APPLIED MINERALS INC.

DRAGONITE™

Halloysite Based: Halogen Free, Reinforcing Flame Retardant for Engineering Thermoplastics

BCC – Stamford CT, May 22nd 2012

Dr. Chris DeArmitt - CTO

APPLIED MINERALS INC.

Agenda

- Applied Minerals
- Halloysite structure & properties
- Enhancing plastics
- Case study: PET pallets
- Commercial aspects
- Conclusions

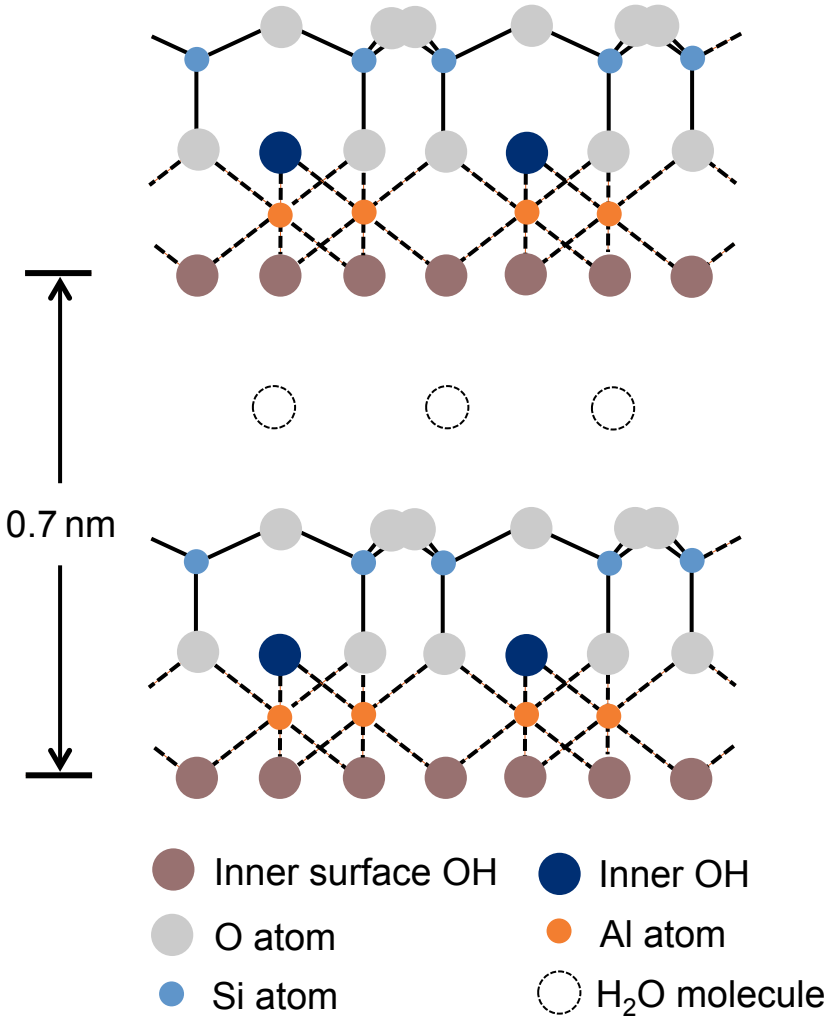
Applied Minerals at a Glance

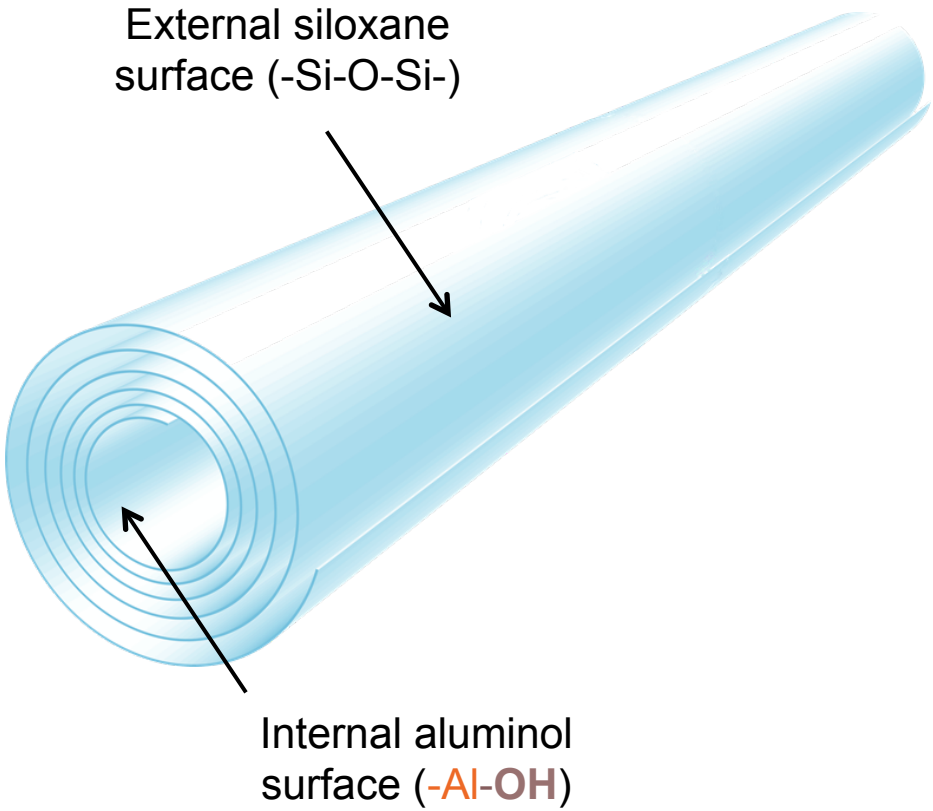
- US based publicly traded SEC reporting company.
- Owner and operator of the Dragon Mine Halloysite Clay Deposit in Utah USA
- Over 30 years of proven reserves
- Product grades marketed under the *Dragonite*™ trade name
- World renowned technical experts in geology, minerals characterization, plastics and materials
- Over $ 7M invested to date in resource characterization and quantification
- Became commercial in 2010 with 30 000 tons annual capacity and expanding in 2012

