Toray’s Advanced Materials
- Innovation by Chemistry -

Toray Industries, Inc.
Executive Vice President and Representative Director
Hiroaki Kobayashi
I. Technology Innovation Supported by Materials Innovation
### Society in 21st Century & Industrial Circumstance

#### Newly Created Industrial Fields
- **Information Tele-communication**
  - Ubiquitous Network
  - High Speed Communication
  - Next Generation Displays Etc.
- **Healthcare**
  - Global Warming CO₂ Emission
  - Pollution
  - Oil Supply Etc.
- **Environment**
  - Taylor-made Medicine
  - Regenerative Medicine
  - Nursing Care System Etc.
- **Energy**
  - Solar Cell
  - Wind Power
  - Fuel Cell Etc.
- **Safety & Security**
  - Personal Identification
  - Air/Water Purification
  - Safer Construction Materials Etc.

#### Globalization
- Global Competition, Rising Korean & Chinese Companies, Entering Chinese Market

#### CSR
- Corporate Governance, Compliance, Risk management, Safety/Disaster Prevention/Environment

#### IP
- IP Management, Employee Inventions, Technology Transfer, International Harmonization

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**Nanotechnology provides solutions for 21st century**
Innovation by Pursuing Limits

Innovation

Pursuing of Technology Limits
- Higher Strength
- Higher Heat Resistant
- Finer Structure
- Higher Sensitivity

The deeper, the newer

New Technology & New Product

Increasing Social Value
Increasing Economic Value

Feedback

Social imperative
- Environmental issue
- Food Scarcity
- Energy Depletion
- Health & Healthcare

Science & Technology, Value Creation
- Innovative
- Universal
- Versatility
- Create New Field
II. Toray’s R & D Activity
Core Technology of Toray

Polymer Science  Organic Synthetic Chemistry
Nanotechnology  Biotechnology

Technology Innovation

New Material
Nano-material
Biotechnology
Process

Main Strategic Area

Information & Telecommunication
Automobile /Aircraft
Life Science
Environment /Water/Energy

Innovation by Chemistry

Pursuit of Limits
finer, thinner, stronger, more ... "The Deeper, the Newer"

Toray’s Challenge for Technology Innovation

"The Deeper, the Newer"
Example of Toray’s Advanced Materials

Main Strategic Region

Technology Innovation

IT-related Materials
Automobile • Aircraft
Life Science
Environment • Water • Energy

New Materials

Optical Circuit Board Materials
Carbon Fiber Composite Materials
Innovative Synthetic Pharmaceuticals
Organic Semiconductor

Nano Material

New Optical Film
New transparent heat-resistance resin

Nano–multilayer Films
Nano-composite
Nanofibers
PLA Polymers

Biotechnology

Nano–multilayer Films
Nano-composite
Nanofibers
PLA Polymers

Nano Process

Nano–multilayer Films
Nano-composite
Nanofibers
PLA Polymers

Nano Color Filters
PDP-related Materials
Next Generation Molding
Human-friendly Material
Next Generation Recycling

Bio-pharmaceuticals
Bio-tools
Green Chemistry

Human-friendly Material
MBR
- Example of Toray’s Advanced Materials -

Main Strategic Region

Technology Innovation

IT-related Materials

Automobile • Aircraft

Life Science

Environment • Water • Energy

New Materials

Optical Circuit Board Materials

Carbon Fiber Composite Materials

Innovative Synthetic Pharmaceuticals

Organic Semiconductor

Nano Material

New Optical Film

New transparent & heat-resistance resin

Bio-mass Fibers

Nano–multilayer Films

Nano-composite

Nanofibers

PLA Polymers

Nano Process

CNT

Nanoalloy

Bio-pharmaceuticals

Green Chemistry

Bio-tools

Next Generation Recycling

LCD Color Filters

PDP-related Materials

Next Generation Molding

Human-friendly Material

MBR
**Pursuit of Ultimate Strength and Modulus**

**New Materials Innovation**
- Carbon Fiber
- Composite Materials

**Industrial process and technology for pursuit of ultimate performance**

1. PAN polymerization and spinning
2. Oxidization (200~300°C)
3. Carbonization (Graphitization) (1000~3000°C)
4. Sizing
5. Carbon Fiber

