Recyclable Carbon Fiber Composite for Circular Manufacturing

TTRI
Taiwan Textile Research Institute

PRESENTATION

Taiwan Textile Research Institute

Shuh-heng Chen

Recycle
Reduce waste and reuse resources

Sustainable
Lower carbon for a better future

Carbon fiber
High performance and lightweight

Composite
Stronger together for endless possibilities

INNOVATE | COLLABORATE | SUSTAIN | CREATE VALUE

1. DRIVING SUSTAINABILITY OF COMPOSITE MATERIALS — LEADING BRANDS TOWARD LASTING IMPACT

LVMH
(RIMOWA's Parent Company)

REPRESENTATIVE PRODUCTS




CARBON NEGATIVE AND CLIMATE ACTION

- By 2025, 80% of suppliers will be committed to zero carbon emissions growth.
- By 2030, reduce carbon emissions from the supply chain by 30%.
- By 2025, all sites globally will use 100% renewable energy.
- By 2030, reduce absolute carbon emissions from own operations and value chain by >30%.
- Achieve carbon neutral by 2050.

2030 Targets

55% revenue from products (vs. FY2020)

60% reduction in Scope 1 & 2 GHG emissions (vs. FY2020)

MATERIAL CIRCULARITY

- By 2025, 60%–95% of suppliers will use 100% recycled materials.
- Ensure at least 80% of waste is diverted from landfill.
- Recovered ≥80% of waste from our own operations and Nike products.
- 2024: 100% use of recycled polyester.
- By 2025, 90% of products will be made with sustainable materials.

2030 Goals

- 50%+ of our products will be made with recycled or renewable materials.
- 100% of packaging will be made from recycled or renewable materials.

NIKE REGENERATED: A CONTINUOUS JOURNEY

Source: NIKE Impact Report 2021

INNOVATION DESIGN

We design with a circular mindset to maximize sustainability across our value chain.

Source: Dell Our Social Impact Plan for 2030 & Beyond

Circular Economy
ISO59000

Building a Sustainable Circular Future

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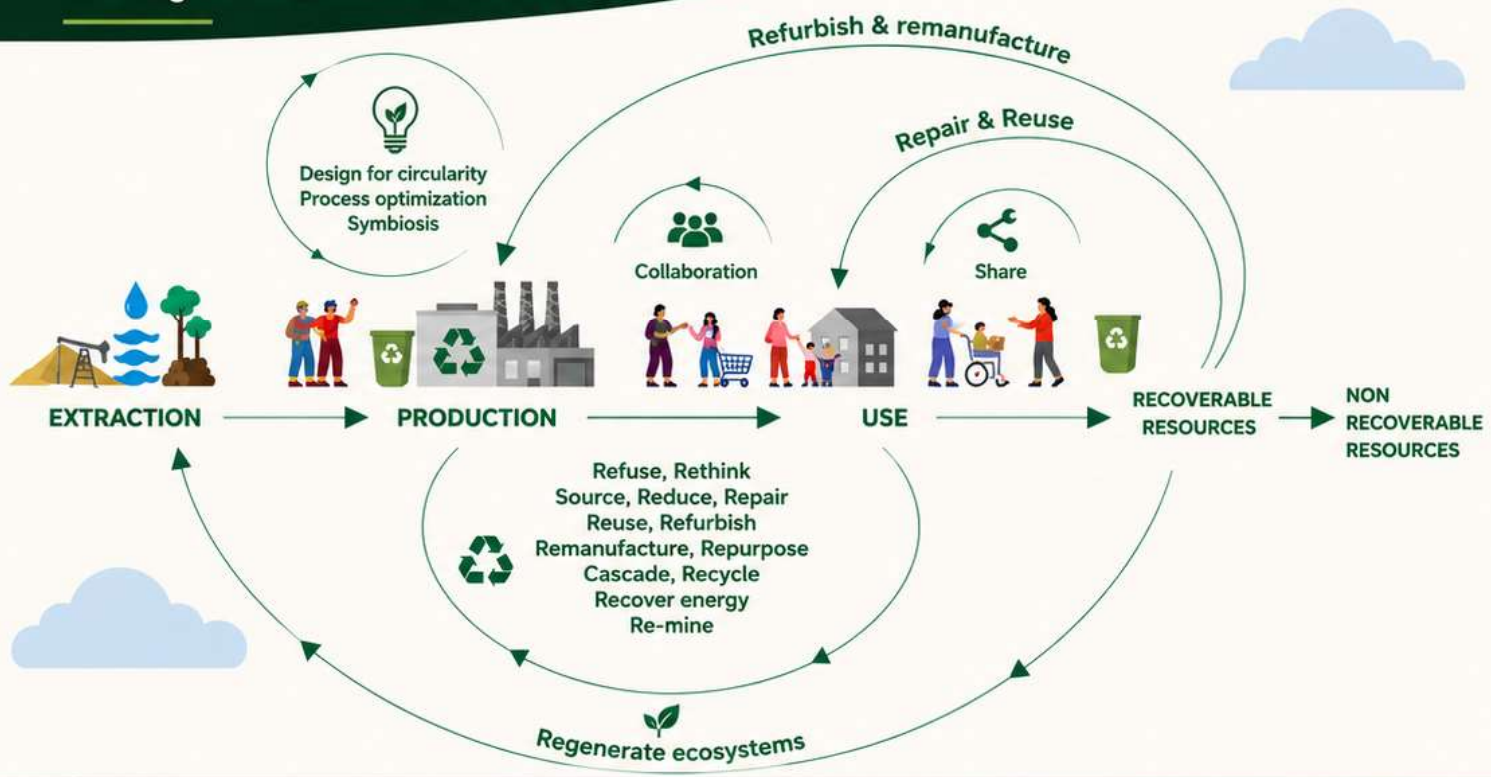