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

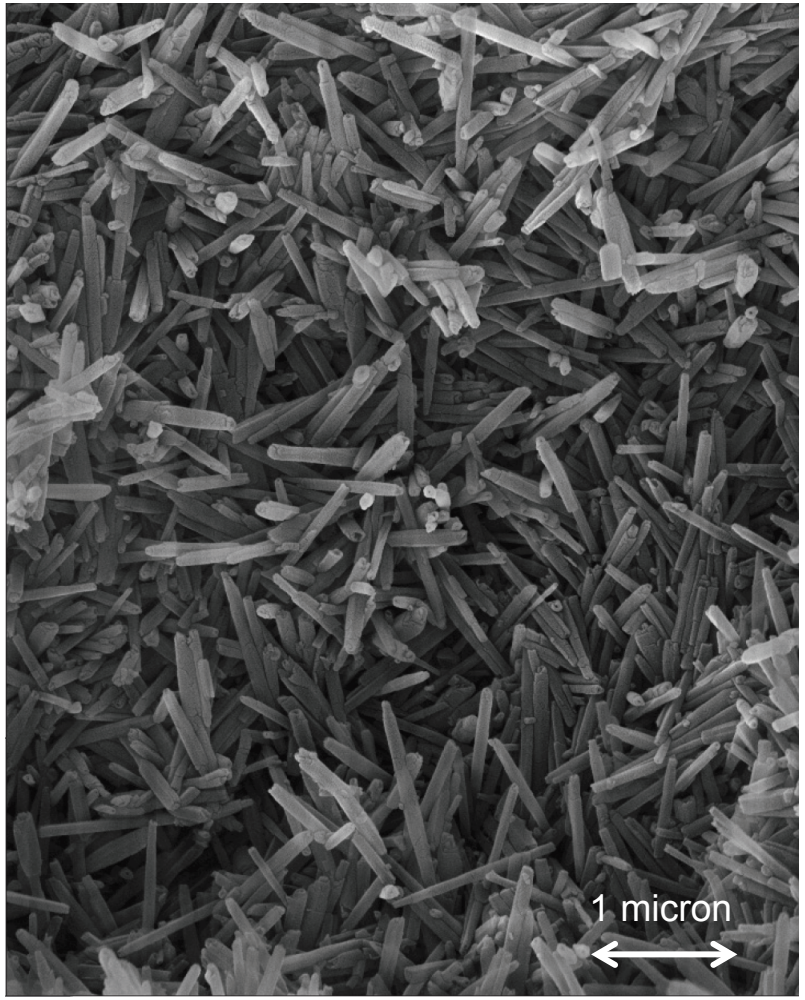
Dragonite Chemistry





Characterization and Quality Control

Length	0.2-2 µm
Outside Diameter	50-70 nm
Inside Diameter	15-45 nm
Aspect Ratio (L/D)	10-40
Particle Size (d_{100}) < 5 µm	95-100%
Particle Size (d_{90}) < 2 µm	80-98%
BHT Surface Area	65 m^2g^{-1}
True Specific Gravity	2.53 gcm^{-3}
Bulk Density	~16 lbs / ft^3
BHT Pore Volume	20%
Oil (linseed) Absorption	40 lbs / 100 lbs
Cation Exchange Capacity	11 meq /100g



Halloysite Property Overview

- Aluminosilicate mineral: $Al_2Si_2O_5(OH)_4 \cdot nH_2O$
- Molecular weight: 294.19
- CAS: 1332-58-7
- Density: 2.54 ± 0.03 gcm^{-3}
- Refractive index at room temperature: 1.534, dried at 100°C 1.548
- Specific heat capacity: 0.92 $kJkg^{-1}K^{-1}$
- Thermal conductivity: 0.092 $WK^{-1}m^{-1}$
- Thermal diffusivity: 5.04 x 10^{-4} cm^2 sec^{-1}
- CTE: 10.0 ± 1.5 perpendicular to the layer, 6.0 ± 2.0 parallel
- Colorless and UV transparent
- pH in water 6.4-7.2
- Particle shape: 1-2 microns long, 50nm across, 15nm diameter hole
- Modulus ~130 GPa
- Surface area: 65-120 m^2g^{-1}
- Dragonite™ purity: 95-100%

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

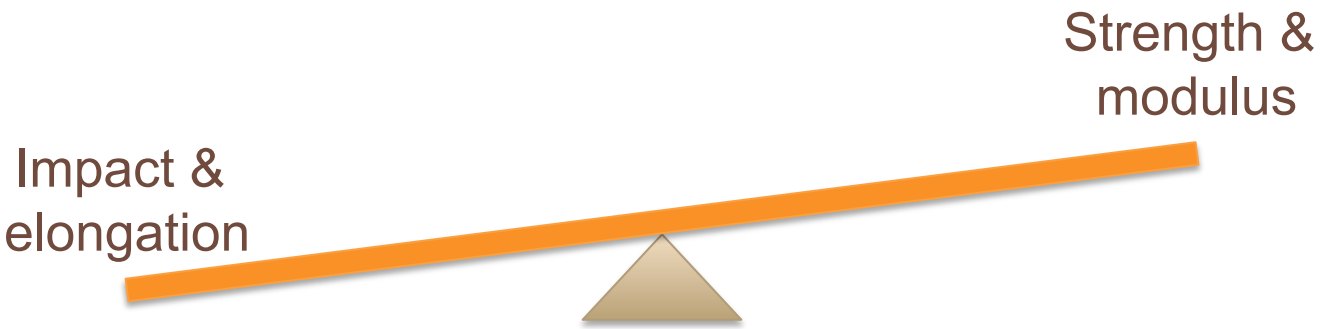
Hollow

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

Bound water

- Fire retardance, temperature indicator, foaming agent

Property See-Saw



- 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

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The Challenge

Customer target is for a high-performance pallet:

- Flexural Modulus ~1000 kpsi
- Flexural Strength ~18000 psi
- Notched Izod Impact resistance ~1 J/cm^2
- MFI 15 g/10 min due to existing mold
- Fire retardance to UL 2335
- Safe, non-migrating and halogen free FR requirement
- Starting point is Rynite 35% GF filled PET but unable to achieve mechanicals and UL 2335 with existing FR packages

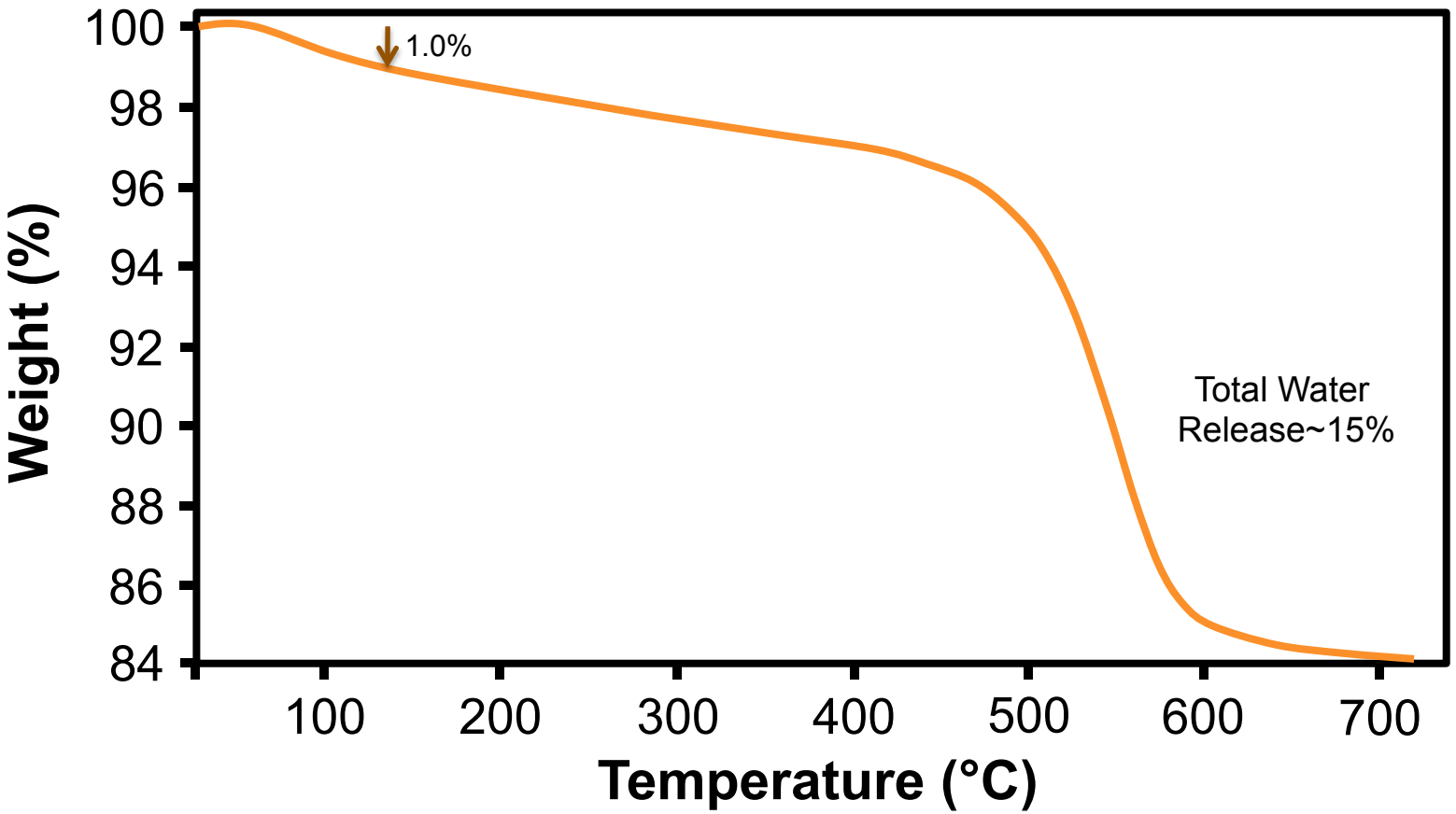
Why Dragonite?