**Merit of Carbon Fiber**
- Lightweight
- Specific gravity = 1.8
- 2/3 of Al
- Rust resistance
- Chemical resistance
- High conductivity
- Dimensional stability etc

**Polymer design**
- Control of fiber structure

**Control of defect**
- Orientation by draw

**Control of graphite crystalline**
- (size, orientation)

**Graph:**
- Carbon Fiber
- Glass Fiber
- Aramid Fiber
- Steel Wire
- Nylon Fiber

**Graphene Oxidization to Carbonization (Graphitization):**
- From 200 to 300°C
- From 1000 to 3000°C

**Diameter:**
- 7 um

**Modulus (GPa):**
- Carbon Fiber

**Strength (GPa):**
- Glass Fiber
- Aramid Fiber
- Steel Wire
- Nylon Fiber

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New Materials Innovation
Carbon Fiber
Composite Materials

Pursuit of Ultimate Strength
/ Control of Surface Defect

Image of fiber surface at nano-size (STM)

Size of defect
Nano
Sub-micron
Micron

Strength (GPa)
0 2 4 6 8 10


nm

0 500 1000 1500 2000

TORAY
Replacement of 50% of structure with CFRP yields 20% reduction of whole structural weight versus aluminum alloy.
Expansion of Aircraft Application

**B777**
- Tail Fin
- Floor Beams
- Engine Covering

**B787**
- Wings
- Fuselage
- Wing Mount

“**All-composite-materials Aircraft**”
- Tail Fin
- Horizontal Stabilizer
- Fuselage
- Fuselage Fairing

Components using composite materials

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<td>Mode</td>
<td>B767</td>
<td>B777</td>
<td>B787</td>
</tr>
<tr>
<td>Section using CFRP</td>
<td>Secondary structures</td>
<td>Primary structures (tail assembly etc.)</td>
<td>Primary structures (main wings, tail assembly, etc.)</td>
</tr>
<tr>
<td>Using CF type</td>
<td>T300H</td>
<td>T800H</td>
<td>T800S</td>
</tr>
<tr>
<td>CFRP utilization (wt%)</td>
<td>3</td>
<td>12</td>
<td>50</td>
</tr>
<tr>
<td>CFRP utilization/plane (ton)</td>
<td>1.5</td>
<td>9.6</td>
<td>35</td>
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**New Materials Innovation**
- Carbon Fiber
- Composite Materials

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[TORAY]
Expansion of Automobile Applications

New Target: From exterior panels to main strutures

First full-scale test of CFRP passenger car
Front side member made of CFRP

- Hood (-12kg)
- Roof (-10kg)
- Impact beam (-3kg)
- Trunk lid (-5kg)
- Rear spoiler (-4kg)
- Defuser (-10kg)
- Propeller shaft (-5kg)
- Platform (-144kg)

Total weight: 2060kg
Test speed: 47km/h

Approx. 200 kg weight reduction

CFRP Application Sections and Weight Reduction

Comparisons with conventional materials such as steel

“Innovation Global Warming Countermeasure Technology Program” (METI: 2003 to 2007)
Example of Toray’s Advanced Materials

- **Main Strategic Region**
  - Technology Innovation
  - New Materials
    - Optical Circuit Board Materials
    - Carbon Fiber Composite Materials
    - Innovative Synthetic Pharmaceuticals
    - Organic Semiconductor
  - Nano Material
    - Nano-multilayer Films
    - Nano-composite
    - Nanofibers
    - PLA Polymers
  - Bio
    - Bio-pharmaceuticals
    - Bio-tools
    - Green Chemistry
  - Process
    - LCD Color Filters
    - Next Generation Molding
    - Human-friendly Material
    - Next Generation Recycling
    - MBR
Pursuit of Ultimate Thin Fibers

Nano Material Innovation Nanofibers

10,000nm (10 μm) 1,000nm (1 μm) 100nm 10nm

Hair (∼50 μm) 6 μm

Conventional Fibers (Polyester, Nylon et.al.)

