Commercialization of Nanofibers produced by Hybrid Electrospinning

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Amogreentech Co., Ltd.
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AMO Group Overview

Global Leader in IT, Automotive, High Efficient Energy & Bio Technologies

AMOTECH
Established in Oct., 1994 (Public since 2003)
- EMC
- Antenna
- BLDC Motor

AMO GREENTECH
Established in Jan, 2004
- Nanocrystalline Core
- Nano Fiber
- Thermal Plastic / Materials
- Flexible Battery
- Thin FPCB
- Water/Air Filter

AMOSENSE
Established in Nov., 2008
- Wireless Charging
- Ceramic Division
- Packaging Division
- Sensors
- Circuitry
- Integration S/W

AMO LIFESCIENCE
Established in Sept, 2016
- Cell Culture
- Magnetic Beads
- Wound Patch
- Smart Skin
- E-Health Care Device
Amogreentech’s Nano Materials

Nano Crystalline

Nano Particles

Nano Composite Plastic

Nano Membrane

Plastic
**Amogreentech’s Business Area**

<table>
<thead>
<tr>
<th>Nanocrystalline</th>
<th>Nano Membrane</th>
<th>Thermal Materials</th>
<th>Battery</th>
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<tr>
<td>Core</td>
<td>Air Vent (IPX4)</td>
<td>Thermal Plastic</td>
<td>ESS(UPS)</td>
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<tr>
<td>• CT</td>
<td>IP67/68 membrane with High</td>
<td>Thermal Coating</td>
<td>Flexible Battery</td>
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<tr>
<td>• CMC/Powder Core</td>
<td>resistance to water pressure</td>
<td>Thermal Interface Material</td>
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<tr>
<td>Wireless Power Supply</td>
<td>Nano Sensors</td>
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<tr>
<td>LF Antennas materials</td>
<td>Water Treatment Filter</td>
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</tbody>
</table>

**Flex / Nano Ink**
- Nano Ink
- Metal Mesh
- FPCB
  - Ultra Thin FPCB
  - Multi Layer FPCB
  - Direct Printing FPCB

**Water / Air Filter**
- Water Filter
- Air Filter
- Fuel Filter
Based on Nano technology
Patents Acquisition to become Global Leader in Materials Field

1,038 Patents
(2018. 6. 30)

Advanced Materials
491 (47%)

Functional Parts
339 (33%)

Environment & Energy
208 (20%)

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<td>Metallic Converter</td>
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<td>Water treatment</td>
<td>107</td>
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<tr>
<td>Air-Vent system</td>
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<tr>
<td>Sum</td>
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</table>
What is Nanofiber?

**Overview**

- **1/20 diameter compared to conventional microfiber**
  - Diameter below several hundred nm
- **Expanding applications with innovative performance**
  - Functional Textile, Vent, Filter, Sound Absorber, Next Generation Energy, Bio application, etc.

**Features**

**High specific surface area**

- **Nanofiber**
  - Size: 200 nm
  - Relative index of surface area

- **Microfiber**
  - Size: 20 µm

**Small pore structure**

- **Nanofiber**
  - Size of pore
- **Microfiber**

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Why use Nanofiber Membrane?

Features

- Super specific surface area
- Narrow pore size distribution
- High Porosity (70~85%)
- Perfect 3D Open pore structure (No blinded pore)
- Excellent uniformity
- Excellent breathability
- Excellent molecular recognition ability
- Excellent adsorb-ability
- Easy to incorporate functional additives

Microfibers vs. Nanofibers
Fabrication of Nanofiber Membrane

Nanofiber Membrane: Manufactured by Electrospinning

- Polymer solution
- Syringe pump
- Stainless steel nozzle
- Electrospinning jet
- Earthed metal plate
- HT supply
- Insulating stand

Unperturbed droplet

Con-jet

Spraying

Nanofibers (\(\phi 0.1-1 \mu m\))

Human hair (\(\phi 80 \mu m\))

4,500 fps
Existing membrane

Nanofiber membrane (AMOTEX®)

Membrane formed by nanofibers

Features of Nano Membrane

- High specific surface area
- Fiber diameter of 5 ~ 500 nm
- High porosity (3D structure)
- Small pore structure
Application of Nanofiber Membrane

- **Filters**
  - Water & Air filters
  - Fuel filter
  - Gas turbine filter

- **Functional Fabric**
  - Garment & Outdoor cloths
  - Protection fabrics
  - Sport wear
  - Military cloths

- **Electric & Energy**
  - Carbon nanofiber applications
  - Separator for 2\textsuperscript{nd} batteries
  - Anode, Cathode material for 2\textsuperscript{nd} batteries
  - Transparent film as electrode

