APPLIED MINERALS INC.

DRAGONITE™

Halloysite for reinforcement and processing improvement in polymer foams

InnoPlast – Plastic Modification Technologies
Las Vegas October 17th-19th

Dr. Chris DeArmitt - CTO

APPLIED MINERALS INC.

Agenda

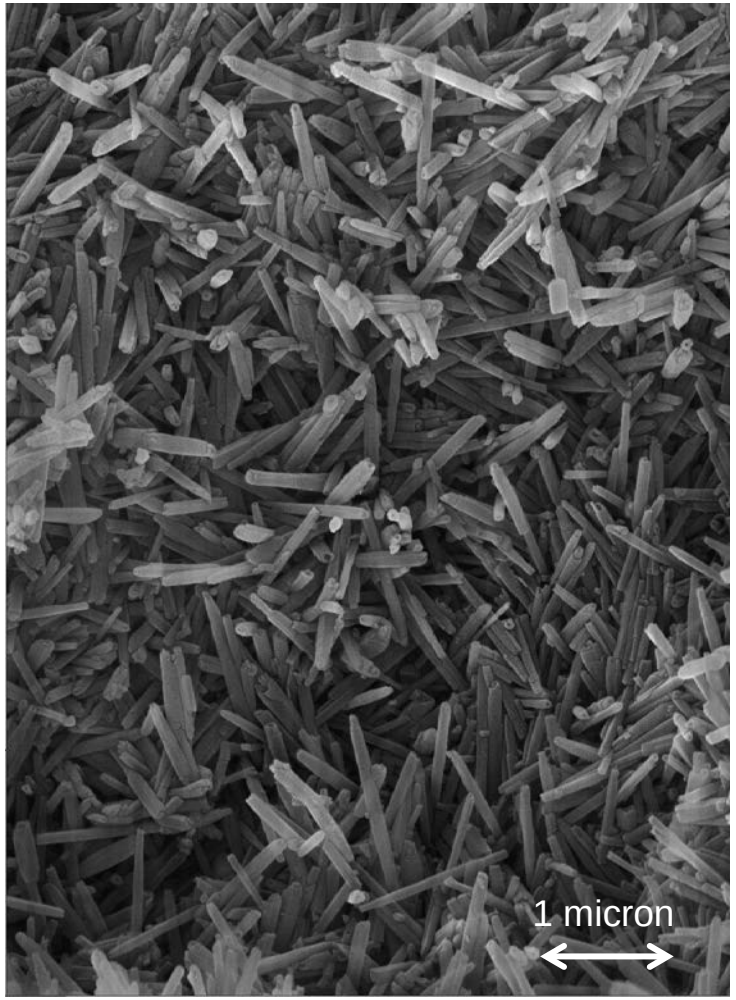
- Applied Minerals
- Halloysite structure & properties
- Enhancing plastics
- Case study: Cycle time reduction
- Case study: Injection molded foam
- Case study: Extruded foam
- Case study: FR HDPE pallets
- Commercial aspects
- Conclusions

Applied Minerals at a Glance

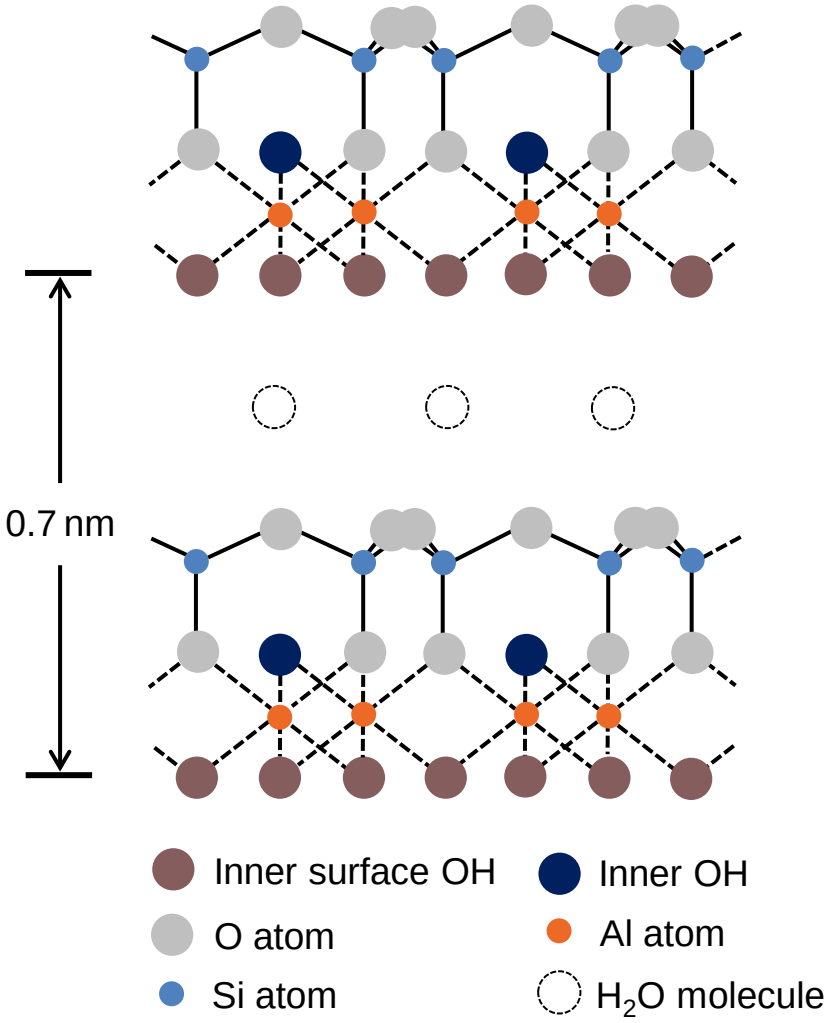
- US based publicly traded SEC reporting company
- Owner and operator of the Dragon Mine Halloysite Clay Deposit in Utah USA
- Over 30 years of proven reserves
- Product grades marketed under the *Dragonite*™ trade name
- World renowned technical experts in geology, minerals characterization, plastics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

