APPLIED MINERALS INC.

December 7th, 2011

DRAGONITE™

Halloysite – The Natural Reinforcement for Elastomeric Systems

Presented by: Dr. Chris DeArmitt – CTO

Silicone Elastomers 2011

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Agenda

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

Markets Addressed

Plastics

Productivity +20%
Mechanicals +20%
Flame retardance

Coatings & Adhesives

UV cure speed +20%
Mechanicals +20%
Improved adhesion

Environment

Oil clean-up
Soil remediation
Water purification

Elastomers

Reinforcement
Flame retardance
Thermal stability

Markets Addressed

- Additive for plastics, elastomers and coatings
- Global fillers for plastics market is > $13 BN (> 9 Million tons)[1]
  - Elastomers 50%
  - Thermoplastics 35%
  - Thermosets 15%
- Global market for fillers in coatings > $1.8 BN[2]
- Global controlled release market > $21 BN (for drugs alone)[3]
- Global soil remediation market $25-30 BN[4]

1. Strategic Analysis of the Global High Performance Fillers Market, Frost & Sullivan 2008
2. World Inorganic Filler Market, Acmite Market Intelligence 2009
3. Controlled-Release Drug Delivery Analysis, Epsicom 2008
4. Advances in Applied Bioremediation, Springer 2009 ISBN 978-3-540-89620-3

Reinforcements Market

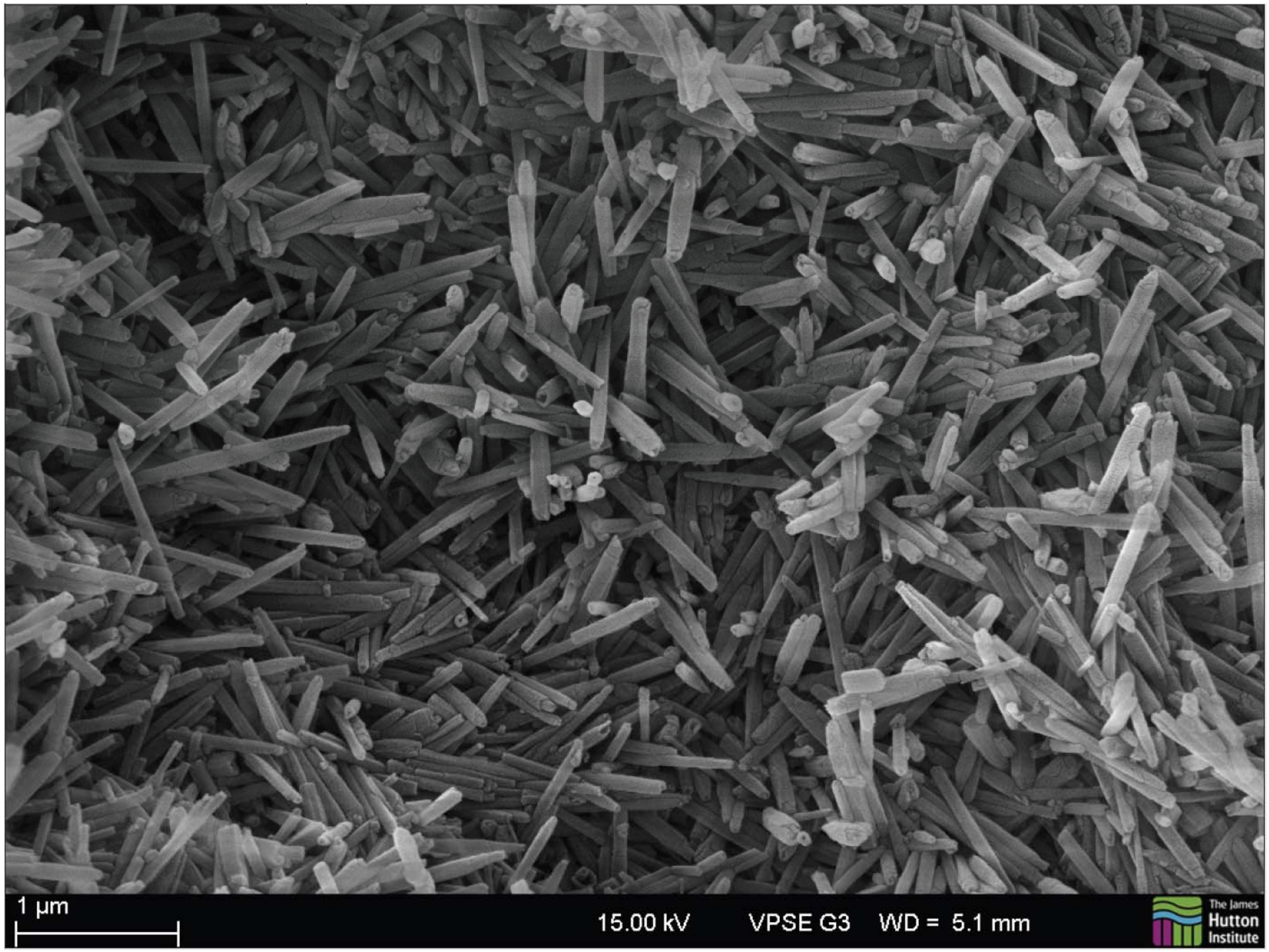
Filler	Millions of Tons	Billions of Euros
Carbon Black	4.5	3.96
Natural $CaCO_3$	2.3	0.17
Precipitated $CaCO_3$	0.2	0.12
Precipitated Silica	0.3	0.3
$Al(OH)_3$	0.3	0.17
Talc	0.3	0.14
Kaolin	0.2	0.03
Others	0.8	0.12
Total	8.9	5.01