ISO 59004
Circular Economy – Terminology, Principles and Guidance for implementation

ISO 59010
Guidance on business models and value networks

ISO 59020
Measuring and assessing circularity

ISO 59040
Product Circularity Data Sheet

ISO 59014
Secondary materials – Principles, sustainability and traceability requirements

ISO TR 59031 / ISO TR 59032
Technical Reports supporting the implementation of circular economy

- Drive circular design and innovation
- Promote collaboration and value sharing
- Maximize resource efficiency and minimize waste
- Build a sustainable future for generations

Zero-Waste rFC/rPC
FRTP Circular Pathway

Turning Waste into Value, Closing the Loop in 5 Seconds

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Zero Waste
Maximize resource use and minimize waste

Circular & Sustainable
Closed-loop system for a circular future

High Performance
Maintain material properties through multiple cycles

5-Second Cycle
Rapid remolding enables high efficiency and scalability

Value Creation
Turn waste into high-value products and solutions

rCF & rPC sourcing

Air-laid NW (nonwoven) for light weight · Ultra-thin · high flexural modulus composite plate

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CARBON FIBER (rCF) PROCESS

1 Selvage

2 Separate

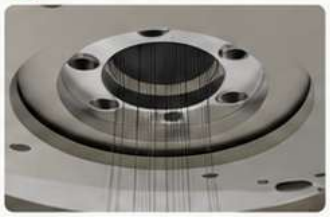
3 Water washing

POLYMER (rPC) PROCESS

Post-consumer PC sources

1 rPC

2 Spinning



rCF/rPC NW

Resource Recovery from Waste

Lightweight Nonwoven

Ultra-thin & High Performance

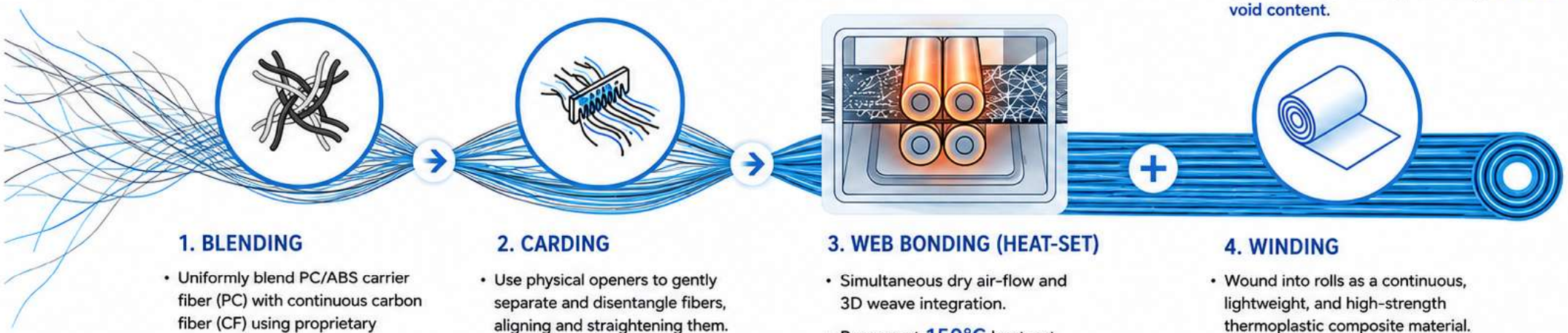
Sustainable Solution

Turning Waste into Value
for a Circular Future

BREAKING THROUGH TRADITIONAL LIMITS – FROM “RESIN IMPREGNATION” TO “STRUCTURAL INTEGRATION”

A revolutionary leap in thermal plastic composite materials toward lasting performance.