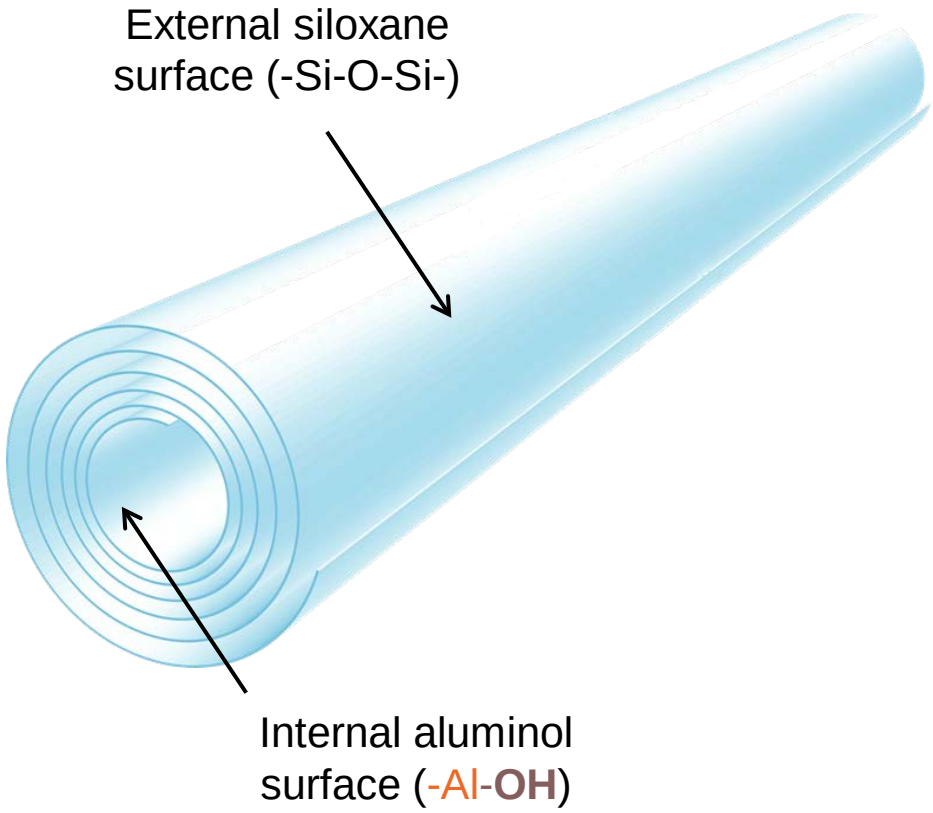
Characterization and Quality Control

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



Dragonite Chemistry





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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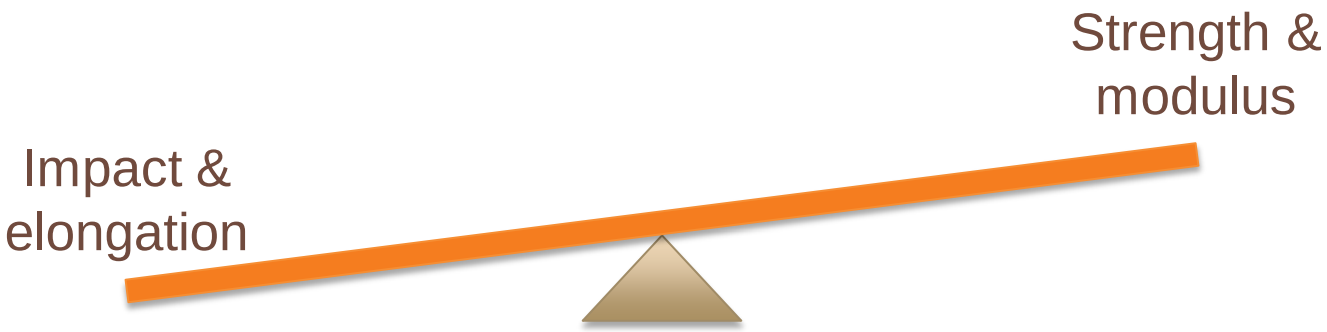
Dragonite in Plastics

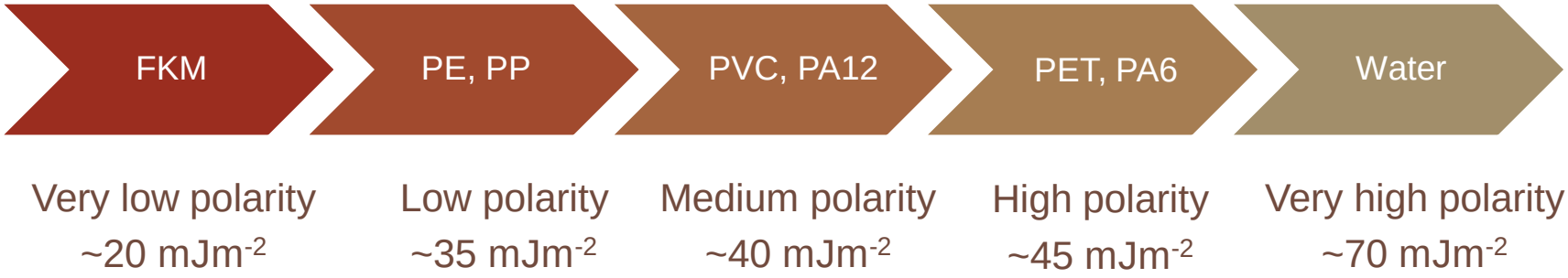
Plastic Type	Reinforcement	Cycle Time / Nucleation	Transparent Film	Flame Retardance
PE	✔	✔	✔	✔
PP	✔	✔	✔	✔
EVA	✔	TBD	✔	✔
PA6	✔	✔	TBD	✔
PA12	✔	✔	TBD	✔
PVC	✔	TBD	✔	✔
PLA	✔	✔	✔	✔
Epoxy	✔	TBD	TBD	✔
EPDM	✔	TBD	TBD	✔
Suggested Grade	Dragonite™ XR or HP	Dragonite™ HP	Dragonite™ HP	Dragonite™ XR

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

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

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Dragonite HP: DSC Results in HDPE

Performed independently by Dr. Yash Khanna

Material	Tcc $3^{o}Cmin^{-1}$	Tcc $10^{o}Cmin^{-1}$
HDPE Control 1	117.3	114.5
HDPE Control 2	117.3	113.9
		115.2
		114.9
Average	**117.3**	**114.6**
+ 1% Dragonite HP	119.6	116.2
+ 1% Dragonite HP	119.5	116.5
Average	**119.55**	**116.35**

US20120101209A1 Nucleating Agent for Polyethylenes

Dragonite Nucleation of HDPE studied by XRD

	Content (%)		Crystallite Size (Å)	
	Crystalline (CI)	Monoclinic	110	200
Control HDPE	67.6 (0.5)	2.7 (0.2)	164 (1)	134 (1)
1% Dragonite HP	73.8 (0.8)	1.3 (0.4)	139 (2)	100 (4)
1% Dragonite HP plus stearate	63.0 (1.1)	2.0 (0.6)	165 (2)	136 (3)

Three Injection molded HDPE tensile bars were made for X-ray diffraction (XRD) analysis.

XRD patterns were obtained from the bulk (as opposed to the surface) of the samples by slicing the injection-molded bars and looking into the core of the specimens. One scan was obtained from each of the samples. Data were collected using CuKα radiation from 5° to 65° 2θ.

