EXCITING FUNCTIONAL FILLERS THAT YOU MAY NOT HAVE TRIED

Dr. Chris DeArmitt FRSC
OUTLINE

• Introduction to LKAB Minerals (formerly Minelco)
• Magnetite – a multi-functional specialty filler
• Phlogopite mica – PW80 a new breakthrough grade
• HyperCarb – pure Huntite, a new functional filler
• Conclusions
THE LKAB GROUP IN BRIEF

- World leading producer of upgraded iron ore
- Delivered 25.5 Million MT in 2013, plan to grow to 37 Million MT
- Two underground mines in Kiruna and Malmberget and open pit mining in Svappavaara
- Producer of 90% of EU’s iron ore
- ~4,400 employees
- 30 companies in 15 countries
  - E.g. Drilling, Concrete, Explosives, Railway, Harbour, Construction.
- Turnover 2013: USD 3.2 Billion
BROAD APPLICABILITY

We focus our R&D resources on mineral and application development in the areas of:

Civil Engineering and Construction

Polymers and Coatings

Refractory and Foundry
MAGNiF – HIGH PURITY MAGNETITE
MAGNETITE PROCESSING
MAGNETITE ORE

1. Density 5.2 gcm$^{-3}$
2. Moh Hardness ~6
3. Semi-conductive
4. Thermally conductive
5. High specific heat capacity
6. Extremely pure

1. Sound deadening, weights
2. Solid surfaces
3. Anti-static, shielding, induction & microwave heatable, tracer
4. Improved productivity
5. Heat storage
6. Food contact approved
MAGNETITE IN USE
PHLOGOPITE MICA – VHAR REINFORCEMENT
## MINERAL REINFORCEMENTS COMPARED

<table>
<thead>
<tr>
<th>Particle Dimensions (Malvern)</th>
<th>Calcined Clay</th>
<th>Wollastonite</th>
<th>Talc</th>
<th>Phlogopite Mica PW80</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_{50}$</td>
<td>3</td>
<td>3.5</td>
<td>12</td>
<td>37</td>
</tr>
<tr>
<td>$D_{90}$</td>
<td>10</td>
<td>13</td>
<td>40</td>
<td>95</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Reinforces in</td>
<td>2 directions</td>
<td>1 direction</td>
<td>2 directions</td>
<td>2 directions</td>
</tr>
</tbody>
</table>
PHLOGOPITE MICA

1. Chemically inert
2. Electrical insulator
3. Bronze colored
4. Stable to 900ºC
5. Platy shape
6. Extremely pure (low quartz)

1. Barrier
2. Dielectric
3. Pigment
4. FR applications
5. Reinforces in two directions, sound deadening
6. Food contact approved
SEM OF PHLOGOPITE MICA PW80

Mag = 2.00 K X  
10μm  
EHT = 5.00 kV  
WD = 12 mm  
Detector = SE2  
Photo No. = 685
# REINFORCEMENT COMPARISON IN PA6

<table>
<thead>
<tr>
<th>Property</th>
<th>Talc 40%</th>
<th>Calcined Clay 40%</th>
<th>Wollastonite 40%</th>
<th>Phlogopite Mica 40%</th>
<th>GF 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus (MPa)</td>
<td>7400</td>
<td>6120</td>
<td>5514</td>
<td>10370</td>
<td>11980</td>
</tr>
<tr>
<td>Flexural Strength (MPa)</td>
<td>120</td>
<td>150</td>
<td>135</td>
<td>155</td>
<td>290</td>
</tr>
<tr>
<td>Tensile Modulus (MPa)</td>
<td>7470</td>
<td>6313</td>
<td>5450</td>
<td>11160</td>
<td>13215</td>
</tr>
<tr>
<td>Break Stress (MPa)</td>
<td>74</td>
<td>87</td>
<td>83</td>
<td>95</td>
<td>195</td>
</tr>
<tr>
<td>Break Strain (%)</td>
<td>2.8</td>
<td>6.4</td>
<td>8.4</td>
<td>1.7</td>
<td>2.6</td>
</tr>
<tr>
<td>Unnotched Charpy (kJm⁻²)</td>
<td>28.5</td>
<td>80</td>
<td>No Break</td>
<td>29</td>
<td>79</td>
</tr>
<tr>
<td>Notched Charpy (kJm⁻²)</td>
<td>3.5</td>
<td>6.4</td>
<td>6.4</td>
<td>4.0</td>
<td>12.8</td>
</tr>
<tr>
<td>Shrinkage = (%)</td>
<td>0.65</td>
<td>1.31</td>
<td>1.06</td>
<td>0.58</td>
<td>0.1</td>
</tr>
<tr>
<td>Shrinkage</td>
<td></td>
<td>(%)</td>
<td>0.97</td>
<td>1.66</td>
<td>1.64</td>
</tr>
<tr>
<td>Warpage (%)</td>
<td>0.32</td>
<td>0.35</td>
<td>0.58</td>
<td>0.29</td>
<td>0.88</td>
</tr>
</tbody>
</table>
# REINFORCEMENT COMPARISON IN PA6