- Integrates dry air-flow and three-dimensional weave technology.
- Processes at **150°C** heat-set temperature with rapid heating and initial setting.
- Forms the structure through fiber entanglement (load-bearing network), achieving **ultra-low void content.**



1. BLENDING

- Uniformly blend PC/ABS carrier fiber (PC) with continuous carbon fiber (CF) using proprietary proportions.
- Utilize tailored fiber lengths (e.g., 50 mm) to achieve optimal system performance.

2. CARDING

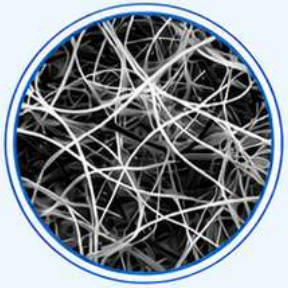
- Use physical openers to gently separate and disentangle fibers, aligning and straightening them.
- Improve fiber dispersion and lay the foundation for a uniform structure.

3. WEB BONDING (HEAT-SET)

- Simultaneous dry air-flow and 3D weave integration.
- Process at **150°C** heat-set temperature with rapid heating and initial setting.
- Builds a load-bearing network with **ultra-low void content.**

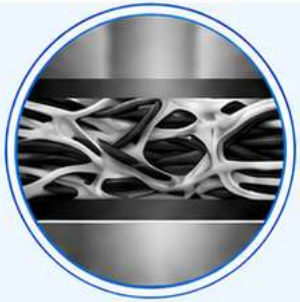
4. WINDING

- Wound into rolls as a continuous, lightweight, and high-strength thermoplastic composite material.
- Standard roll width up to 300 m, suitable for continuous downstream composite molding.



FIBER-LEVEL DISPERSION & ENTANGLEMENT

Black carbon fibers and white PC carrier cotton are uniformly dispersed and entangled, forming a three-dimensional network structure.



DENSE AIR-VOID-FREE STRUCTURE

PC fibers undergo in-situ fusion and integrate with carbon fibers under pressure to form a continuous reinforcement structure, effectively eliminating voids and enhancing interfacial strength.

1 THERMOSET COMPOSITE MANUFACTURING PROCESS

1 Raw Materials
Carbon fiber fabrics (woven / nonwoven) + Thermoset resin

2 Preform Process
Impregnate fabrics with resin

Form prepreg or preform

3 Lay-up
Stack prepreg or preform

Manual or automated layer arrangement

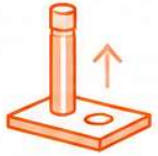
4 Vacuum Bagging
Vacuum seal to remove air

Remove air and consolidate layers

5 Curing
Heat and pressure cure in autoclave

Crosslinking and solidification

6 Demolding
Remove part after curing



Remove from mold and trim

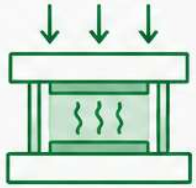
2 THERMOPLASTIC COMPOSITE MANUFACTURING PROCESS

1 Raw Materials
Carbon fiber fabrics (woven / nonwoven) + Thermoplastic resin

2 Lay-up (Manual)

Manual stacking of fabrics (dry or pre-impregnated with thermoplastic resin)

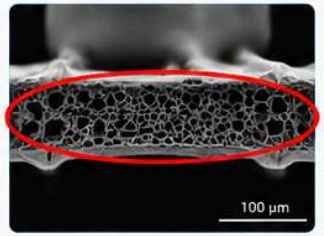
3 Compression Molding



Melt and press into shape

4 Cooling & Demolding

Cool to solidify and remove part



Thermoplastic material resin impregnation is insufficient

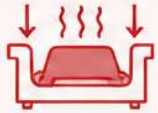
3 ZERO-WASTE CARBON FIBER BLENDED WITH SPUN FIBER LIGHTWEIGHT COMPOSITE MATERIAL

1 Fabric Formation
Use spun fiber blending technology to form fabric

2 Cutting

Cut fabric and prepare stacks prepare layup

3 Thermoforming
Heat and press to melt and consolidate the spun fiber fabric



4 Cooling & Demolding

Cool to solidify and remove part

- Zero waste
- Lightweight
- High performance
- Sustainable solution

Applications

High-Performance & Sustainable Solutions for Future Products

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KEY TECH

- PC spinning and PC/rCF NW structure for FRTP composite
- CF ≧ 100mm ‧ FAW = 100~600 gsm ‧ Fiber content = 40~60%
- F.M. ≧ 30 GPa ‧ F.S. = 300 MPa (ASTM D790)
- 70% energy saving

CF SHOE PLATE

Lightweight | High Flexural Modulus | Energy Saving

CASE FOR LAPTOP

High Strength & Rigidity | Lightweight Design | Recyclable & Sustainable

From Waste To Value → Zero-Waste Materials → Advanced Processing → High-Performance Composites → Sustainable Applications → Circular Economy

Circular High-Performance Recycled Carbon Fiber Shoe Plate

Closing the Loop for a Sustainable Future

DECATHLON

1,817 Stores

79 Countries

1. GRS Certification

Ensure compliance with global recycling standards.