Scans from ~ 10° to 25° were analyzed by profile fitting the data to an amorphous halo (20°), a monoclinic peak (19.5°), and two orthorhombic peaks at 21.5° (110 reflection) and at 24° (200 reflection)

Additive Grade
Dragonite HP™ Reinforcing/Nucleating Additive in HDPE

Dragonite HP	Control	1% Loading	% Increase
Actual Clay Amount (%)	0	1	
HDPE	100	99	
Total	100	100	
Density (gcm^{-3})	0.947	0.954	
Tensile Strength (psi)	3031	3300	9
Elongation to break (%)	101	107	6
Flexural Modulus (1%, kpsi)	110	134	22
Flexural Strength (psi)	3058	3612	18
Notched Izod Impact ft-lb/in	0.64	0.62	0
Unnotched Izod Impact ft-lb/in	NB	NB	0

Additive Grade
Dragonite HP™ Reinforcing/Nucleating Additive in PP

Dragonite HP	Control	1% Loading	% Increase
Actual Clay Amount (%)	0	1	
PP 12 HG12	100	99	
MB LDPE 38%	0	2.63	
Total	100	100	
Density (gcm^{-3})	0.905	0.908	+0.3
Elongation to break (%)	15	16	+6.7
Flexural Modulus (kpsi)	198	248	+25.3
Flexural Strength (psi)	6015	7200	+19.7
Notched Izod Impact ft-lb/in	0.52	0.52	0
Unnotched Izod Impact ft-lb/in	8	12.6	+57.5

Case Study #1
Cycle time reduction for HDPE part

PHASE 1:

Drop-in solution: Significant cycle time reduction

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

PHASE 2:

Additional savings through thin-walling

Better mechanicals enables thin-walling:

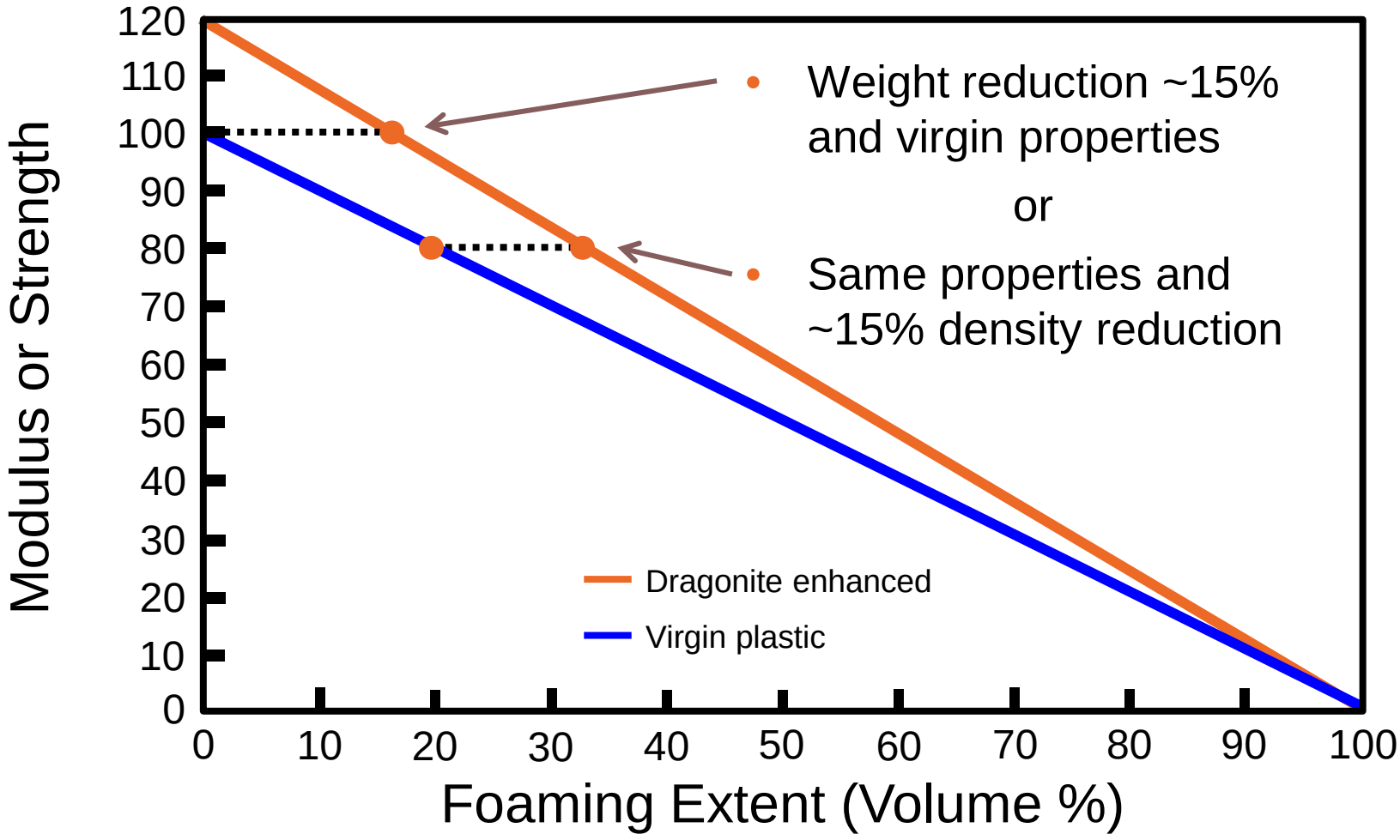
- 5-10% reduction in wall thickness
- 10% further reduction in cycle time
- 5–10¢ per lb additional savings