- **Others**
  - Nanofiber fillers
  - Sensor applications
  - Acoustic absorbent (Building, Automobile, Aircraft)

- **Life Science**
  - Transfer membrane
  - Wound healing
  - Scaffold for GTR membranes
  - Anti-flu mask
  - Barrier material
  - Multi-functional nanoweb
2007
• R&D started
• Lab. Scale facilities were installed

2010
• Pilot plants were installed
  - Spinning width of 500, 1,000mm

2012
• Mass production lines were installed
  - Spinning width of 1,100, 1,700mm
• Productive Capacity was 60,000m²/month

2015
• Facilities for the vents and adhesive area were added

Appearance of the Nanofiber Membrane

Δ Lab. Scale equipment
Δ Production line(1,700mm line)
Δ 1,700mm line in operation
Commercialization of Nanofibers

How do we make a bridge that technology can overcome?

R & D
Early market formation

Death Valley

Technology

Practical use
Commercialization
Maturity
Commercialization of Nanofibers

Discovery of customer needs
Convergence of technology

Practical use
Commercialization
Maturity

R & D
Early market formation
**Optimization of Nanofiber Performance**

**Fiber & Web Flexibility**
- Fiber dia.: > 0.1, < 1µm
- Weight: 0.3 ~ 100gsm
- Thickness: ~ 100µm
- Pore size: 0.1 ~ 10µm

**Processing Flexibility**
- Electric & Air combined hybrid electrospinning
- Post process
  - Calendering
  - Oleophobic (hydrophobic)
  - Hydrophilic

**Production Flexibility**
- Substitution of existing products (Nano+substrate)
  - Pure nanomembrane products

**Material Flexibility**
- PVDF, PAN, PES,
- PU, Biopolymers,
- Blendable,
- Organic & inorganic hybrid

**Conversions Technology**
- Fiber Web Control
Hybrid Electrospinning (Electric & Air)

Morphology Control By Air Force

Setup of mass production technology
Hybrid Electrospinning

### Electric & Air Hybrid Electrospinning

Superior uniformity and productivity Enables mass production

<table>
<thead>
<tr>
<th>Classification</th>
<th>Hybrid E-spinning</th>
<th>Electro Blown</th>
<th>Pure E-spinning</th>
<th>Nozzless E-spinning</th>
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</thead>
<tbody>
<tr>
<td>Methods</td>
<td>Electric+Air</td>
<td>Air+Electric</td>
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<td>Electric</td>
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<td>Nozzle</td>
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<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<tr>
<td>Productivity</td>
<td>◎</td>
<td>◯</td>
<td>X</td>
<td>△</td>
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<tr>
<td>Polymer versatility</td>
<td>◎</td>
<td>△</td>
<td>△</td>
<td>◯</td>
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<tr>
<td>Web thickness</td>
<td>◯</td>
<td>◯</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Web evenness</td>
<td>◯</td>
<td>X</td>
<td>◯</td>
<td>X</td>
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<tr>
<td>Control of fiber diameter</td>
<td>◯</td>
<td>X</td>
<td>△</td>
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<tr>
<td>Web density</td>
<td>◯</td>
<td>X</td>
<td>X</td>
<td>◯</td>
</tr>
</tbody>
</table>

X: Poor, △: Moderate, ○: Good, ◯: Excellent
**Hybrid Electrospinning**

“Very narrow pore size distribution & easy to optimize”

- **Test conditions**
  - Test method : ASTM E 1294
  - Test rig : PMI, CFP1200
  - Test area : 4.9cm$^2$
  - Test fluid : Galwick

![Graph](image_url)
Changes in customer demand for outdoor clothing materials

- **protect**
- **comport**

Breathable Fabric

Improvement of permeability
Nanofiber Membrane

Moisture-proof (waterproof)

+ Breathable (air, sweat permeability)

- Waterproof: pore size control OK!
- Breathable: pore size control OK!
  high porosity OK!
- Wash durability OK!
- Reduction of friction noise OK!
- Price competitiveness OK!
Customer needs for Vent materials

Vent Membrane for acoustic

Moisture-proof (waterproof) + Sound permeability

- Waterproof: pore size control  \(\text{OK!}\)
- Maintain sound permeability: lightweight, soft, high porosity  \(\text{OK!}\)
- Maintain mechanical strength  \(\text{OK!}\)
Example of actual use of Vent (speaker sound test)

**IPX7 grade** 2 Point / Spk 1ea, Rcv 1ea

Speaker

Receiver
Example of actual use of Vent (speaker sound test)
Expanding application areas of Vent

