LKAB Minerals

QUICKER, QUIETER AND QUENCHING WITH SPECIALTY FILLERS

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MINERAL SOLUTIONS FOR OUR WORLD

OUTLINE

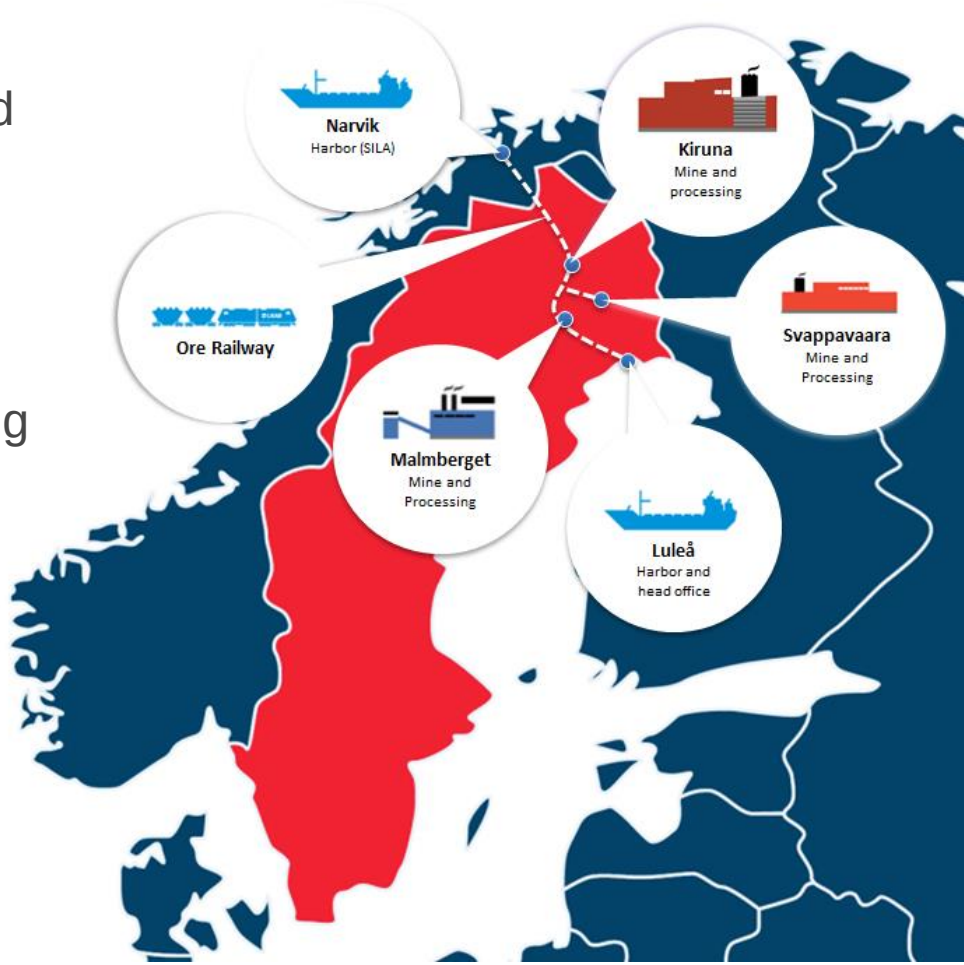
- Introduction to LKAB Minerals (formerly Minelco)
- Magnetite – a multi-functional specialty filler
- Phlogopite MicaFort PW80 a new breakthrough grade
- Performance comparison in nylon and PP
- UltraCarb HMH – a natural mineral flame retardant
- Conclusions

PRESENTER

- KTH, Ytkemiska Institutet, Electrolux (Frigidaire) Stockholm, Electrolux Italy, BASF Germany, Hybrid Plastics, Phantom Plastics, Applied Minerals, LKAB Minerals
- Born in USA, grew up in the UK, 9 years in Sweden, 1 Italy, 4 Germany and now USA 6 years (American & Swedish citizen)
- Experienced in R&D, Marketing, Product Development, Sales
- Expertise in plastics, specialty minerals, materials
- World-class innovator (6 open innovation challenge wins, 14 patents)
- >30 articles, 6 book chapters, 3 encyclopedia chapters
- >30 conference presentations with multiple awards

