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Session 10:
Nano porous alumina structures for innovative seamless R2R printing tools in high-throughput antireflection applications
Outline

- Nano and marco porous structures made by Smartmembranes
- Applications of micro and nano structures in printing processes
- Biomimetic applications of nano porous alumina structures
- Printing process with nano porous alumina templates
- Electrochemical etching process and fabrication of nano porous alumina structures
- Advantages of nano porous alumina in printing processes
Novel porous materials

Nanoporous alumina

Macroporous silicon

Pore diameter 20 - 400nm

Pore diameter 0.5 - 100µm
Novel porous materials

Nanoporous alumina

Macroporous silicon

Pore length up to 150 µm

Pore length up to 500 µm
Nanoporous alumina substrates (AAO)

- **FlexiPor**
  - disordered

- **SmartPor**
  - near field ordered

- **QualiPor**
  - prestructured

Substrate sizes currently up to 300x230mm
Advanced Processing

- surface functionalization
  - specific adjustment of hydrophoby/hydrophily of the pore walls

- deposition of metals and metals oxides
  - thin layer by ALD
  - complete filling by electrochemical deposition

- wetting with polymer melts
  - fabrication of nano rods and nano tubes from desired polymers
Nano- and Microstructures

Light Management

- Light Guiding
- Anti Reflection
- Light trapping
- Microlenses
- Reflection
Nano- and Microstructures

Bionic

- Anti Friction
- Adhesion
- Anti Fingerprint
- Anti Bacterial Surfaces
Structured functional film and sheets

Applications

- Bionic Surfaces
- Lightning solutions
- Solar
- Display
- Haptic
Anti-biofouling of the cicada wing

Very rough surface with low surface area on peaks to reduce the adhesion of bacteria
Moth-eye structure for anti-reflection purposes

The structure consists of a hexagonal pattern of bumps, each roughly 200 nm high and spaced on 300 nm centers.
Moth-eye mold with AAO

Pore length: ~ 200 nm
Pore shape: conical
Pore diameter: 120 - 40 nm
Bioinspired seamless moth-eye mold

Etching of porous structure onto a aluminium cylinder

Nano structure on cylinder surface

Printing process with cylinder on foils

reverse structure on foil; antireflective
Process types

Roll to Roll Process (R2R)

Roll to Plate Process (R2P)
Roll2Roll – the equipment
Resulting properties moth-eye structure and other biomimetic structures

e.g. anti-reflection, adhesion, self-cleaning...
Electrochemical etching of aluminum

Anode: \[ 2 \text{Al} + 3 \text{H}_2\text{O} \rightarrow \text{Al}_2\text{O}_3 + 6 \text{H}^+ + 6 \text{e}^- \]

Cathode: \[ 6 \text{H}^+ + 6 \text{e}^- \rightarrow 3 \text{H}_2 \]
Interfacial reactions

oxide / electrolyte interface

\[ 2\text{Al}^{3+} + 3\text{O}^{2-} \rightarrow \text{Al}_2\text{O}_3 \]

\[ \text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}(1) \]

\[ \text{Al}^{3+} \rightarrow \text{Al}^{3+} \text{(aq)} \]

\[ 2\text{O}^{2-} \rightarrow \text{O}_2(g) + 4\text{e}^- \]

\[ 2\text{H}_2\text{O}(1) + \text{O}^{2-} \rightarrow \text{OH}^{-} + 3\text{H}^+ \]

metal /oxide interface

\[ \text{Al} \rightarrow \text{Al}^{3+}(\text{ox}) + 3\text{e}^- \]

\[ 2\text{Al}^{3+} + 3\text{O}^{2-}(\text{ox}) \rightarrow \text{Al}_2\text{O}_3 \]
Schematic diagram of the kinetics of porous AAO

1. Formation of non-conductive barrier layer
2. Local focus of the electric field in the cavities of the surface irregularities
3. Field-enhanced dissolution of the oxide in the cavities
4. Equilibrium between field-enhanced oxide dissolution and the oxide formation
**SmartPor**: two-step anodization for self-ordered AAO
Advantages of AAO printing molds

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<thead>
<tr>
<th>unique selling points</th>
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<tbody>
<tr>
<td>pore diameter from 20 nm</td>
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<tr>
<td>pitch from 65 nm</td>
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<tr>
<td>pore depth and slope</td>
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<td>seamless cylinder</td>
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<td>cost effective</td>
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<td>easily scalable</td>
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THANK YOU FOR YOUR ATTENTION!