Nanolok™ Technology

for high barrier applications

Presentation to INDA / AATCC Sept. 19, 2005
Outline

• Brief History of InMat
• Target Markets and applications
• Barrier Coating Performance
• Unique Features of InMat® Technology
• Summary and Conclusions
InMat® NanoLok™ Technology

- Reduced Material Costs
- Easier recycle and disposal
- Environmentally Friendly
- Thin coatings have minimal effect on physical properties
1996 - Michelin approaches Hoechst to develop coating to displace tire inner liner

1998 – Technical breakthrough shortly after Hoechst announces divestiture

1999 – Technology as part of Hoechst coating division bought out by DuPont. Nanotech project leaders buy out technology from DuPont, InMat founded

2001 – First commercialization in Wilson tennis balls.
2002 - DOD awards contract to develop chemical warfare agent gloves

2003 – Multiple venture capital investment

2004 - Technology and marketing extension into packaging market
Target Markets for Nanolok™ Technology

• **Sports Balls**
  – The bounce and feel of natural rubber with the air retention of butyl
    • Commercially used in Wilson’s Double Core™ ball
      o butyl nanocomposite

• **Tires**
  – Improved air retention, lower weight, less rolling resistance and cost vs. butyl
    • Major tire companies testing –
      o butyl nanocomposite

• **Chemical Protection**
  – Improved solvent, oil, and flame resistant protective gloves
    o nitrile rubber and neoprene nanocomposite

• **Packaging**
  – High barrier with see-through clarity which can be applied via roll-coat, dip, or spray coat processing
    o polyester and acrylic nanocomposite
OTR and WVTR Requirements for Different Applications

- Oxygen Transmission Rate (cc/m²-day-atm)
- Water Vapor Transmission Rate (gm/m²-day)

- Flexible packaging, Rigid packaging, Medical packaging
- Rubber products, tires, Sports Balls
- Organic Semiconductors, OLED’s
Vermiculite sheet extent 10 - 30 microns

Exfoliated thickness ~ 1 nm
Very high aspect ratios can lead to sterically constrained mesoscopic structures even at low concentrations.
0.02 wt. % dispersion of Microlite™ in water showing oriented domain structure.

Between crossed polarizers

With additional optical compensator
AFM imaging shows high orientation and Nanodispersion in InMat Nanolok PT coating

Tapping mode height and phase images of the Nanolok PT3575 coating on 500 gauge PET, in cross-section clamped in a plastic vise, 1.5 μm scan size. PET is toward the right-hand side of the image, with Nanolok on the left. Images by PolyInsight
InMat’s Elastomeric Nanocomposites provide a unique combination of flexibility and barrier properties. The chart illustrates the relative oxygen barrier effectiveness of various elastomers, including Silicone Rubber, EPDM, NR, Bromo-Butyl, Butyl Rubber, InMat, and Air D-Fense® 2000. Using Nanolok™ technology in a Butyl Rubber matrix (also available in Nitrile Rubber and Neoprene) offers improved barrier properties.
Large oxygen permeability reductions demonstrated with several elastomers

<table>
<thead>
<tr>
<th>Latex Type</th>
<th>% Filled</th>
<th>Permeability (cc-mm/m²-day atm)</th>
<th>X Reduction</th>
<th>% Strain</th>
<th>Key secondary properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butyl</td>
<td>50</td>
<td>0.3</td>
<td>300</td>
<td>10</td>
<td>Low Temperature flexibility</td>
</tr>
<tr>
<td>Butyl</td>
<td>30</td>
<td>1.2</td>
<td>75</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Butyl</td>
<td>20</td>
<td>2.5</td>
<td>36</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Butyl</td>
<td>0</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chloroprene*</td>
<td>30</td>
<td>1.5</td>
<td>83</td>
<td>12</td>
<td>Ozone, UV, oil, and solvent resistance</td>
</tr>
<tr>
<td>Chloroprene</td>
<td>0</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrile*</td>
<td>30</td>
<td>2.3</td>
<td>57</td>
<td>14</td>
<td>Solvent, oil and fuel resistance</td>
</tr>
<tr>
<td>Nitrile</td>
<td>0</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EPDM</td>
<td>20</td>
<td>17</td>
<td>11</td>
<td>15</td>
<td>Ozone, UV, sunlight, steam, brake fluid, and weak acid resistance</td>
</tr>
<tr>
<td>EPDM</td>
<td>0</td>
<td>185</td>
<td></td>
<td></td>
<td></td>
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</table>
A 50 micron InMat coating provides more chemical protection than a butyl rubber glove.
InMat’s Non-Elastomeric Nanocomposites provide the lowest oxygen permeability of any polymeric coating
Nanolok™ barrier vs. EVOH, Bairocade & PVDC