- 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

Ideal Foam Nucleating Agent

- High surface area
- Irregular shape / anisotropic
- Easily dispersible
- Reinforcing
- Nucleates crystal growth
- Safe
- Inexpensive
- Natural
- Available

Foam Mechanical Properties



Case Study #2
Foamed injection molded HDPE parts

Property	HDPE 897	No HNT	1% HNT	3% HNT	1% HNT from MB	1% HNT from MB
Pressure (psi)	1000	1000	1000	1000	1000	**2200**
Shot Size (inch)	2.1	1.6	1.6	1.6	1.6	**1.4**
Color	Natural	White	Yellow	Yellow	White	**White**
Mean weight (g)	4.414	4.205	4.242	4.242	4.235	**4.048**
Shrinkage (%)	**4**	0.8	1.2	0.4	0.8	**1.2**
Density (%)	**0**	- 8.25	- 8.8	- 8.25	- 9.3	**- 13.6**
Flex Modulus (kpsi)	**133**	139	150	147	151	**152**
Flex Strength (psi)	**3412**	3373	3477	3488	3468	**3430**
Elongation (%)	**150-450**	320-475	140-325	55-225	60-190	**31-360**
Notched Izod	**NB**	11.62	13/HB	12.75	14.6	**13.6**

2.2 % KibbeChem AccuLite 250 Endothermic (equal to 1% chemical blowing agent) except Sample 1 none used & Sample 6 1.1% temperature & back pressure constant

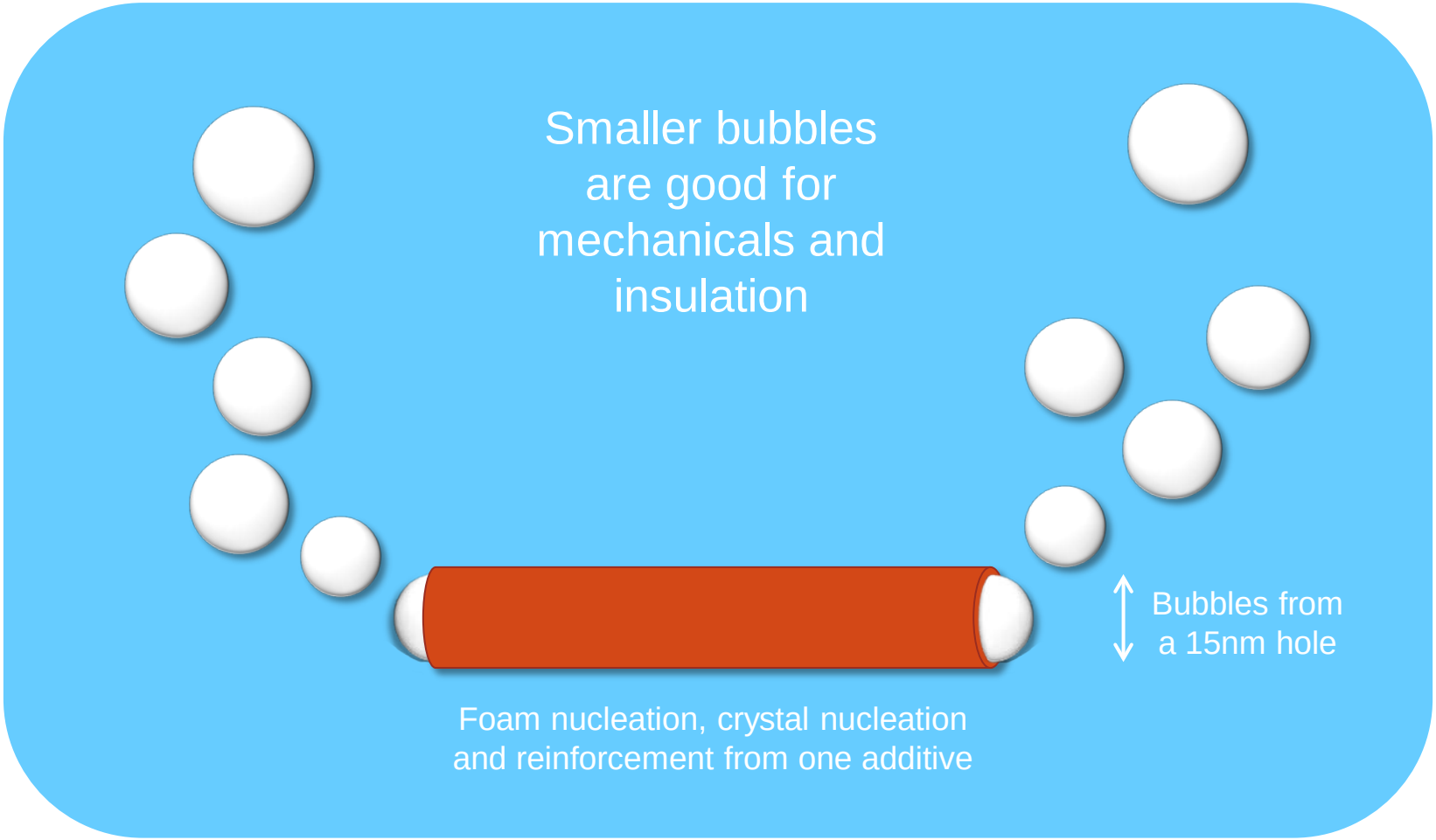
Case Study #2
Foamed injection molded HDPE parts