Microfibers (Polyester, Nylon et.al.)

Man-made Suede

Nano Material Innovation Nanofibers

Pursuit of Ultimate Thin Fibers

Hair (∼50 μm) 6 μm

Conventional Fibers (Polyester, Nylon et.al.)

Microfibers (Polyester, Nylon et.al.)

Man-made Suede

Nano Material Innovation Nanofibers
Innovation of Synthesis of Microfibers

Polymer-mosaic fibers (Islands in sea fibers) → Removing sea component → Microfibers

- Each island
- Sea

Applications:
- Garments
- Car interiors
- Furniture
- Industrial Materials

Man-made Suede (launched at 1970)

Nano Material Innovation Nanofibers
Pursuit of Ultimate Thin Fibers

Conventional Fibers (Polyester, Nylon et.al.)
- Diameter: 6 μm

Microfibers (Polyester, Nylon et.al.)
- Diameter: 100nm

Nanofibers (Nylon, Polyester et.al.)
- Diameter: 10nm

Hair (~50 μm)

Man-made Suede

Bundles (Aggregation)

Fiber Dispersion

Nano Material Innovation Nanofibers
**Nano Material Innovation**

**Nanofibers**

**Pursuit of Ultimate Thin Fibers**

- Surface area (m² g⁻¹)
- Diameter (nm)

![Graph showing the comparison of surface area and diameter for Nanofibers, Microfibers, and Conventional fibers.]

- **Amount of fibers to reach the moon**
  - Microfibers: 450g
  - Nanofibers: 0.15g

**Features**

- fineness
- adsorption
- absorption
- slow release

**Applications**

- textile
- abrasive cloth
- filter
- medical device
- cosmetics

- commodity polymers
  - Nylon
  - Polyester
  - Polyolefin et. al.

- using existing plants

- Launched in 2006

**Side view of N6 nanofibers**

![Image of nanofibers with a 100nm scale bar.]

**Launched in 2006**

**TORAY**
Nano Material Innovation
“NanoMATRIX”

(Policy) Pursue and develop “Seeing and finding nano-processing technology”
“Wearing and understanding innovative function” in Toray’s textile
‘nano-scale technology for processing textile’.

“NanoMATRIX”
Continuous Coating on the single fiber surface by functional material

Expected advantages
➢ Level up function
➢ Improve durability of function
➢ Keep soft handle

Bring a new products to market

- “BEAULAVAGE” (2004)
  - Easy to wash out of rouge and etc. even if they stick
- “ANTI POLLEN” NT (2005)
  - Easy not to stick pollens and easy to shake off

Coating on the single fiber surface by functional material. Thickness: 10~30nm

SEM Photograph of Coated functional material on the single fiber

TEM photo of Coated single fiber cross-section

200nm
Nano-multilayer Films

Nano Effect

Single Layer Thickness (nm)

Thermal Shrinkage (%)

Tear Resistance (N/mm)

Better

5nm

Copolymerization

PET

Expanding Applications

- Glass Protective Films (for safety & security)
- Electronic Materials
- Optical Functional Tapes

Nano Material Innovation
Nano-multilayer Films

1000nm (=1 μm)

3 layers

100nm

10nm

~2000 layers

1nm

Nano Effect

Better

1

200 400 600

Expanding Applications
Nano-vestigial Films

Falling Ball Penetration Test

Failed

Penetrated

PET Film

Succeeded

Newly Developed Film

(Height 3m, Weight 2.2kg)

Expanding Applications

- Glass Protective Films (for safety & security)
- Electronic Materials
- Optical Functional Tapes

★ Launched in 2004
# Separation Membrane for Water Treatment

## - Types and Surface Morphologies -

<table>
<thead>
<tr>
<th>Size</th>
<th>1 nm</th>
<th>10 nm</th>
<th>100 nm</th>
<th>1000 nm</th>
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<tbody>
<tr>
<td>Ions, Small molecules</td>
<td>Polymers</td>
<td>Colloids</td>
<td></td>
<td></td>
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<tr>
<td>Monovalent ions</td>
<td>Organic matter</td>
<td>Viruses</td>
<td></td>
<td></td>
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<tr>
<td>Trihalomethanes</td>
<td>Multivalent ions</td>
<td>Coliform</td>
<td></td>
<td></td>
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<td>Seawater Desalination</td>
<td>Drinking Water Production (Removal of hardly decomposed substances)</td>
<td>Wastewater Reclamation &amp; Reuse</td>
<td></td>
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**Membrane Types and Surface Morphologies**