<table>
<thead>
<tr>
<th>Vents</th>
<th>Portable Electronics</th>
<th>Automotive</th>
<th>Packaging</th>
<th>Ink &amp; Toner</th>
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<td>(<strong>Automotive</strong> titles)**</td>
<td><img src="image1" alt="Portable Electronics" /></td>
<td><img src="image2" alt="Automotive" /></td>
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<td><strong>Vent</strong></td>
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<td><img src="image19" alt="Packaging" /></td>
<td><img src="image20" alt="Ink &amp; Toner" /></td>
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</tbody>
</table>

- Portable Electronics: ![Portable Electronics](image21)
- Automotive: ![Automotive](image22)
- Packaging: ![Packaging](image23)
- Ink & Toner: ![Ink & Toner](image24)

- Lamps
- ECU
- Battery
- Agriculture
- Consumer Cleaner&Foods
- Industrial
- Ink
- Toner cartridge
### Expanding application areas of Vent

<table>
<thead>
<tr>
<th>Vents</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hearing device</strong></td>
<td><strong>Telecommunication Infrastructure</strong></td>
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<tr>
<td>Hearing device</td>
<td><strong>Solar panels</strong></td>
</tr>
<tr>
<td><strong>Lights</strong></td>
<td><strong>Liquid Storage Tanks</strong></td>
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<tr>
<td><strong>Sensor</strong></td>
<td><strong>Hearing device</strong></td>
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<td><strong>Telecommunication Infrastructure</strong></td>
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<td><strong>Liquid Storage Tanks</strong></td>
<td><strong>Solar panels</strong></td>
</tr>
</tbody>
</table>

- **Expanding** application areas of Vent
- **Liquid Storage Tanks**
- **Telecommunication Infrastructure**
- **Solar panels**
- **Sensor**
Customer needs for heat dissipation (insulation)

Requires high performance & thinness

Copper Sheet

- Surface: 90°C
- Heat Source: 100°C
- X-Y: 400 W/mK
- Z: 400 W/mK

Graphite

- Surface: 70°C
- Heat Source: 100°C
- X-Y: 1500 W/mK
- Z: 5 W/mK

AGT HTF

- Surface: 70°C
- Heat Source: 100°C
- X-Y: 400 W/mK
- Z: 0.3 W/mK

HTF: Hybrid Thermal Film
(In plan: 400 W/mK, Through plan: 0.3 W/mK)

Thermal Insulation
Heat Spreading

Needs for heat control

Customer needs for heat dissipation (insulation)
Customer needs for heat dissipation (insulation)

- Heat dissipation through fast horizontal heat conduction by Cu (400 W / mK)
- Superior vertical insulation property by Nano Web (0.3 W / mk)

→ Surface temperature is lowered by "heat dispersion layer + heat insulating layer"
→ Price competitiveness compared to existing heat-insulating sheet

Hybrid structure with thin thickness satisfies customer's demand
Why use Nanofibers in Filtration area?

Features
- Narrow pore size distribution
- High Porosity (70~80%)
- Perfect 3D Open pore structure (No blinded pore)
- Excellent uniformity
- Fixed pore construction

Benefits
- Excellent removal efficiency
- Very low pressure drop
- Longer filter service life
- Lower energy costs
- Reduced equipment downtime
- Reduced investment costs due to compact size of filter systems
- Customize design & manufacturing

Nano filter Advantage

Micro membrane
- Diameter of fiber: 1~3µm
- Porosity: 20~35%

Amogreentech
- Diameter of fiber: 0.1~0.3µm
- Porosity: 65~70%

Wide distribution: range of pore size distribution: 0.1~1.2µm

Narrow distribution: range of pore size distribution: 0.4~0.6µm
Powerless water purification system
3 layer membrane filtration module

Membrane for sewage / waste water
Flat membrane filtration module system for sewage / waste water

Portable Water Bag

Ultrafine dust filter
Automatic Ventilation Products
Electrospin PVDF membrane is “more sensitive” than commercial PVDF membrane.
# Expanding application areas of Nanofibers

<table>
<thead>
<tr>
<th>Filters</th>
<th>Bio &amp; Medical</th>
<th>Electronic materials</th>
<th>Textile</th>
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<tbody>
<tr>
<td>&lt;Liquid Filter&gt;</td>
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</table>

Expanding application areas of Nanofibers
Commercialization of Nanofibers

Find Needs of Customers ➔ Value Creation

- Needs
  - Customers
  - Market

- Technology
  - Suppliers
  - Researchers

- Find & Convergence
  - Social Infra (Government)

Commercialization (Industrialization)
Challenging the world with advanced material products

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