- Nucleation of crystallization gives faster solidification
- Nucleation of cell formation leads to better mechanicals and surface finish
  - 10-15% weight reduction and same mechanicals as unfoamed HDPE or
  - Same mechanicals as present foam but at lower density
- In automotive applications opt for lower density
- Or go for the cost advantage

Case Study #3
Foamed extruded HDPE sheet

- Nucleation of crystallization gives faster solidification
- Nucleation of cell formation leads to better mechanicals and surface finish
- 30% less endo-exo blowing agent needed (KibbeChem AccuLite 416)
- Production speed up by 30-40% **compared to the foamed control**
- Cheaper, better products

Next Step: Active Nucleation



Tubes hold up to 20 volume % actives
Loading well proven and scaled up with QC method in place

Case Study #4
FR HDPE for pallets

Property	Nova HDPE	Dragonite HP	Dragonite HP:30% RDP	Dragonite HP:KF	Dragonite HP:SP
Clay (weight %) by ash	0	**25**	**25**	24	26
Density (gcm^{-3})	0.944	**1.112**	**1.09**	1.10	1.10
MFI (g/10 min)	1.5	**1.0**	**1.8**	1.0	0.8
Flexural Modulus (kpsi)	108	**222**	**134**	198	213
Flexural Strength (psi)	2880	**4300**	**2917**	4100	4377
Notched Izod (ft-lb/in)	2.1	**0.8**	**1.8**	1.0	0.8
Unnotched Izod (ft-lb/in)	NB	**10**	**NB**	7.6	7.6
Elongation at break (%)	38	**27**	**55**	27	15
Horizontal Burn Rate (inch/min)	1.07 CB Cont drip	**0.92 Falling burning mass**	**0.87 Falling mass no drip**	1.07 Falling mass no drip	0.97 Falling mass no drip

Customer guideline horizontal burn rate < 1 inch / minute should pass UL2335 FR pallet test

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Availability and Pricing

- Dragonite HP™ high-purity Halloysite is commercially available from Applied Minerals
- DragoniteHP™ is shipped directly from the Dragon Mine Utah, USA in powder form
- Dragonite/Foam masterbatch concentrates are available from KibbeChem
- Supply is > 30ktons / yr to support large-scale applications
- Samples of Dragonite HP™ Powder or MB are available
- Technical support is available from Applied Minerals

Conclusions

- Tubular materials have long held great promise
- Due to high aspect ratio, surface area and easy dispersibility, Halloysite provides effective reinforcement with no downside
- Crystal nucleation gives excellent mechanicals and productivity boost
- Foam nucleation improves mechanicals and lowers weight
- Dragonite™ is 100% natural, safe, cost-effective and abundant enough to support large-scale commercial applications
- The benefits are proven by the rapid development and commercialization of new applications in multiple fields

Thank You For Your Time

Q&A

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Dragonite Nucleation of HDPE studied by XRD