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

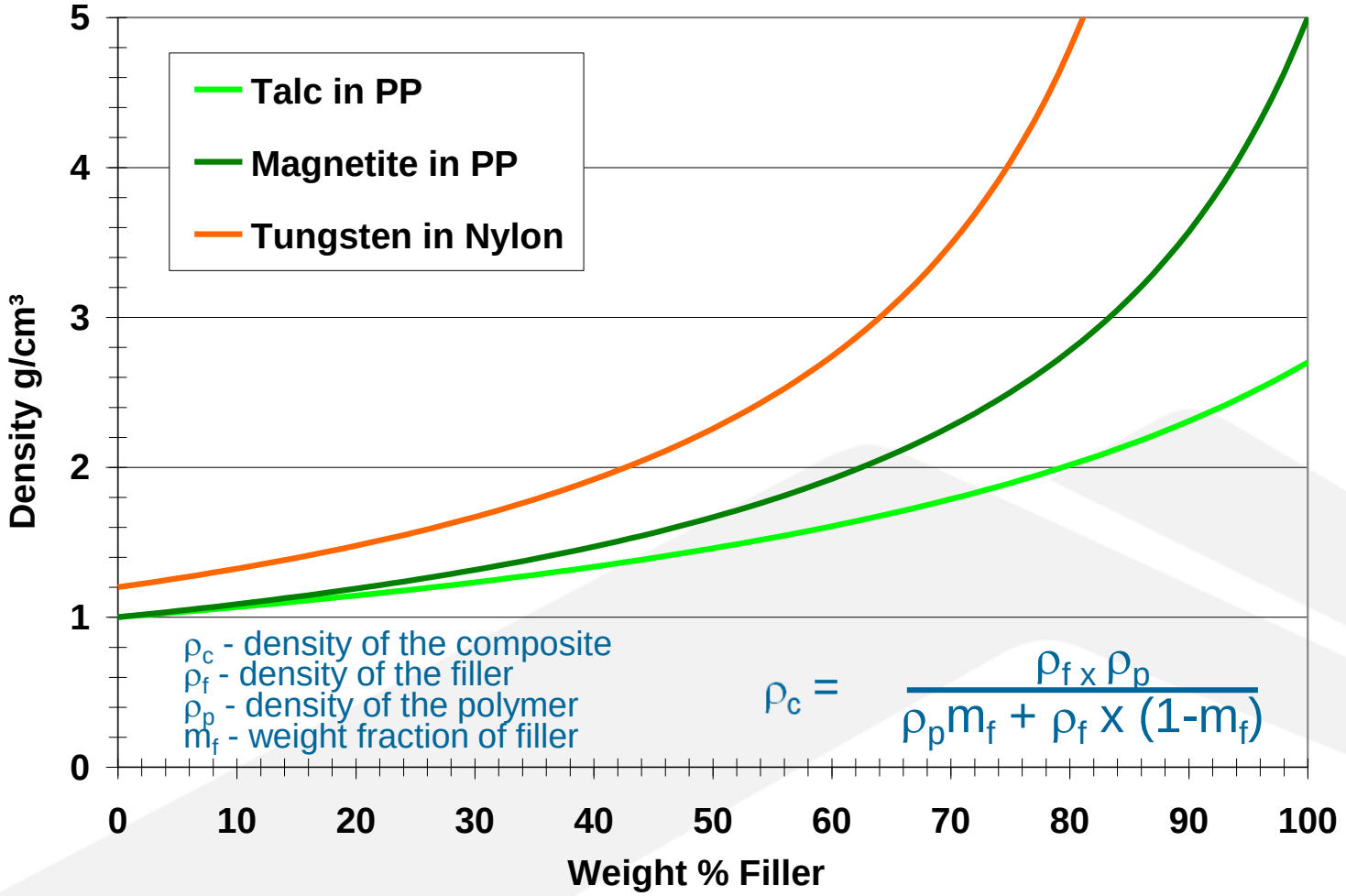
MAGNETITE PROCESSING

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

DENSITY ENHANCEMENT WITH MAGNIF



MAGNETITE IN USE