- **RO (Reverse Osmosis)**
- **NF (Nanofiltration)**
- **UF (Ultrafiltration)**
- **MF (Microfiltration)**

*Fine pores of RO Membrane (0.6~0.8nm)*

**Pursuit of limitation by deepening & fusion of membrane and microorganism technology**
High Boron Rejection RO Membrane
(Separation Membrane for Seawater Desalination)

New technology points

Densification of membrane structure by using precise molecule design & nanofabrication technology

Concept

Performance of Membrane

[Positron Annihilation Spectroscopy]
/ Nanostructure analysis technology by TRC

Proof of correlation between pore size & boron removal (The world’s first quantification)

Support layer

Substrate

Boron (Diameter : 0.4nm)

Pore

Increase of boron removal rate

Seawater RO desalination plant
High Boron Rejection RO Membrane
(Separation Membrane for Seawater Desalination)

Nano Material Innovation Membrane

New technology points

Densification of membrane structure by using precise molecule design & nanofabrication technology

Concept → Performance of Membrane

Nano-pore Hollow Fiber Membrane for Artificial Kidney

Artificial Kidney

Nano-pore
(Radius : ~5nm)

Membrane surface

Specific removal of uremic substance from blood (first β 2-microglobulin removal in the world)

Polymer Electrolyte Membrane for Fuel Cells
(Direct Methanol Type)

Fuel Cells (Cell)

Anode

Electrolyte Membrane
(Non-Fluorine)

Cathode

Non-freezing water
(Proton Conduction)

Methanol

Polymer

High ionic conductivity and low methanol cross over (1/10 of conventional membrane) (world top level)

Seawater RO desalination plant
Polymer Alloy/Nanoalloy

Polymer A + Polymer B

Conventional Alloy

Transmission Electron Microscope photo (cross section of polymer)

Phase-inversed Alloy

Low water absorption PA

High impact PA
High impact PBT
High impact PPS

Nano-dispersed Alloy

High thermal resistant PLA
High thermal resistant PET
Flexible PLA

Nano-co-continuous Alloy

High chemical resistant PET
Innovative PBT/PC

Polymer Design
Compatibilizer Design

Nano-dispersing Technology
Nano-co-continuous Alloy

Toray succeeded in developing a world’s first nano-alloy technology which makes it possible to combine only the best properties of two different polymers.

We plan to place the material on the market within one year, especially for automobile parts, electric and electronic parts, and transparent sheet and so on.
Toray is developing non-petrochemical raw materials making full use of Toray’s technologies.
Example of Application of PLA Polymer

Improved heat-resistance with original nanoalloy technology

Non-halogenated flame-retardant technology

Enhanced performances of PLA for electronics use with Toray’s original nanoalloy technologies.

Toray has contributed to global environment thorough reduction of CO2 emission and fossil resources consumption.
# Example of Toray’s Advanced Materials -

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Interferon

Establishment of large scale production technology (Beads culture)

The world first interferon product
Launched in 1985 (Toray, Daiichi)

Indication: Hepatitis B & C Melanoma/Brain tumors

Natural Human Interferon-β : Feron

Fibroblast cells on the beads

New Drug Research

We discovered the optimum binding site of PEG on IFN (●)

Innovated the active PEGylated IFN-β (World’s first)

• Improved and durable therapeutic effects
• Many indications (Start clinical trial in 2008)

Structure elucidation of mouse interferon-β
(Tokyo Univ. & Toray)