	HDPE	PP	PVC	PA6
Modulus (%)	**+30**	**+27**	**+6.5**	**+22**
Yield Strength (%)	**+15**	**+23**	**+5**	**+13.5**
Notched Izod	**No change**	**+40**	**No change**	**No change**
Nucleation	**Yes**	**Yes**	*****	**Yes**

All at **1 weight % loading** incorporated using standard twin-screw extruder
* PVC has very low crystallinity, nucleation not yet investigated

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Case Study #4
FR HDPE for pallets

Property	Nova HDPE	Dragonite HP	Dragonite HP:30% RDP	Dragonite HP:KF	Dragonite HP:SP
Clay (weight %) by ash	0	**25**	**25**	24	26
Density (gcm^{-3})	0.944	**1.112**	**1.09**	1.10	1.10
MFI (g/10 min)	1.5	**1.0**	**1.8**	1.0	0.8
Flexural Modulus (kpsi)	108	**222**	**134**	198	213
Flexural Strength (psi)	2880	**4300**	**2917**	4100	4377
Notched Izod (ft-lb/in)	2.1	**0.8**	**1.8**	1.0	0.8
Unnotched Izod (ft-lb/in)	NB	**10**	**NB**	7.6	7.6
Elongation at break (%)	38	**27**	**55**	27	15
Horizontal Burn Rate (mm/sec)	0.42 CB Cont drip	**0.36 Falling burning mass**	**0.34 Falling mass no drip**	0.42 Falling mass no drip	0.38 Falling mass no drip

Customer guideline horizontal burn rate < 0.38 should pass UL2335 FR pallet test

Dragonite Nucleation of HDPE studied by XRD

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	Crystalline (CI)	Monoclinic	110	200
Control HDPE	67.6 (0.5)	2.7 (0.2)	164 (1)	134 (1)
1% Dragonite HP	73.8 (0.8)	1.3 (0.4)	139 (2)	100 (4)
1% Dragonite HP plus stearate	63.0 (1.1)	2.0 (0.6)	165 (2)	136 (3)
	5.64	5.02	11.73	8.62
	5.41	4.90	10.88	8.02
	5.30	4.79	10.09	7.36
	5.24		9.42	6.91

Dragonite Nucleation of HDPE studied by XRD

	Content (%)		Crystallite Size (Å)	
	Crystalline (CI)	Monoclinic	110	200
Control HDPE	67.6 (0.5)	2.7 (0.2)	164 (1)	134 (1)
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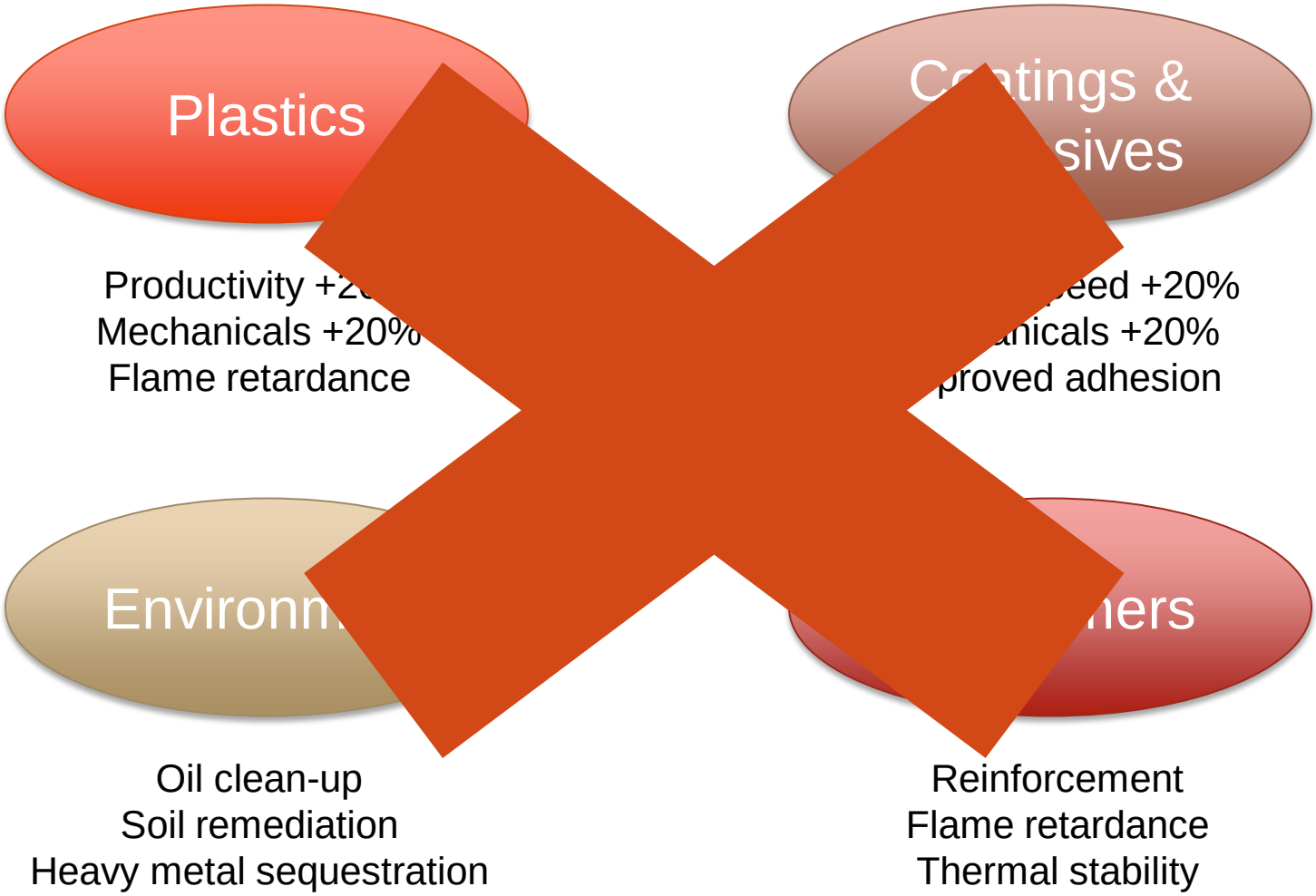
Technology Description - What is Halloysite?