- Other solutions had failed to provide the answer
- Phosphorous-based systems plasticize
- Halogenated products not acceptable
- Mineral based FR like ATH and MDH not appropriate for PET
- Dragonite known to reinforce while retaining impact and providing FR
- Natural, safe, non-migrating, cost-effective and commercially available in quantity

Experimental Plan

- Prepare a highly loaded Dragonite masterbatch in recycled PET copolymer that can be combined with commercial Rynite GF PET
- Pre-drying the Dragonite and good dispersion essential
- Selected Americhem due to their experience with hydrolytically unstable polymers, excellent dispersion ability and QC
- Dragonite has some reactivity so adding a surfactant or stabilizer can be beneficial
- In this case 2% RDP was chosen due to proven affinity to Dragonite and previously reported results (BCC 2011)
- The aim was to add the Dragonite masterbatch in the minimum amount needed to pass UL 2335

Dragonite Thermal Stability by TGA



Dragonite Solution

35%GF Rynite Control- 7 g/10'
65 Rynite/ 35 Americhem MB - 20 g/10'
60 Rynite/ 40 Americhem MB - 24 g/10'

	Ctrl	1	2	3
Rynite 35% CGF filled PC	100	80	65	60
45% MB of HNT in Copolyester	**0**	**20**	**35**	**40**
residue from ash test 750 C, 30 minute	34.3	36%	37.8	36.8
% Actual clay	0	9.9	16	18.6
% CGF	34.3	27.6	15.75	21
Color	black	black	black	black
Speific Gravity	1.58	1.595	1.585	1.598
Flex modulus, tangent, Kpsi	1577	1115	1085	1026
Flex modulus,1 %, kpsi	1510	1110	1066	1020
Flex Strength, psi	31112	19849	19417	17643
Break strain under flex	3.2	2.37	2.4	2.24
Tensile Strength, psi	16690	11538	12281	11056
% el @ yield	6.5	5	4.92	4.63
% El @ break	6.5	5	4.92	4.63
Notched Izod Impact, ft-lb/in	1.58	0.75	0.89	0.71
Unnotched izod ft-lb/in	13.4	8.1	9.2	7.2

