Over 50% reduction** in CO₂ emissions
- Achieve Carbon Neutrality in Europe

By 2050
- **Achieve Carbon Neutrality**
- Introduction of CCUS

Environmental Improvement Model of Carbon Fiber

Strategy for Carbon Neutrality (AP-G 2025)

1. Quantify LCA improvement effect at customer’s products
2. LCI reduction of our products (carbon fiber, prepreg, etc.)
3. Promote Material Eco-SYSTEM (use of recycled / bio-based raw materials)
In order to capture business opportunities towards the carbon-neutral society, we provide the best products and realize business expansion through social contribution by leveraging our core strengths of carbon fiber composite materials, “high functionality” and “reliability (usability)”
Descriptions of predicted business results, projections and business plans contained in this material are based on assumptions and forecasts regarding the future business environment, made at the time of publication.

Information provided in this material does not constitute any guarantee concerning the Toray Group’s future performance.