PHLOGOPITE MICAFORT – VHAR REINFORCEMENT

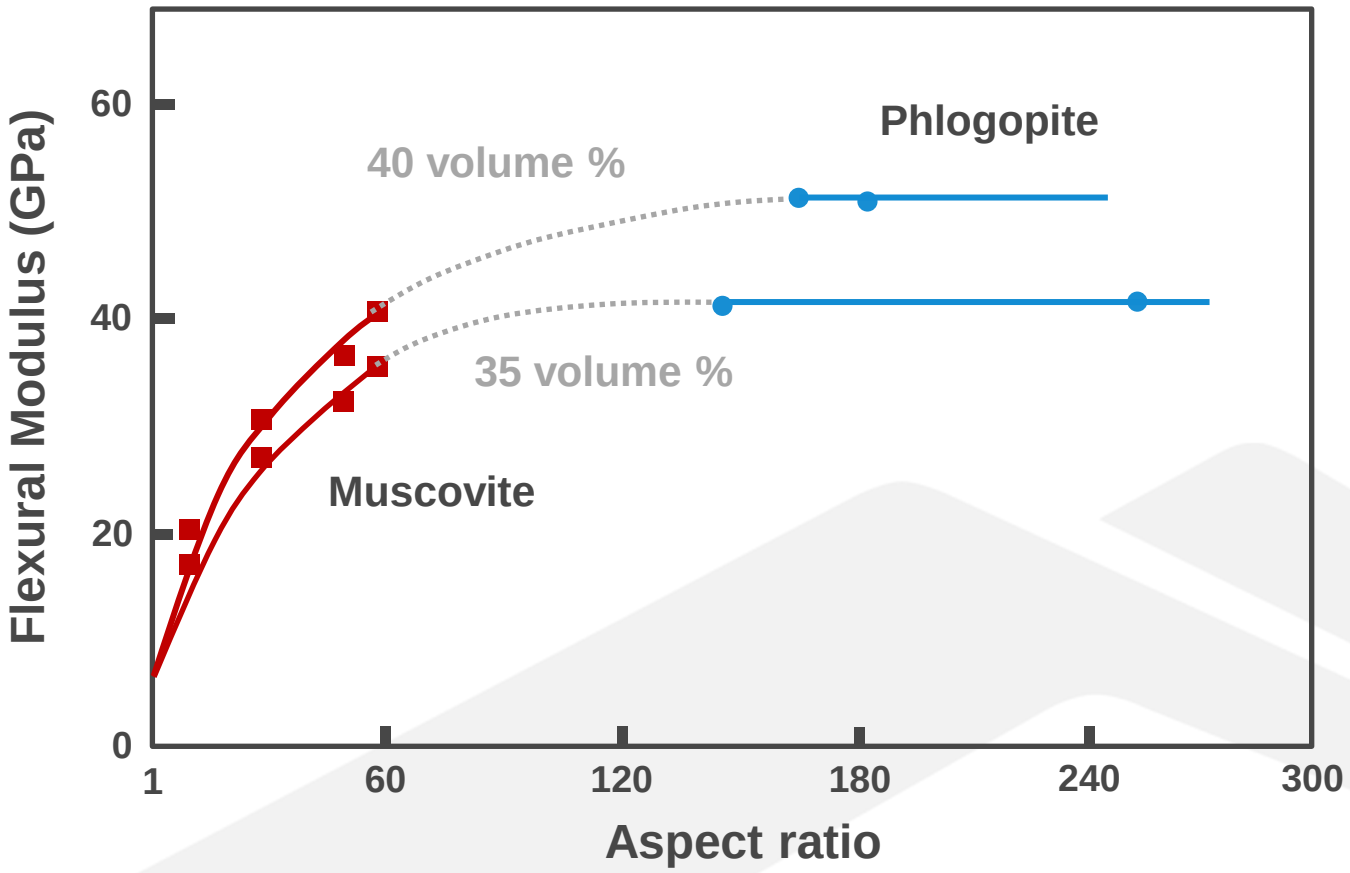
PHLOGOPITE MICA

1. Chemically inert
2. Electrical insulator
3. Bronze colored
4. Stable to >900ºC
5. Platy shape
6. Extremely pure (no quartz*)