Source: Rothon Consultants

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™ SEM



Halloysite Property Overview

- Aluminosilicate mineral: $Al_2Si_2O_5(OH)_4 . nH_2O$
- Molecular weight: 294.19
- CAS: 1332-58-7
- Density: 2.70 ± 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
- 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

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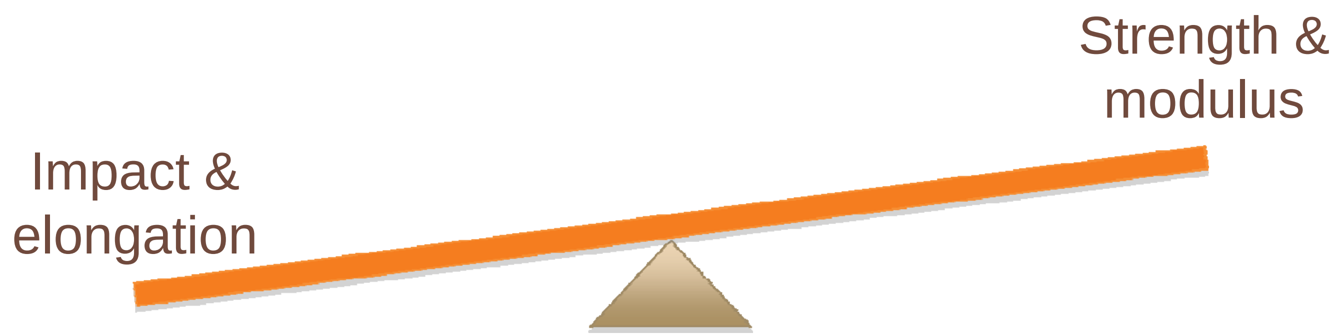
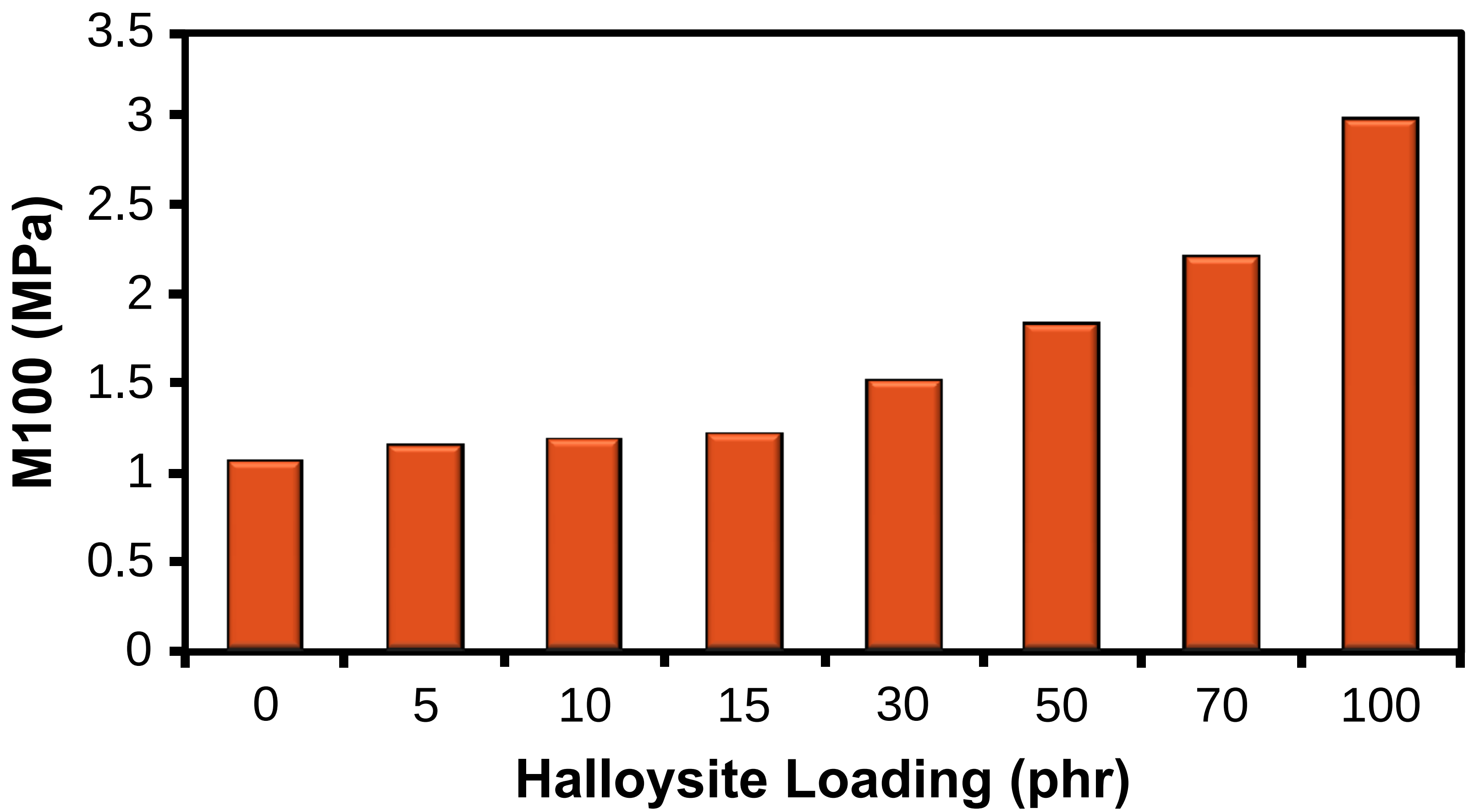
Property See-Saw



