Reinforcement, faster processing and fire-retardance using Halloysite a natural, tubular mineral

Presented by: Dr. Chris DeArmitt – CTO
AMI - Minerals in Compounding 2011
Information provided and statements contained in this presentation that are not purely historical are forward-looking statements within the meaning of Section 27A of the Securities Act of 1933, as amended Section 21E of the Securities Exchange Act of 1934 as amended and the Private Securities amended, Section 21E of the Securities Exchange Act of 1934, as amended, and the Private Securities Litigation Reform Act of 1995. Such forward-looking statements only speak as of the date of this presentation and the Company assumes no obligation to update the information included in this presentation. Such forward-looking statements include information concerning our possible or assumed future results of operations, including descriptions of our business strategy. These statements often include words such as “believe,” “expect,” “anticipate,” “intend,” “plan,” “estimate,” or similar expressions. These statements are not guarantees of performance or results and they involve risks, uncertainties, and assumptions. For a further description of these factors, see Item 1A, Risk Factors, included within our Form 10-K for the year ended December 31, 2010, which was filed on April 15, 2011. Although we believe that these forward-looking statements are based on reasonable assumptions, there are many factors that could affect our actual financial results or results of operations and could cause actual results to differ materially from those in the forward-looking statements. All future written and oral forward-looking statements by us or persons acting on our behalf are expressly qualified in their entirety by the cautionary statements contained or referred to above. Except for our ongoing obligations to disclose material information as required by the federal securities laws, we do not have any obligations or intention to release publicly any revisions to any forward-looking statements to reflect events or circumstances in the future or to reflect the occurrence of unanticipated events.

Cautionary Note to U.S. Investors - The United States Securities and Exchange Commission permits U.S. mining companies, in their filings with the SEC, to disclose only those mineral deposits that a company can economically and legally extract or produce. We use certain terms on this website (or press release), such as “measured,” “indicated,” and “inferred” “resources,” which the SEC guidelines strictly prohibit U.S. registered companies from including in their filings with the SEC. U.S. Investors are urged to consider closely the disclosure in our Form 10-K which may be secured from us, or from our website at http://www.sec.gov/edgar.shtml.
Agenda

- Introduction to fillers
- What is Halloysite?
- Mechanical properties
- Processing advantages
- Flame retardance
- Sustained release of actives
- Availability and pricing
- Conclusions
Halloysite Property Overview

- Aluminosilicate mineral: $\text{Al}_2\text{Si}_2\text{O}_5(\text{OH})_4 \cdot n\text{H}_2\text{O}$
- Molecular weight: 294.19
- CAS: 1332-58-7
- Density: $2.70 \pm 0.03 \text{ gcm}^{-3}$
- Refractive index at room temperature: 1.534, dried at $100^\circ \text{C}$ 1.548
- Specific heat capacity: 0.92 kJkg$^{-1}$K$^{-1}$
- Thermal conductivity: 0.092 WK$^{-1}$m$^{-1}$
- Thermal diffusivity: $5.04 \times 10^{-4} \text{ cm}^2 \text{ sec}^{-1}$
- CTE: $10.0 \pm 1.5$ perpendicular to the layer, $6.0 \pm 2.0$ parallel
- Colorless and UV transparent
- pH in water 5.4
- Particle shape: 1-2 microns long, 50nm across, 15nm diameter hole
- Surface area: 65-120 m$^2$g$^{-1}$
- Dragonite™ purity: 95-100%
Technology Description - What is Halloysite?