2. Collection Points

Establish consumer shoe return collection stations.

3. Transportation to Disassembly Center

Transport collected shoes to the disassembly facility.

4. Material Sorting

Sort shoes according to material types.

5. Separation of Upper and Midsole

Disassemble shoes into individual components.

6. Reshaping Carbon Plate

Remold the carbon fiber plate.

7. Carbon Plate Reinforcement

Add new materials to reinforce the carbon plate.

8. Labeling and Traceability

Apply labeling for traceability and quality assurance.

NANPAO

POU CHEN GROUP

High Performance
Exceptional strength and durability

Lower Carbon
Reduces CO_2 emissions and environmental impact

Closed Loop
Resources circulate, waste minimized

Fully Traceable
Digital traceability ensures transparency and trust

Better Future
Together for a sustainable planet and society

Carbon Footprint Comparison of Carbon Fiber Shoe Plates

Life Cycle Stage	Thermoset			rCF/rPC		
	Carbon Emissions (Kg CO_2e/piece)			Carbon Emissions (Kg CO_2e/piece)		
Raw Material	Carbon fiber	31kg CO_2e / kg 60wt%	0.511	rCF	2kg CO_2e / kg 60wt%	0.033
	Resin	6.5kg CO_2e / kg 40wt%	0.071	rPC fiber	4.5kg CO_2e / kg 40wt%	0.049
Raw Material Manufacturing	3K Twill Carbon Fabric Production		0.079	Web-forming		Validation
	UD Prepreg Production		0.326			Validation
Transportation	Carbon Fabric & UD Material Transport (Formosa Taffeta → Gueiren Plant)		0.137			0.137
Product Manufacturing	Carbon Fiber Insole Manufacturing (Gueiren Plant)		1.330	Thermo-press		Validation
Product Distribution	Insole Distribution (Gueiren Plant → Decathlon Taichung)		0.278			0.278
Use Phase	Product Use Phase		—	—		
End-of-Life Treatment	Landfill Disposal		Negligible	reshape		Validation
Carbon Emissions of Carbo Plate (Kg CO_2e/piece=27.5g)	2.732			1.5~1.8		

Key Takeaway

The rCF/rPC shoe plate can reduce carbon emissions by approx. **35% ~ 45%** compared to traditional thermoset carbon fiber shoe plate.

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UNMANNED SYSTEMS TECHNOLOGY REQUIREMENT ANALYSIS

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1. FIXED-WING UAV
(Surveillance / Mapping)

Long-endurance missions including patrol, terrain mapping, and reconnaissance.

Lightweight / High stiffness / Weather resistance / Fatigue resistance

2. HEAVY-LIFT MULTI-ROTOR UAV
(Logistics / Emergency Delivery)

For disaster relief, remote area delivery, and urgent medical supply missions.

Lightweight / High stiffness / Impact resistance / Fatigue resistance

3. HARSH ENVIRONMENT UAV
(Maritime / Offshore Operations)

For maritime patrol, monitoring, fishery assessment, and corrosion-prone environments.

High corrosion resistance / Waterproof / Salt spray resistance / High temperature resistance

COMPOSITE AIRFRAME

- **Structural Strength:** Tensile strength ≥ 1,200 MPa (ASTM D3039), Compressive strength ≥ 800 MPa (ASTM D695)
- **Corrosion Resistance:** Pass ASTM B117 salt spray test
- **Impact Performance:** Compliant with MIL-STD-810H impact standard (Method 516.8, Procedure IV)
- **Overall Performance:** Meets MIL-STD-810H for impact and environmental durability

4. AGRICULTURAL SPRAYING DRONE
(Pest Control / Crop Spraying)

For precision spraying of pesticides and fertilizers.

High chemical resistance / Acid & alkali resistance / UV resistance / Waterproof

5. AERIAL PHOTOGRAPHY DRONE
(Aerial Imaging / Surveying)

For stable hover, low-noise flight, and high-quality imaging.

Vibration damping / Low noise / Good heat dissipation / Lightweight / High stiffness

6. UNMANNED SURFACE VESSEL (USV)
(Port Patrol / Ocean Survey)

For port patrol, ocean monitoring, and hydrographic survey missions.

Weather resistance / Impact resistance / UV resistance / Waterproof

OUR GOAL

Develop lightweight, high-performance, and highly durable composite solutions to meet the diverse and demanding requirements of unmanned systems.

Lightweight | High Performance | Durability | Versatility

THANK YOU
FOR YOUR ATTENTION

Innovating Composites for a Sustainable Future

LIGHTWEIGHT

HIGH PERFORMANCE

SUSTAINABLE