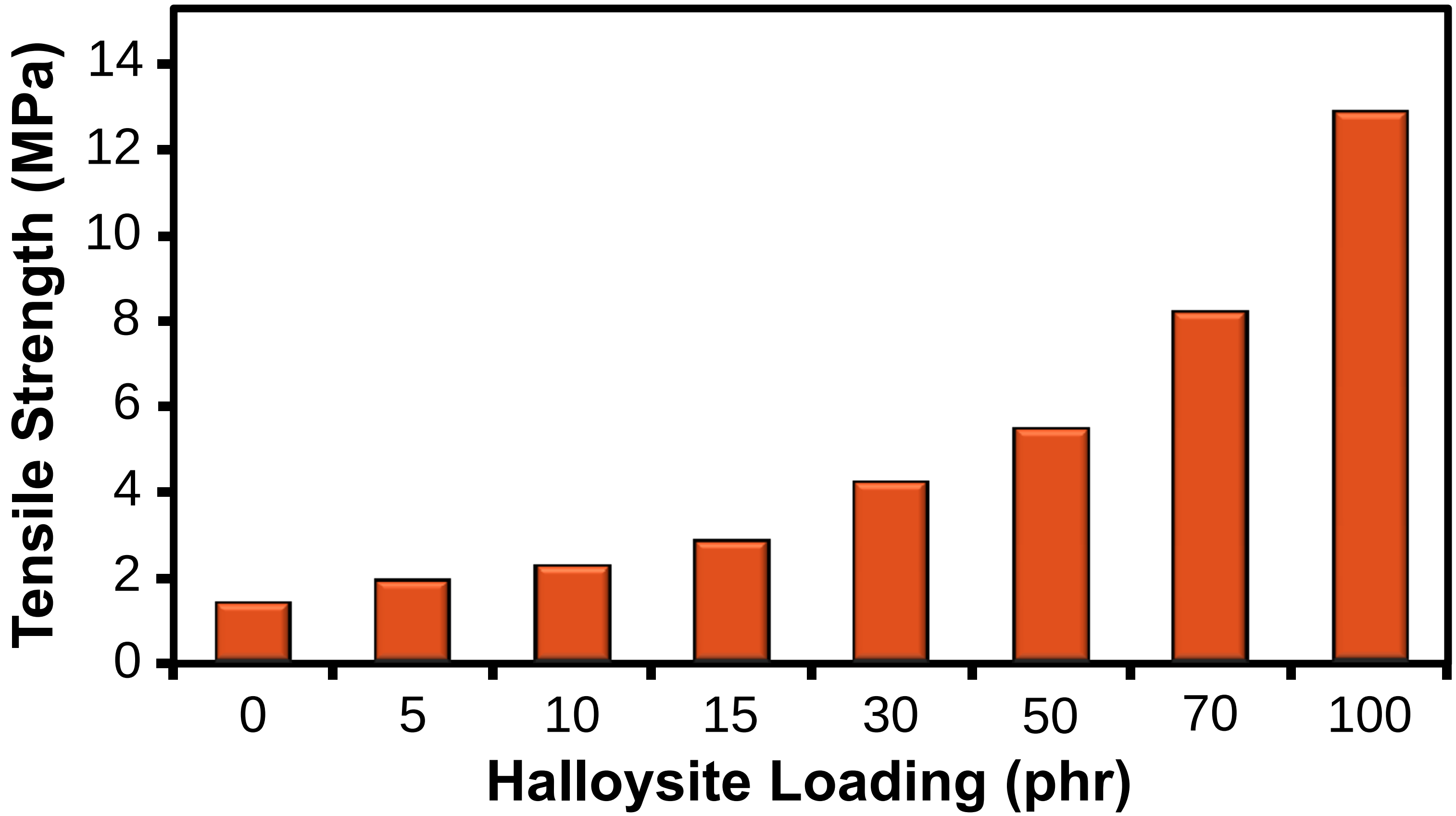
- Isotropic fillers retain impact but do not reinforce
- Reinforcing fillers ruin impact resistance and elongation to break
- Halloysite reinforces and retains or improves impact and elongation
- This is possible due to shape, surface area and easy dispersibility