- Halloysite is a natural aluminosilicate clay with a hollow tubular morphology.
- Naturally exfoliated morphology means no need to chemically separate particles and makes for easy dispersion.
- Halloysite nanotubes typically have diameter ~50nm with lengths ranging from 1 to 2 microns giving an aspect ratio of ~20.
- Traditional uses include fine china, fillers in paints and paper, food extenders, catalysts and molecular sieves.
Dragonite™ Intrinsic Properties and Applications

**High aspect ratio**
- Reinforcement of plastics, elastomers, coatings etc.

**High surface area**
- Catalysts, adsorbents, carrier, elastomers, immobilization, nucleation of crystal growth and foam cell formation

**Hollow**
- Controlled release, thermal insulation, light-weighting, wicking, membranes, reverse osmosis

**Bound water**
- Fire retardance, temperature indicator, foaming agent
Markets Addressed

**Plastics**
- Productivity +20%
- Mechanicals +20%
- Flame retardance

**Environment**
- Oil clean-up
- Soil remediation
- Water purification

**Coatings & Adhesives**
- UV cure speed +20%
- Mechanicals +20%
- Improved adhesion

**Elastomers**
- Reinforcement
- Flame retardance
- Thermal stability
Agenda

- Introduction to fillers
- What is Halloysite?
- **Mechanical properties**
- Processing advantages
- Flame retardance
- Sustained release of actives
- Availability and pricing
- Conclusions
## Dragonite in Plastics

<table>
<thead>
<tr>
<th>Plastic Type</th>
<th>Mechanical Reinforcement</th>
<th>Nucleation/Cycle Time Reduction</th>
<th>Clear Film</th>
<th>Flame Retardance</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>PP</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>EVA</td>
<td>✔</td>
<td>TBD</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>PA6</td>
<td>✔</td>
<td>TBD</td>
<td>TBD</td>
<td>✔</td>
</tr>
<tr>
<td>PA12</td>
<td>✔</td>
<td>✔</td>
<td>TBD</td>
<td>✔</td>
</tr>
<tr>
<td>PVC</td>
<td>✔</td>
<td>TBD</td>
<td>✔</td>
<td>TBD</td>
</tr>
<tr>
<td>PLA</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>TBD</td>
</tr>
<tr>
<td>Epoxy</td>
<td>✔</td>
<td>TBD</td>
<td>TBD</td>
<td>✔</td>
</tr>
<tr>
<td>EPDM</td>
<td>✔</td>
<td>TBD</td>
<td>TBD</td>
<td>✔</td>
</tr>
</tbody>
</table>

### Suggested Grade
- **Dragonite™ XR or HP**
- **Dragonite™ HP**
- **Dragonite™ HP**
- **Dragonite™ XR**
Dispersibility of Halloysite and Polarity

- **Halloysite** has been shown to disperse well in all types of system, from apolar to very polar.
- Wetting through the tubes gives mechanical bonding even in cases where no specific chemical interaction takes place.
- In thermosets, thermoplastics and elastomers, effective reinforcement is reported even without dispersants or coupling agents.
- Dispersants and coupling agents may also be used.
Isotropic fillers retain impact but do not reinforce

Reinforcing fillers ruin impact resistance and elongation to break

Halloysite reinforces and retains or improves impact and elongation

This is possible due to shape, surface area and easy dispersibility
### Halloysite in LLDPE

<table>
<thead>
<tr>
<th>Property</th>
<th>LLDPE</th>
<th>10% Halloysite</th>
<th>20% Halloysite</th>
<th>30% Halloysite</th>
<th>40% Halloysite</th>
<th>60% Halloysite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus (MPa)</td>
<td>180</td>
<td>327</td>
<td>453</td>
<td>570</td>
<td>635</td>
<td>1378</td>
</tr>
<tr>
<td>Flexural Strength (MPa)</td>
<td>8.2</td>
<td>12.7</td>
<td>14.9</td>
<td>16.8</td>
<td>19.1</td>
<td>23.0</td>
</tr>
<tr>
<td>Impact Resistance (KJm(^{-2}))</td>
<td>50</td>
<td>37.5</td>
<td>22.1</td>
<td>14.4</td>
<td>10.6</td>
<td>5.4</td>
</tr>
<tr>
<td>PHRR (KWM(^{-2}))</td>
<td>920</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>480</td>
<td>---</td>
</tr>
</tbody>
</table>