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

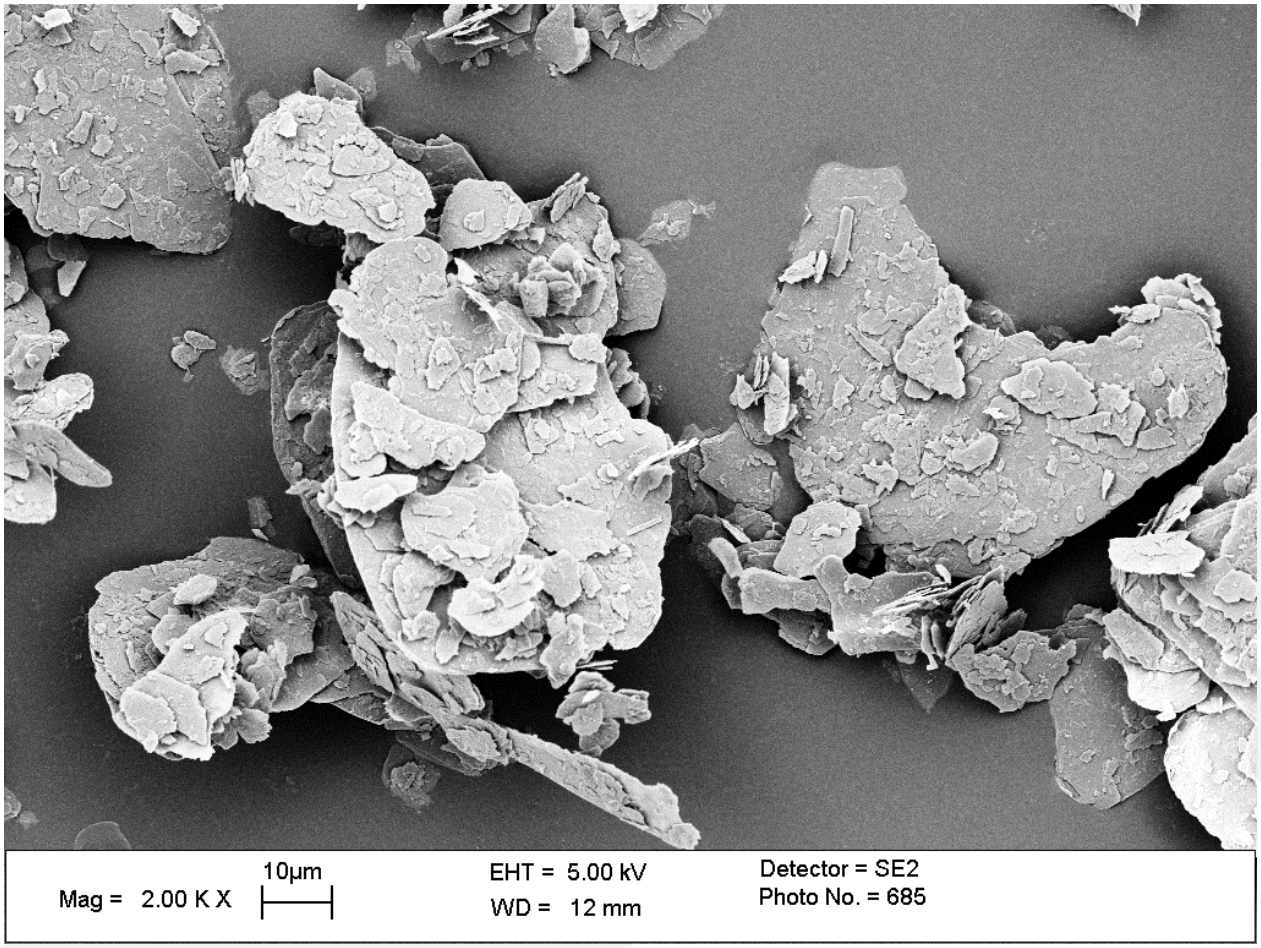
* No detectable quartz within the limits of XRD (<0.1%)

ASPECT RATIO AND FLEXURAL MODULUS



G. C. Hawley in Handbook of Reinforcement for Plastics, J. V. Milewski, H. S. Katz, Van Nostrand Reinhold Company, NY, USA, 1987

SEM OF PHLOGOPITE MICAFORT PW80



MINERAL REINFORCEMENTS COMPARED

Particle Dimensions (Malvern)	Calcined Clay	Wollastonite	Talc	Phlogopite MicaFort PW80
D_{50}	3	3.5	12	37
D_{90}	10	13	40	95
Aspect Ratio	Medium	Medium	High	Very High
Reinforces in	2 directions	1 direction	2 directions	2 directions

In real parts platy fillers give superior strength and modulus plus low warpage

REINFORCEMENT COMPARISON IN PA6

Property	Talc 40%	Calcined Clay 40%	Wollastonite 40%	Phlogopite Mica 40%	GF 40%
Flexural Modulus (MPa)	7400	6120	5514	10370	11980
Flexural Strength (MPa)	120	150	135	155	290
Tensile Modulus (MPa)	7470	6313	5450	11160	13215
Break Stress (MPa)	74	87	83	95	195
Break Strain (%)	2.8	6.4	8.4	1.7	2.6
Unnotched Charpy (kJm^{-2})	28.5	80	No Break	29	79
Notched Charpy (kJm^{-2})	3.5	6.4	6.4	4.0	12.8
Shrinkage ═ (%)	0.65	1.31	1.06	0.58	0.1
Shrinkage ‖ (%)	0.97	1.66	1.64	0.87	0.98
Warpage (%)	0.32	0.35	0.58	0.29	0.88