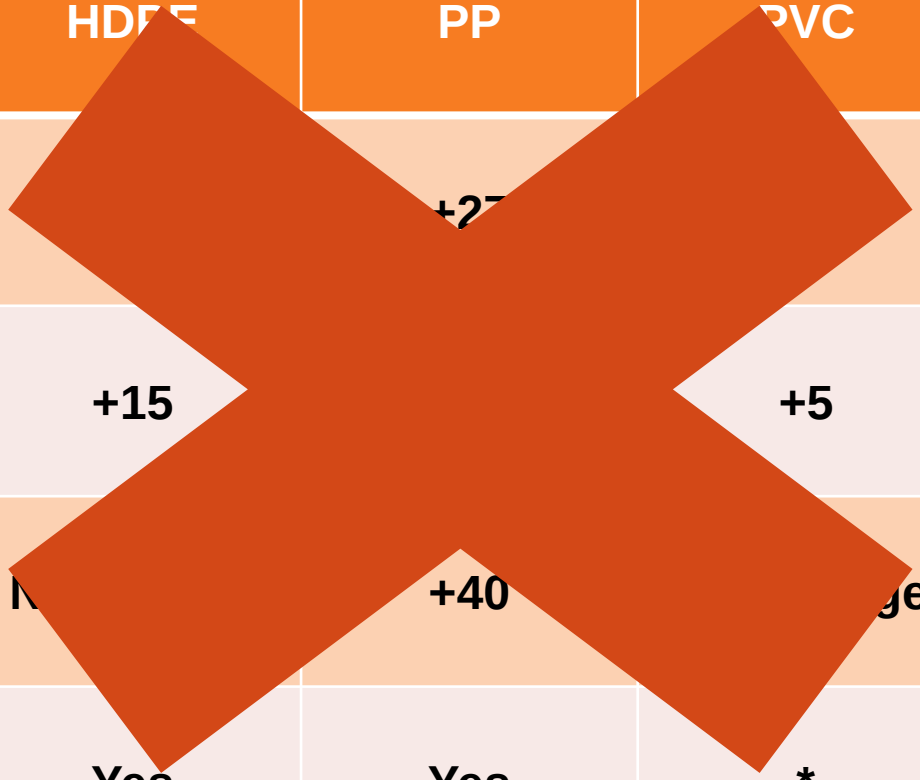
- Halloysite is a natural alu tubular morphology
- Naturally exfoliate eans emically separate particles and makes ersion
- Halloysite nanotubes typ ily have diameter ~50nm ith lengths ranging from 1 to 2 microns giving an aspect ratio of ~20
- Traditional uses include fine china, fillers in paints and paper, food extenders, catalysts and molecular sieves

Markets Addressed



Dragonite in Semi-crystalline Plastics

Property	HDPE	PP	PVC	PA6
Modulus (%)		+27		+22
Yield Strength (%)	+15		+5	+13.5
Notched Izod	N	+40	ge	No change
Nucleation	Yes	Yes	*	Yes



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