Strength and PHRR further increased by addition of graft copolymer coupling agent

Reinforcing and Flame-Retardant Effects of Halloysite Nanotubes on LLDPE
## Dragonite in PP Film

<table>
<thead>
<tr>
<th>Property</th>
<th>PP</th>
<th>1% Dragonite</th>
<th>2% Dragonite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus (psi)</td>
<td>129</td>
<td>140</td>
<td>143</td>
</tr>
<tr>
<td>Yield Strength (psi)</td>
<td>4046</td>
<td>4978</td>
<td>5379</td>
</tr>
<tr>
<td>Tear Strength</td>
<td>1178</td>
<td>1142</td>
<td>1122</td>
</tr>
<tr>
<td>Elongation to break</td>
<td>540</td>
<td>610</td>
<td>574</td>
</tr>
</tbody>
</table>

When blowing film an increase in bubble stability was noted.
### Dragonite in PVC

<table>
<thead>
<tr>
<th>Property</th>
<th>PVC</th>
<th>1% Dragonite</th>
<th>2% Dragonite</th>
<th>3% Dragonite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus (kpsi)</td>
<td>459</td>
<td>490</td>
<td>488</td>
<td>521</td>
</tr>
<tr>
<td>Yield Strength (psi)</td>
<td>13084</td>
<td>13771</td>
<td>13834</td>
<td>14010</td>
</tr>
<tr>
<td>Elongation to break (%)</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Notched Izod (ft-lb/in)</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Unnotched Izod (ft-lb/in)</td>
<td>7.3</td>
<td>7.2</td>
<td>10.2</td>
<td>12.5</td>
</tr>
</tbody>
</table>
## Dragonite in PA6

<table>
<thead>
<tr>
<th>Property</th>
<th>PA6</th>
<th>4% Dragonite</th>
<th>8% Dragonite</th>
<th>14% Dragonite</th>
<th>19% Dragonite</th>
<th>27% Dragonite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus (Kpsi)</td>
<td>398</td>
<td>521</td>
<td>539</td>
<td>671</td>
<td>700</td>
<td>891</td>
</tr>
<tr>
<td>Flexural Strength (psi)</td>
<td>14785</td>
<td>18428</td>
<td>18351</td>
<td>20272</td>
<td>21041</td>
<td>21817</td>
</tr>
<tr>
<td>Notched Izod Impact (ft-lb/inch)</td>
<td>1.2</td>
<td>0.94</td>
<td>0.90</td>
<td>0.95</td>
<td>0.94</td>
<td>0.93</td>
</tr>
<tr>
<td>Density (gcm⁻³)</td>
<td>1.13</td>
<td>1.16</td>
<td>1.186</td>
<td>1.226</td>
<td>1.262</td>
<td>1.317</td>
</tr>
</tbody>
</table>

Dragonite pre-dried, no surface treatment
Case Study #1
Dragonite HP™ in HDPE Temporary Flooring

Objective:
- To increase strength and stiffness of a 1000lb compression molded part while retaining the excellent impact resistance of HDPE
- Reduce warpage caused by thermal expansion and contraction (CTE)

Solution:
- Reduced warpage & CTE by with as little as 1% loading of Dragonite HP™
- Retained the impact resistance of the control
- Drop-in solution
Nanotubes in Perspective

...the production capacity for all carbon nanotubes, nanofibers, graphenes, fullerenes and nanodiamonds was 4,065 tons in 2010, and is expected to exceed 12,300 tons in 2015. The actual production was less than 25% of the capacity in 2010 and about 50% of the capacity in 2015. Total production value is estimated at about $435 million in 2010 and is expected reach a value of $1.3 billion in 2015.