<table>
<thead>
<tr>
<th>Property</th>
<th>GF25% Talc 15%</th>
<th>GF 25% Clay 15%</th>
<th>GF 25% Wollastonite 15%</th>
<th>GF 25% Phlogopite Mica 15%</th>
<th>GF 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural Modulus (MPa)</td>
<td>9843</td>
<td>9350</td>
<td>9080</td>
<td>10550</td>
<td>11980</td>
</tr>
<tr>
<td>Flexural Strength (MPa)</td>
<td>210</td>
<td>213</td>
<td>226</td>
<td>231</td>
<td>290</td>
</tr>
<tr>
<td>Tensile Modulus (MPa)</td>
<td>11400</td>
<td>9950</td>
<td>10100</td>
<td>12200</td>
<td>13215</td>
</tr>
<tr>
<td>Break Stress (MPa)</td>
<td>140</td>
<td>144</td>
<td>144</td>
<td>165</td>
<td>195</td>
</tr>
<tr>
<td>Break Strain (%)</td>
<td>2.4</td>
<td>3.4</td>
<td>2.6</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>Unnotched Charpy (kJm$^{-2}$)</td>
<td>52.3</td>
<td>43.6</td>
<td>50.3</td>
<td>60</td>
<td>79</td>
</tr>
<tr>
<td>Notched Charpy (kJm$^{-2}$)</td>
<td>7.4</td>
<td>5.6</td>
<td>6.9</td>
<td>8.6</td>
<td>12.8</td>
</tr>
<tr>
<td>Shrinkage = (%)</td>
<td>0.22</td>
<td>0.26</td>
<td>0.23</td>
<td>0.22</td>
<td>0.1</td>
</tr>
<tr>
<td>Shrinkage</td>
<td></td>
<td>(%)</td>
<td>0.91</td>
<td>0.99</td>
<td>1.04</td>
</tr>
<tr>
<td>Warpage (%)</td>
<td>0.69</td>
<td>0.73</td>
<td>0.81</td>
<td>0.59</td>
<td>0.88</td>
</tr>
</tbody>
</table>
SOUND DAMPING - VHAR MICA VS OTHER MINERALS

CUSTOMER FEEDBACK ON PW80

“It’s magic”
high performance coatings company

“It blew everything else out of the water”
leading plastics manufacturer

“significantly better than everything else”
Fortune 500 company
VHAR PHLOGOPITE MICA

- High purity Phlogopite Mica as starting material
- State of the art wet grinding and classification for optimal aspect ratio and particle size control
- Excellent reinforcement alone or in combination with glass fiber
- The best solution for nylon, PP and other engineering thermoplastics, comparable to double the amount of talc
- Warpage control, superb electrical properties and sound damping are other key advantages
HYPERCARB – PURE HUNTITE
HMH: A BLEND OF TWO MINERALS

**Huntite:**
magnesium calcium carbonate

\[
\text{Mg}_3\text{Ca} (\text{CO}_3)_4 + 1 \text{kJ/g} \\
\rightarrow 3\text{MgO} + \text{CaO} + 4\text{CO}_2
\]

**Hydromagnesite:**
hydrated magnesium carbonate

\[
\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2\cdot4\text{H}_2\text{O} + 1 \text{kJ/g} \\
\rightarrow 5\text{MgO} + 4\text{CO}_2 + 5\text{H}_2\text{O}
\]
HYDROMAGNESITE & HUNTITE DECOMPOSITION

Residual Mass (%) vs Temperature

- Hydromagnesite
- Huntite
- UltraCarb LH15

Temperature: Fahrenheit 0-1470

Residual Mass: 0-100
PLATY MORPHOLOGY

HMH

ATH

HUNTITE
ANALYSIS OF THE ASH RESIDUE

Increasing Huntite content gives a stronger ash residue.
## HUNTITE

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Calcium magnesium carbonate</td>
<td>High surface area</td>
</tr>
<tr>
<td>2. High surface area</td>
<td>High refractive index and small</td>
</tr>
<tr>
<td>3. High refractive index and small</td>
<td>Alkaline</td>
</tr>
<tr>
<td>4. Alkaline</td>
<td>Platy shape</td>
</tr>
<tr>
<td>5. Platy shape</td>
<td>Extremely pure</td>
</tr>
<tr>
<td>6. Extremely pure</td>
<td></td>
</tr>
</tbody>
</table>

| Acid scavenger, chemical & physical blowing agent, dissolvable         |                                                                             |
| 1. Acid scavenger, chemical & physical blowing agent, dissolvable      | 2. Foam nucleation, rheology                                                 |
| 2. Foam nucleation, rheology                                           | 3. Partial TiO₂ replacement                                                  |
| 3. Partial TiO₂ replacement                                            | 4. Allows unimpeded cure                                                     |
| 4. Allows unimpeded cure                                               | 5. Reinforces in two directions                                               |
| 5. Reinforces in two directions                                         | 6. Food contact approved                                                     |
CONCLUSIONS

• Specialty minerals allow new levels of performance
• Established minerals like mica can still be innovative
• Magnetite has been used for decades but its full potential has not yet been tapped
• HyperCarb, pure Huntite is a new functional filler with unique properties that gives new opportunities
Information herein is intended for guidance only and given in good faith but without guarantee. LKAB Minerals is not responsible for the product’s suitability for a particular purpose. The only warranty LKAB Minerals makes is the express written warranty extended on the sale of its products.

THANK YOU! – QUESTIONS?