Source: PPG, Nippon-Gohsei, Solvin and InMat, 25°C

O₂ Permeability (cc-mil/100in²/day/atm)

% Relative Humidity

Source: PPG, Nippon-Gohsei, Solvin and InMat, 25°C

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Secondary Properties can be controlled by formulation and choice of polymer matrix

<table>
<thead>
<tr>
<th>Aqueous Dispersed Polymer</th>
<th>Oxygen Permeability unfilled (cc-mm/m²-day-atm)</th>
<th>Oxygen Permeability (30-40% filled) (cc-mm/m²-day-atm)</th>
<th>Times reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanolok PT</td>
<td>2</td>
<td>0.002</td>
<td>1000</td>
</tr>
<tr>
<td>Nanolok Ac 1*</td>
<td>9</td>
<td>0.0003</td>
<td>30,000</td>
</tr>
<tr>
<td>Nanolok Ac 2*</td>
<td>30</td>
<td>0.0002</td>
<td>150,000</td>
</tr>
<tr>
<td>Nanolok PVDC*</td>
<td>0.4</td>
<td>0.008</td>
<td>50</td>
</tr>
</tbody>
</table>

* Formulations still under development
InMat coatings use nanoclays in a thin coating to provide barrier improvements.

Oxygen transmission rate is reduced by a factor of >100 on PET and >1000 on PP.
Thin coatings of Nanolok PT can provide large reductions in oxygen transmission rate

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Substrate Thickness (microns)</th>
<th>Substrate OTR (cc/m²-day-atm)</th>
<th>Coated Substrate OTR (1 micron Nanolok PT)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>PET</td>
<td>12</td>
<td>120</td>
<td>0.8-2.0</td>
</tr>
<tr>
<td>BOPP</td>
<td>20</td>
<td>3000</td>
<td>1.5-2.0</td>
</tr>
</tbody>
</table>

*The range of OTR is due to variations in substrate surface and coating uniformity due to non-optimized coating process.
InMat strategy

• Large (>> 10x) changes in permeability
• Aqueous coating formulations
• Use commercially available nano-clays
• Choose polymer for both barrier and required secondary properties
• Provide cost advantage by material reduction (i.e. replace thick film with much thinner film)
Unique Features of InMat’s Nanocomposite Coatings

• Exfoliated Clay:
  – Not functionalized with cationic organic molecules
  – High weight fraction
  – Very large aspect ratio – no degradation during processing
  – Can be self aligning (mesoscopic) in suspension

• Formulations
  – Good suspension stability
  – Can be applied using standard coating techniques on standard packaging materials

• Coating
  – Very large reductions in permeability relative to the unfilled polymer
  – Good dispersion and flexibility controlled by proprietary technology
Processing

• Nanolok PT has been coated on PET film at speeds up to 200 ft/min.
  • 0.2-0.5 micron in a single pass, multiple passes used to increase thickness
  • PE adhesion lamination demonstrated

• Higher speed processing is being investigated.
• Dip coating and spray coating have been demonstrated with both elastomeric and non-elastomeric formulations.
• InMat optimizes formulations to meet the processing needs of its customers.
Summary and Conclusions

• InMat has already demonstrated its capability to make high barrier nanocomposite coatings with a wide variety of polymers in order to meet market needs.

• Its elastomeric barrier coatings offer a unique combination of barrier and flexibility.

• Its non-elastomeric barrier coatings provide the most cost effective oxygen barrier coating technology for packaging and other markets using non-elastomeric polymers for barrier.
• Nanolok™ and Air D-Fense™ are trademarks of InMat, Inc.
• InMat® is a registered trademark of InMat, Inc.
• Double Core™ is a trademark of Wilson Sporting Goods.