- Production capacity of the Dragon Mine exceeds the global capacity of all those materials combined
- Furthermore, Dragonite is safe, natural and is less than 1/100th the cost of even the cheapest carbon nanotubes
Agenda

- Introduction to fillers
- What is Halloysite?
- Mechanical properties
- Processing advantages
- Flame retardance
- Sustained release of actives
- Availability and pricing
- Conclusions
Case Study #2
Cycle Time Reduction for HDPE Part

**PHASE 1:**
Drop-in solution: Significant cycle time reduction

<table>
<thead>
<tr>
<th></th>
<th>Virgin HDPE</th>
<th>HDPE + 1% Dragonite HP</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycle time per part (seconds)</td>
<td>107</td>
<td>80</td>
<td>25%</td>
</tr>
<tr>
<td>Parts per hour</td>
<td>34</td>
<td>45</td>
<td>32%</td>
</tr>
<tr>
<td>Cost per part ($)</td>
<td>8.07</td>
<td>7.53</td>
<td>7%</td>
</tr>
<tr>
<td>Effective cost of HDPE ($/lb)</td>
<td>0.85</td>
<td>0.76</td>
<td>11%</td>
</tr>
</tbody>
</table>

- At 1 wt% Dragonite-HP loading, the customer achieved a 25% reduction in cycle time resulting in significant manufacturing cost reduction
- Results based on actual commercial process of the end user
- The customer was able to reduce the visibility of sink marks by >60%
- A 20% increase in stiffness without affecting impact resistance of the final part
- Also validated in PP copolymer and homopolymer
- Applies to injection molding and extrusion

**PHASE 2:** Testing in Progress
Additional savings through thin-walling

Better mechanicals enables thin-walling:
- 5-10% reduction in wall thickness
- 10% further reduction in cycle time
- 5–10¢ per lb additional savings
Low Shear Viscosity in PP (230° C)

Overlay of 3 PP samples

- ▲ PP +25% Dragonite
- ◊ PP +1% Dragonite
- ⚪ Unmodified PP

Shear Rate (1/s)

Viscosity (Pa.s)
Agenda

- Introduction to fillers
- What is Halloysite?
- Mechanical properties
- Processing advantages
- Flame retardance
- Sustained release of actives
- Availability and pricing
- Conclusions
## Flame Retardancy: Dragonite-XR vs. MDH- Magnesium Hydroxide

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dragonite XR</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Magnesium Hydroxide (ST)</td>
<td>0</td>
<td>60</td>
<td>40</td>
<td>30</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>PP 20 MFI</td>
<td>100</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td><strong>Flexural Modulus tangent (kpsi)</strong></td>
<td>207</td>
<td>432</td>
<td>467</td>
<td>464</td>
<td>521</td>
<td>557</td>
</tr>
<tr>
<td>Flexural Modulus 1% (kpsi)</td>
<td>212</td>
<td>373</td>
<td>391</td>
<td>392</td>
<td>440</td>
<td>461</td>
</tr>
<tr>
<td>Flexural Strength (psi)</td>
<td>6517</td>
<td>5131</td>
<td>5350</td>
<td>5347</td>
<td>5666</td>
<td>6200</td>
</tr>
<tr>
<td>Tensile Modulus (kpsi)</td>
<td>150</td>
<td>277</td>
<td>275</td>
<td>285</td>
<td>300</td>
<td>294</td>
</tr>
<tr>
<td>Tensile Strength (psi)</td>
<td>5180</td>
<td>3242</td>
<td>3182</td>
<td>3189</td>
<td>3650</td>
<td>3818</td>
</tr>
<tr>
<td>Notched Izod Impact ft-lb/in</td>
<td>0.44</td>
<td>0.54</td>
<td>0.54</td>
<td>0.5</td>
<td>0.45</td>
<td>0.43</td>
</tr>
<tr>
<td>Smoke</td>
<td>low</td>
<td>low</td>
<td>very low</td>
<td>very low</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td><strong>UL 94 Rating</strong></td>
<td>V2</td>
<td>V1</td>
<td>V1</td>
<td>V1</td>
<td>V1</td>
<td>V1</td>
</tr>
</tbody>
</table>
Advantages of Dragonite-XR™
Reduced Flammability