Halloysite in EPDM Rubber



Morphological, thermal and tensile properties of halloysite nanotubes filled ethylene propylene diene monomer (EPDM) nanocomposites, H. Ismail**,** Pooria Pasbakhsh, M.N. Ahmad Fauzi, A. Abu Bakar*, Polymer Testing 27*: 841-850 (2008).

Halloysite in EPDM Rubber



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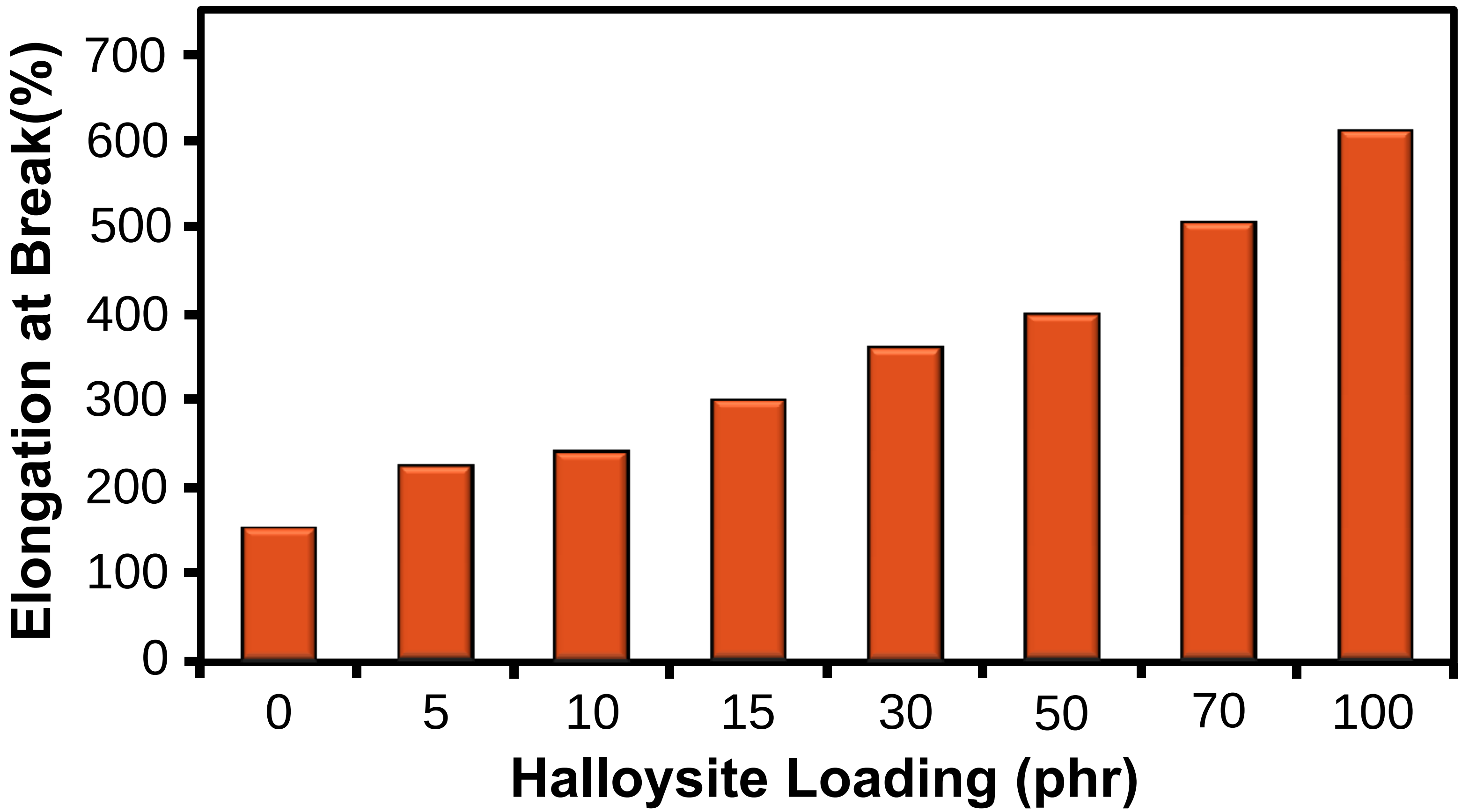

