The PixClearProcess™ High RI ZrO₂ Nanocomposites

Winner of Frost and Sullivan Manufacturing Leadership Council’s Manufacturer of the Year 2017 (<$1B revenue)

Vincent Jao, Director of Asia Sales
### Company Overview

| Disruptive Technology | • Technology leader in Next Generation High-RI Nanocomposites  
| • 46 Issued and Pending Patents  |
| Key Markets Served | • OLED Display, HD Display, OLED Lighting, LED Lighting  |
| Customers & Partners | • 65+ Leading Device & Advanced Materials Companies  |
| Manufacturing | • 5 MT Pilot Baltimore, MD  
| • 40 MT Full-scale, PA, 4Q17  |
| Locations | • Baltimore, MD - HQ  
| • Iowa City, IA - Sales  
| • Taipei, Taiwan - Sales  |
| Distributors | • Korea, Japan, Taiwan  |
ZrO2 Nanocrystal Dispersions are the best available:
- Uniform 10nm capped spheres
- High loadings (>80wt%)
- Increases RI >1.8
- 95% transmittance
- Minimal effect on viscosity
- Broad compatibility

**Technology Leader in High Refractive Index Materials**

![TEM Image of ZrO2 Nanocrystals](image)

**Viscosity vs. Nanocrystal Loading**

**Refractive Index at 650 nm**

![3um Film in Acrylic Polymer](image)
Application Development Capabilities

- NC Preparation
  - Synthesis
  - Capping
  - Purification
- Basic Formulation
  - Dispersion
  - Viscosity
  - Curing Condition
  - Pot Life
  - Shelf Stability
  - Proof of Concept
- Material Application
  - Dispensing
  - Spray Coating
  - Slot Die Coating
  - Inkjet Coating
  - Spin-Coating
  - Drawbar
  - UV Curing
- Film Characterization
  - Refractive Index
  - Wetting
  - Transmission
  - Absorption
  - Thermal Aging
  - Modulus
  - Hardness
  - Haze
  - Surface Tension
- Customer
  - Proof of Concept
  - Testing
  - Integration
  - Reliability Testing
  - Scaling
  - Production
## Broad Compatibility

<table>
<thead>
<tr>
<th>Zirconia Nanocrystals</th>
<th>Dispersion Medium</th>
<th>Polar Solvents</th>
<th>Non-Polar Solvents</th>
<th>Solvent-Free Monomers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Silicone</td>
<td>Siloxane</td>
<td>Epoxy</td>
<td>Acrylics</td>
</tr>
<tr>
<td>Customer Target Material</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benefits</td>
<td>High RI</td>
<td>Transparency</td>
<td>Dielectric</td>
<td>Hardness</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Inkjet</td>
<td>Slot Die</td>
<td>Imprint</td>
<td>Dispense</td>
</tr>
</tbody>
</table>

- **LED**
- **OLED Display**
- **OLED Lighting**
- **Display**
- **OC&F**
Capping Variations in the PixClear® 4pack

- For the cross-linking materials: PCPr has higher acrylic cross-link capping resulting in greater substrate adhesion, hardness, and better performance with processing chemicals.
- PCPB-2 has higher dispersibility capping leading to higher RI nanocomposites.

*RI at 450 nm with up to 90wt% loading measured by ellipsometer using base polymer with 1.58 RI at 450 nm.
Significant Customer Benefits in Rapidly Growing Markets

**OLED Display**
Increases OLED display brightness 50% to 200%

**LED, LCD, QD, and Reflective Displays**
Provides substantial operating efficiencies across all display technologies

**OLED Lighting**
Increases OLED lighting efficiency by >100%

**LED Lighting**
Releases up to 35% of trapped light in LEDs

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**Total Available Market ($B)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Non-OLED Display</th>
<th>LED Lighting</th>
<th>OLED Display</th>
<th>OLED Lighting</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>$16</td>
<td>$103</td>
<td>$32</td>
<td>$16</td>
</tr>
<tr>
<td>2020</td>
<td>$151</td>
<td>$210</td>
<td>$56</td>
<td>$42</td>
</tr>
</tbody>
</table>

(1) Source: Wall Street research, BCG, UBI Research and IHS
PixClear® delivers:

- 1.75+ RI
- 95% transparency
- Flexible or rigid
- 100%+ light efficiency improvement
- Improved scratch resistance
OLED Display Simulation Using High RI Lenses

- Optimized pixel structure for control
- Added high RI lenses
- Greater luminance at all viewing angles
- Reduced color shift from 0 - 60 degrees

Data from work with DuPont. Used with Permission.
**PixClearProcess™ ZrO2**

<table>
<thead>
<tr>
<th>Product</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZrO2 Nanoparticle</td>
<td>• Synthesizing ZrO2 nanoparticle for all products</td>
</tr>
</tbody>
</table>
| Capped ZrO2 Nanoparticle    | • Application specific surface modification  
                               • Same equipment and process for all products |
| Nano Dispersions and Formulations | • Broad Materials Compatibility  
                                  • Wide Range of Applications |
Scaled PixClearProcess™

Volume
- 5 MT pilot line today
- >40 MT on line 4Q17
- Further scaling without constraints

Quality
- State of the art quality control and characterization capabilities
- Consistent Lot to lot quality, over multiple years

Compliance
- Fully compliant with all US and International EH&S and standards.

Cost
- >95% Mfg cost reduction from lab to Mass Production
- Driving compelling value propositions

PixClearProcess™

ZrO₂
Robust Process Control and Analytics

- Process Control – Siemens based custom process control and monitoring system
- Analytics – Multiple tools measuring particle size, dispersion quality, and purity i.e. DLS, UV-VIS, TGA, GC, etc.
Global Business Development and Sales Footprint

- **Masaru Iida**: Advisory Board Member - Japan
- **Shree Deshpande**: VP BD/Sales Midwest Office
- **Cale Yeary**: BD Associate Midwest Office
- **Vincent Jao**: Asia Sales Director Taiwan
- **EU**: Pixelligent Direct
- **AMC Korea**, **Inabata Japan**, **Inabata Taiwan**, **China Agency (TBD)**

- **HQ & Manufacturing**
- **Manufacturing**
- **Sales & Distribution**
One of the only Nanomaterials Companies that is Delivering both Scale and Breakthrough Technology in numerous multi-billion dollar markets: OLED Display, Display, OLED Lighting, & LED Lighting.
Select Customers & Partners
引领和陪伴中国制造走向中国创造