Heat release rate of neat PP and PP/Halloysite composites

Source: 2010 Society of Chemical Industry: Du, Guo, Jia
PET FR Development

- Reinforcing, halogen free flame retardant
- Good mechanicals in combination with glass fiber
- High water release temperature >400°C means Dragonite™ is ideally suited to polymers processed at high temperature
- Char strength boosted with Dragonite-XR plus glass fiber
- Synergistic fluxing effect under investigation

30% + 5% GF  30% + 10% GF  30% + 15% GF
Agenda

- Introduction to fillers
- What is Halloysite?
- Mechanical properties
- Processing advantages
- Flame retardance
- Sustained release of actives
- Availability and pricing
- Conclusions
Halloysite Tubules
### Loading the Tubes

<table>
<thead>
<tr>
<th>Property</th>
<th>Density</th>
<th>Weight % Oil</th>
<th>Volume % Oil</th>
<th>Loading %*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dragonite</td>
<td>2.666</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>1 Wintergreen</td>
<td>2.503</td>
<td>5.2</td>
<td>11</td>
<td>58</td>
</tr>
<tr>
<td>2 Wintergreen</td>
<td>2.583</td>
<td>2.7</td>
<td>5.9</td>
<td>31</td>
</tr>
<tr>
<td>3 Wintergreen</td>
<td>2.111</td>
<td>21</td>
<td>37</td>
<td>190</td>
</tr>
<tr>
<td>4 Winter &amp; Cedar</td>
<td>2.479</td>
<td>5</td>
<td>12</td>
<td>63</td>
</tr>
<tr>
<td>5 Tinuvin 292</td>
<td>2.467</td>
<td>5.2</td>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>6 Tinuvin 292</td>
<td>2.448</td>
<td>5</td>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>7 Tinuvin 292</td>
<td>2.466</td>
<td>5.2</td>
<td>13</td>
<td>68</td>
</tr>
<tr>
<td>8 Mustard</td>
<td>2.620</td>
<td>1</td>
<td>2.6</td>
<td>14</td>
</tr>
</tbody>
</table>

Based on Halloysite having 19% Lumen volume
Cedar Oil 0.95 gcm\(^{-3}\) Oil of Wintergreen 1.17 gcm\(^{-3}\) Tinuvin 292: 0.99 gcm\(^{-3}\)
50:50 Cedar + Wintergreen assumed 1.06 gcm\(^{-3}\) Mustard 1.00 gcm\(^{-3}\)
Agenda

- Introduction to fillers
- What is Halloysite?
- Mechanical properties
- Processing advantages
- Flame retardance
- Sustained release of actives
- Availability and pricing
- Conclusions
Availability and Pricing

- Dragonite™ brand high-purity Halloysite is commercially available from Applied Minerals
- Dragonite™ is shipped directly from the Dragon Mine in Utah, USA
- Masterbatch concentrates are available as well as neat powder
- Supply is plentiful (>30ktons) to support large-scale applications
- Pricing is in the $1-3 / lb range
- Samples are available to interested parties
- Technical support is also available
Conclusions

- Nanotubular materials have long held great promise
- High cost, lack of availability and other factors have slowed progress until now
- Dragonite™ is 100% natural, safe, cost-effective and abundant enough to support large-scale commercial applications
- Due to high aspect ratio, surface area and easy dispersibility, Halloysite provides effective reinforcement to plastics and elastomers
- Water release at high temperature give a halogen-free FR alternative for high temperature and engineering polymers
- The hollow tubes provide a controlled release effect
Thank You For Your Time

Q&A
Applied Minerals Contact:
Dr. Chris DeArmitt, CTO
(212) 226-4254
cdearmitt@appliedminerals.com
www.appliedminerals.com