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Halloysite in EPDM Rubber

Material	M100 Modulus (MPa)	Tensile Yield Strength (MPa)	Elongation to Break (%)	UL 94 Classification
EPDM Unfilled	1.07	1.32	151	Unclassified
+5 phr Halloysite	1.16	1.94	223	Unclassified
+10 phr Halloysite	1.21	2.21	241	Unclassified
+15 phr Halloysite	1.24	2.85	299	Unclassified
+30 phr Halloysite	1.52	4.19	361	V-2
+50 phr Halloysite	1.85	5.42	400	V-1
+70 phr Halloysite	2.22	8.15	506	V-1
+100 phr Halloysite	2.99	12.86	613	V-0

Morphological, thermal and tensile properties of halloysite nanotubes filled ethylene propylene diene monomer (EPDM) nanocomposites, H. Ismail, Pooria Pasbakhsh, M.N. Ahmad Fauzi, A. Abu Bakar, *Polymer Testing 27*: 841-850 (2008).

Halloysite with Natural Rubber

Material	200% Modulus (MPa)	300% Modulus (MPa)	Tensile Strength (MPa)	Elongation to Break (%)
Natural Rubber	0.83	1.12	14	1496
+10 phr Silica	1.03	1.03	12	996
+10 phr Halloysite	1.12	1.54	18	1270
+10 phr Halloysite + silane	1.24	2.18	15	1050

Preparation and properties of natural nanocomposites based on natural rubber and naturally occurring halloysite nanotubes, S. Rooj, A. Das, V. Thakur, R.N. Mahaling, A. K. Bhowmick, G. Heinrich*, Materials and Design 31*: 2151-2156 (2010).

Halloysite with SBR

Material	300% Modulus (MPa)	Tensile Strength (MPa)	Elongation to Break (%)	Permanent Set (%)
SBR	1.33	2.4	610	4
+10 phr Halloysite	2.27	3.4	580	6
+20 phr Halloysite	3.02	4.7	590	8
+30 phr Halloysite	3.57	6.6	600	16
+40 phr Halloysite	5.09	8.4	580	20
+50 phr Halloysite	4.81	9.3	600	30

Morphology, interfacial interaction and properties of styrene-butadiene rubber/modified Halloysite nanotube nanocomposites
Z.-X. Jia, Y.-F. Luo, S.-Y. Yang, B.-C. Guo, M.-L. Du, D.-M. Jia , *Chin. J. Polym. Sci 27(6)*: 857-864 (2009).
1:1 molar mixture of hexamethylenetriamine and resorcinol as coupling agent

Halloysite with FKM Fluoroelastomer

Material	100% Modulus (MPa)	(E'_O-E'_∞)Modulus (MPa)	Tensile Strength (MPa)	Elongation to Break (%)
FKM gum	2.5	7.45	4.5	197
+5 phr Halloysite	3.0	8.50	6.2	217
+10 phr Halloysite	3.4	13.91	6.8	205
+20 phr Halloysite	3.6	15.48	7.3	200
+30 phr Halloysite	2.6	11.97	5.6	254

Tube-like natural halloysite/fluoroelastomer nanocomposites with simultaneous enhanced mechanical, dynamic mechanical and thermal properties, S. Rooj, A. Das, G. Heinrich, *European Polymer Journal* doi:10.1016/j.eurpolymj.2011.06.007.

Dispersibility of Halloysite and Polarity

FKM	PE, PP	PVC, PA12	PET, PA6	Water
Very low polarity ~20 mJm^{-2}	Low polarity ~35 mJm^{-2}	Medium polarity ~40 mJm^{-2}	High polarity ~45 mJm^{-2}	Very high polarity ~70 mJm^{-2}