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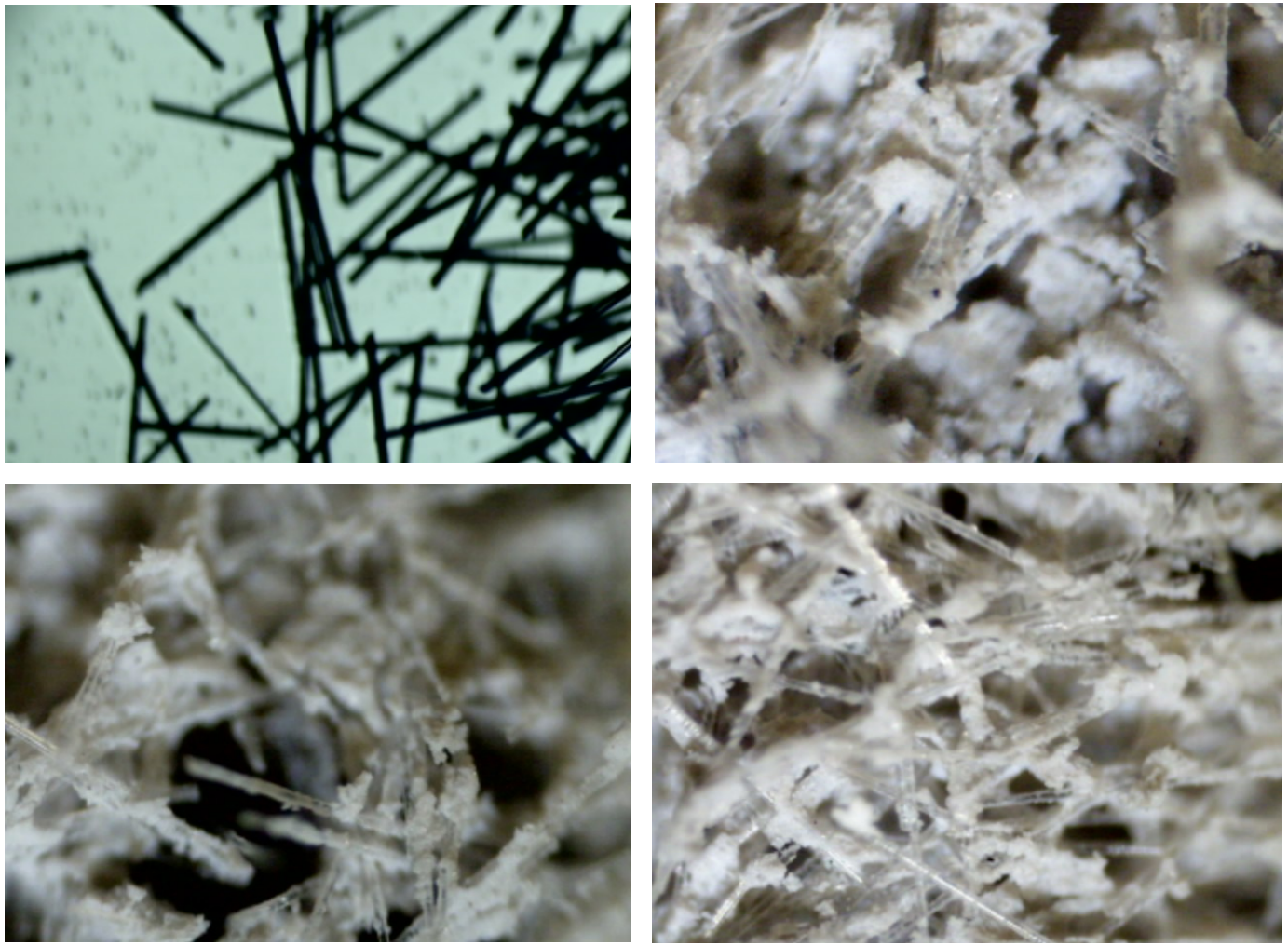
% Actual clay	0	9.9	16	18.6
% CGF	34.3	27.6	15.75	21
Density of char				1.485
UL vertical, 23x 10 sec S/E	X	X	X	X
Burning up to clamp	CB	CB	CB	CB
Flaming VB Drip	No	No	No	No
S/E < 30 seconds	No	No	No	No
Smoke	blk	blk	blk	blk
seconds to burn 5 cm (needs >180s)	135	150	165	229
burning rate horizontal,	0.344827586	0.333	0.3030	0.2183
Average weight of tensile bars	12.71	12.8	12.99	13.18

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™ plus glass fiber
- Synergistic fluxing effect

30% GF + 5% HNT 30% GF + 10% HNT 30% GF + 15% HNT

Ceramification?



Pallet Formulation Summary

- All mechanical targets met
- Dragonite is reinforcing so it was possible to replace a portion of the glass fiber and still have good strength and modulus
- Impact resistance was retained at an acceptable level
- By adding the Dragonite in recycled PET copolymer the flow was increased, essential for injection molding
- Fire retardance to UL 2335 certification anticipated (underway)
- Safe, non-migrating and halogen free FR requirement
- We continue to optimize this formulation while also extending this reinforcing FR masterbatch approach to PP, PA6 etc.

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Commercial Status

- Dragon Mine Halloysite deposit characterized and proven in 2010
- Commercialization status:
  - Nucleation of HDPE and PP for better mechanicals and reduced cost in injection molded parts and extruded profiles
  - The only reinforcing and halogen-free mineral fire retardant for engineering plastics (recent Samsung press release)
  - Reinforces foams, improves productivity and helps surface appearance
  - Several new developments in the pipeline

Availability

- 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 (>30 ktons) to support large-scale applications
- Samples are available to interested parties
- Technical support is also available

Thank You For Your Time

Q&A

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