~140 nm

4 nm

Interferon

Polyethylene Glycol (PEG)
**DNA Chip**

**Feature of TORAY DNA chip**
- Flat substrate (conventional)
- Columnar structure (newly developed)

**Performance of Toray’s DNA chip**

- **Sensitivity:** 100-fold higher than conventional chip

**Appearance**
- High performance DNA chip
  - “3D-Gene”

**Columnar structure**
- Increased probe DNA
- Accelerated reaction

**High sensitivity**

**Signal/Noise**

- Toray’s DNA chip
- Conventional chip

**RNA amount (μg)**
- 0.01
- 0.1
- 1

**Scanned image**
- Magnified Probe DNA

※This project is partially supported by NEDO.
Lab-on-a-Chip

Rapid testing with Lab-on-a-Chip (within 15 mins)

Blood Sampling → Drop on the chip → Measuring System → Complete !!

Structure of Lab-on-a-Chip

Sample Port → Micro-Valves → Channels → Waste Port → Reaction Chamber

Micro-Channels → Micro-Beads

20 μm

4 Key-Technologies

1. Surface Modification
   ※ Adsorption of proteins to the plastic surface were reduced to 30-fold less than non-modified surface

2. Micro Fabrication

3. Biological Measurement

4. Micro Engineering

(Collaborators) Osaka Univ. Prof. Kawai, Nagoya Univ. Prof. Baba

★ We have developed the diagnostic use Lab-on-a-Chip made of plastics. (Only-one in the world)
R&D Strategy of Bio-tools

Academia

Kyoto Univ. (cancer) et. al.

Conventional diagnostic Tests

Clinical Info.

Specimens (cells and tissues)

Blood

Genetic Info. (DNA Chip)

Proteome Info. (Lab-on-a-chip)

Creation of Integrated Database

Focused Disease related Genes/Proteins

Diagnostic Markers

Development of Exam/Diagnostic Tools
* High-performance DNA Chips
* High-performance Protein Analysis

Evidence by inspection

Drug Target Molecule

Development of New Drugs

Toray

Development of Bio-tools
### Toray’s Advanced Materials

#### Main Strategic Region

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- MBR
Pursuit of Particle Dispersion Technology

Nano-level Particle Dispersion

Particle Size

- 10 μm
- 1 μm
- 100nm
- 10nm
- 1nm

Micro size particles

Aggregating nano size particles

Opaque

Aggregate

Visible light wavelength

Nano size Particles

Light

Transparent

Control of refractive index, Improvement of Optical property, Fulfill New function

★ Expected Effect of Deepening of Nano Dispersion Technology :
Pigment of LCD Color Filter (CF)

Structure of LCD

R G B

CF TFT

Back Light

Liquid Crystal

Clear, Bright Display

Suppression of Light Scattering by CF (Measure: Contrast Ratio)

Key Point: Nano-dispersion of Pigment Particle

Stabilization of Nano-Dispersion for Nano-Pigment

Toray’s Technology

Conventional Technology

★ 1.8 times higher Contrast Ratio → Already Applied to Mass Production

Contrast Ratio: 1.8
**PDP Rear Panel Paste Materials**

**Structure of PDP**
- Glass substrate
- Electrode
- Dielectric layer
- Phosphor
- Barrier rib

**TORAY’s technology for forming barrier rib by applying photosensitive glass paste**
- Mask
- Exposure
- Development
- Firing

1. Short process & High productivity
2. Flexibility of pattern shape
3. High accuracy forming

**Rear Panel Paste Materials**
- Photosensitive barrier rib paste
- Photosensitive electrode (silver) paste
- Dielectric paste
- Phosphor paste (Red, Green, Blue)

**Full high definition (barrier rib pitch)**
- 270 μm (HD)
- <150 μm (Full HD)

**Supply to the world largest factory of the MPDP (250,000 sets/month)**
Toray’s Challenge for Technology Innovation

Pursuit of Limits

Innovation by Chemistry

Toray’s Core Technology

Technology Innovation

New Material

Nano-material

Biotechnology

Process

Main Strategic Area

Information & Telecommunication

Automobile /Aircraft

Life Science

Environment /Water/Energy

Aiming at the Most Excellent Company for Advanced Materials by Challenging Technology Innovation
Advanced Materials for Pioneering 21st Century

Innovative Solutions and Products Only Come with Innovative Materials