- 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

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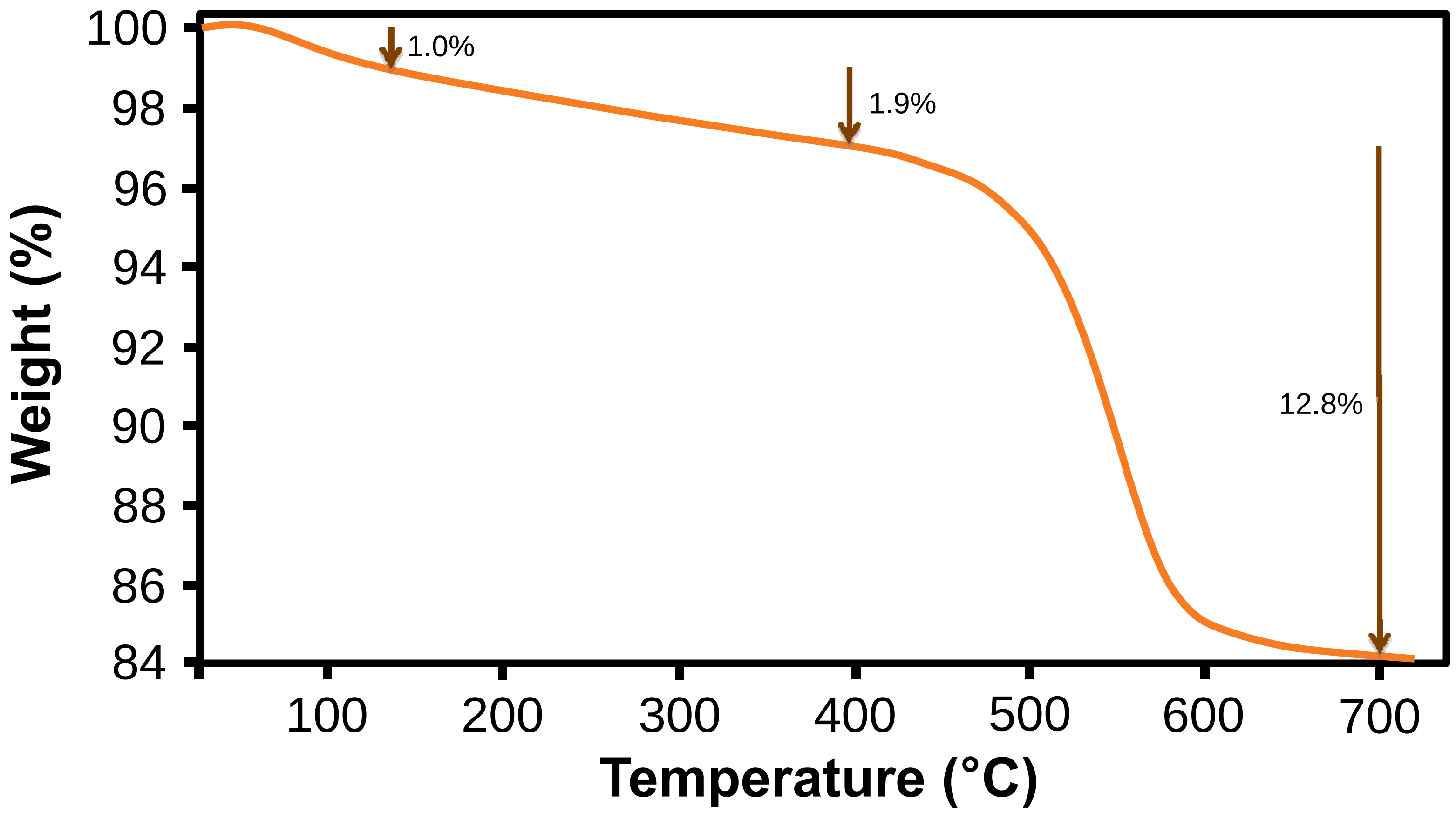
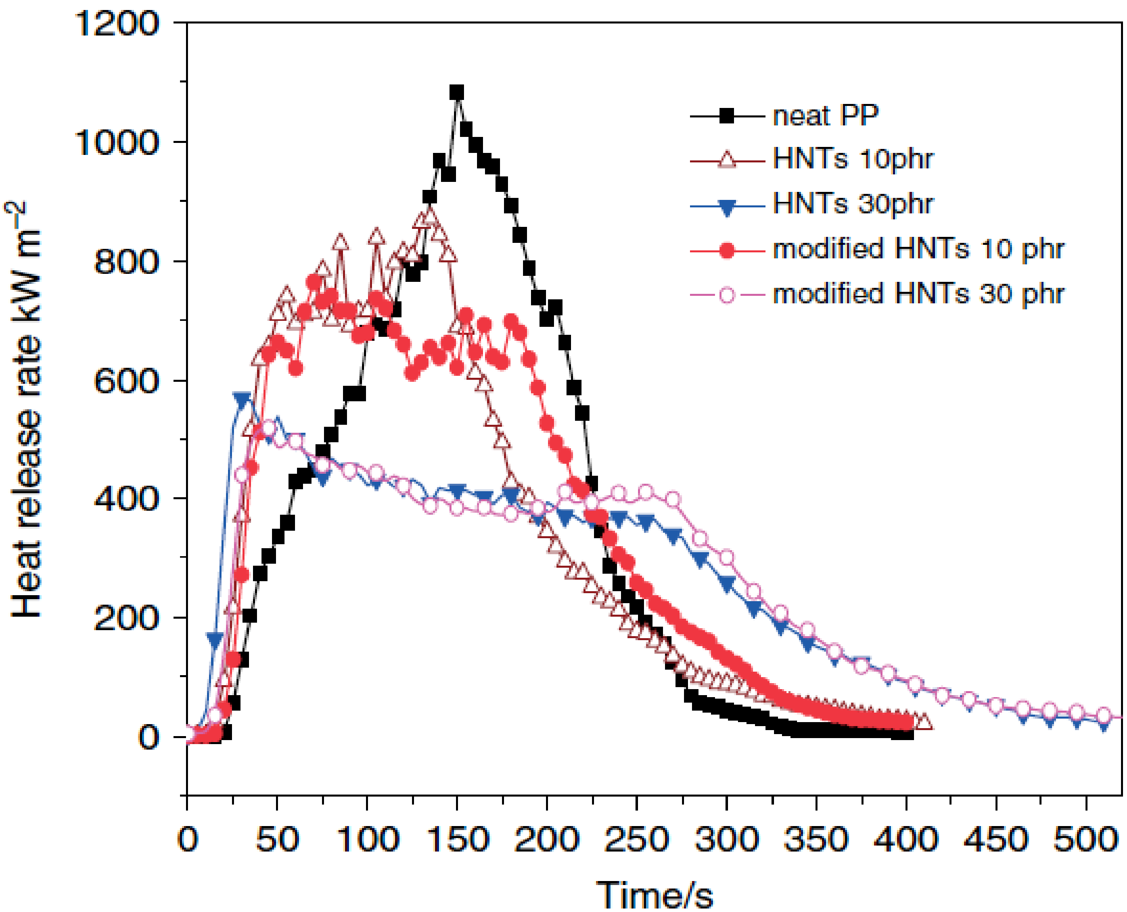
Dragonite Thermal Stability by TGA



Flame Retardancy:
Dragonite XR vs. MDH - Magnesium Hydroxide

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

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™ plus glass fiber
- Synergistic fluxing effect under investigation

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

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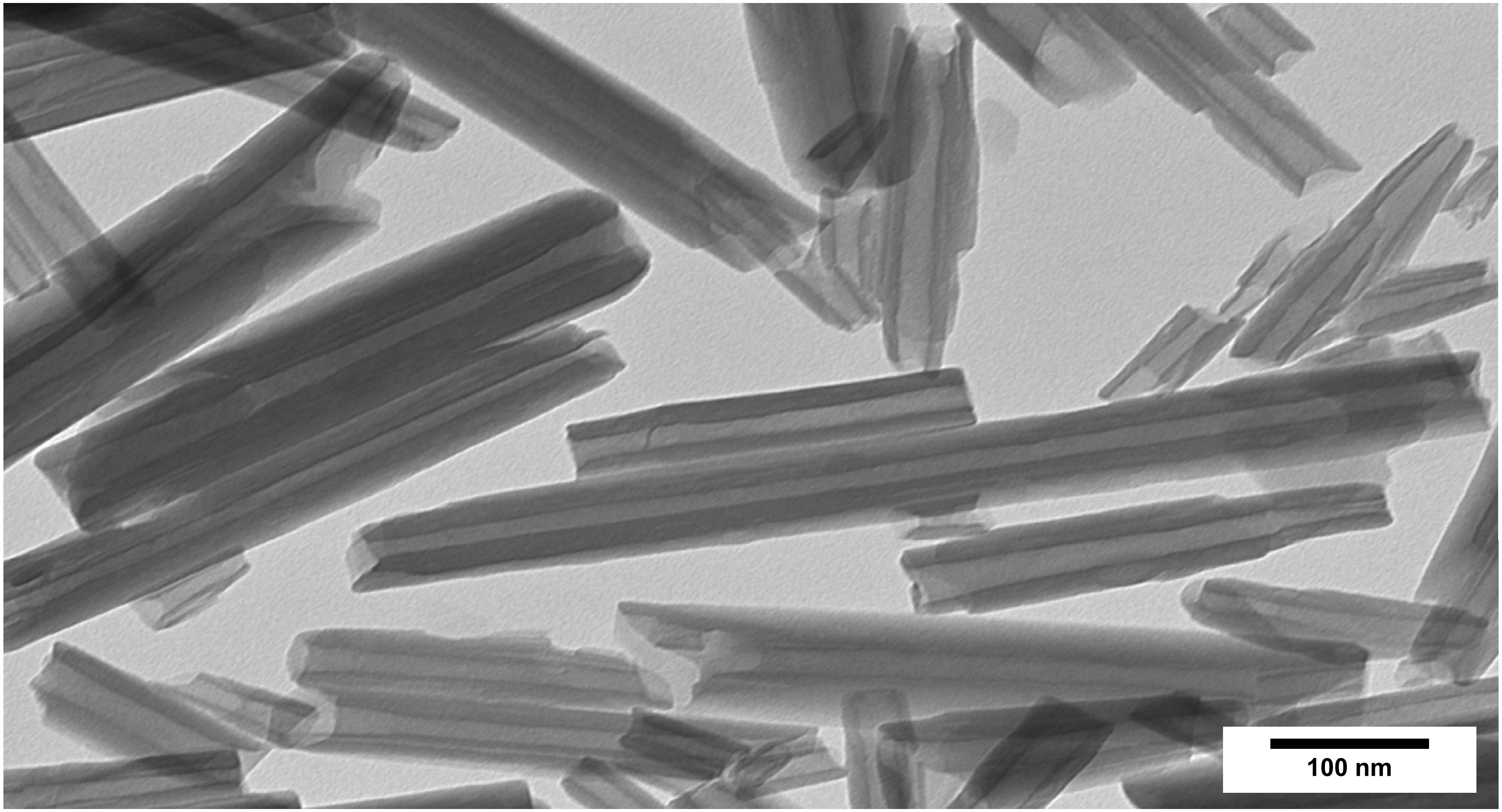
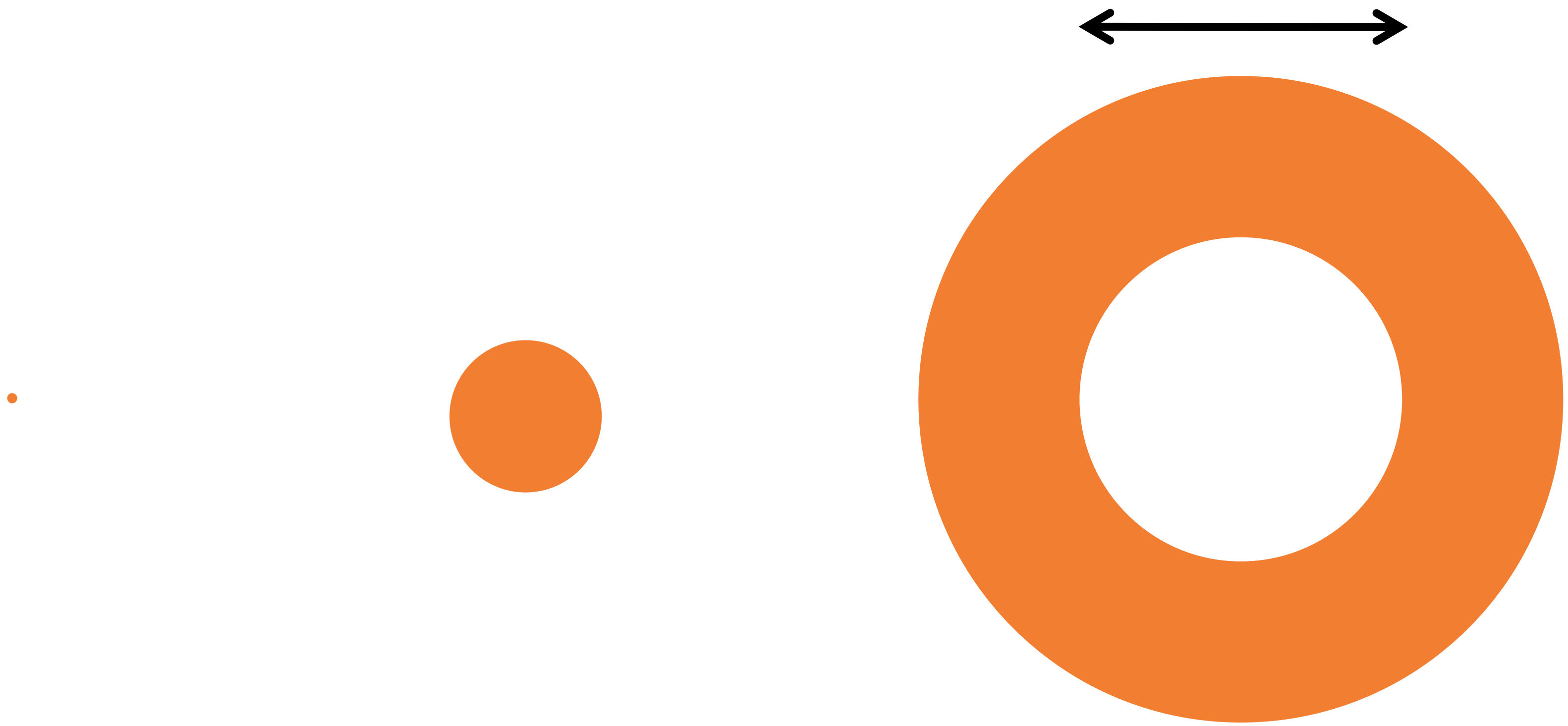
Halloysite Tubules



Controlled-Release

0.5 nm | 7 nm | 15 nm



Glucose
180 Da

Hemoglobin Protein
60 kDa

Dragonite™

Loading the Tubes

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

*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}

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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

iRAP, Inc., ET-113:Production and Application of Carbon Nanotubes, Carbon Nanofibers, Fullerenes, Graphene and Nanodiamonds: A Global Technology Survey and Market Analysis

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

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APPLIED MINERALS INC.