LKAB Minerals data from accredited external laboratory

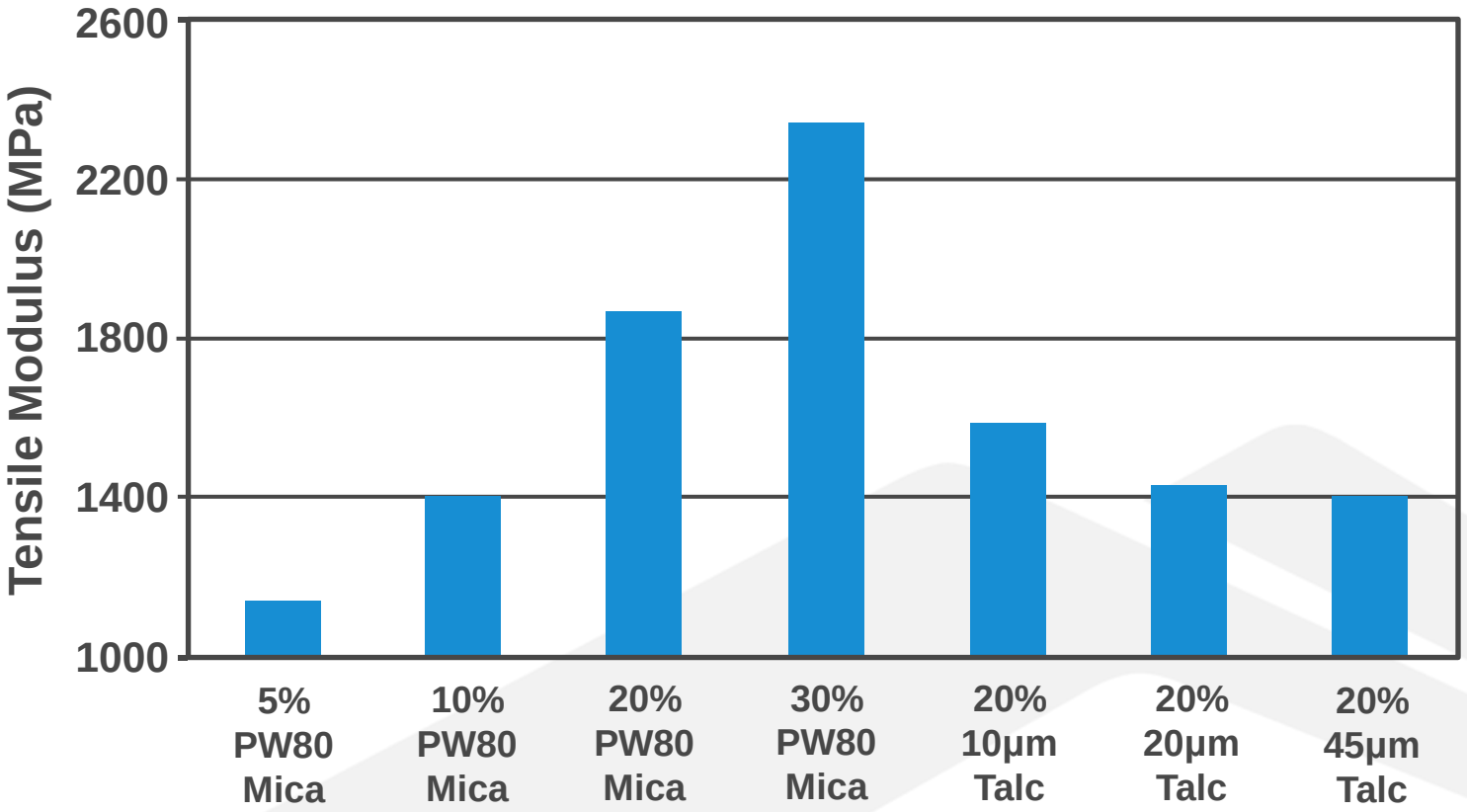
REINFORCEMENT COMPARISON IN PA6

Property	GF25% Talc15%	GF 25% Clay 15%	GF 25% Wollastonite 15%	GF 25% Phlogopite Mica 15%	GF 40%
Flexural Modulus (MPa)	9843	9350	9080	10550	11980
Flexural Strength (MPa)	210	213	226	231	290
Tensile Modulus (MPa)	11400	9950	10100	12200	13215
Break Stress (MPa)	140	144	144	165	195
Break Strain (%)	2.4	3.4	2.6	2.4	2.6
Unnotched Charpy (kJm^{-2})	52.3	43.6	50.3	60	79
Notched Charpy (kJm^{-2})	7.4	5.6	6.9	8.6	12.8
Shrinkage ═ (%)	0.22	0.26	0.23	0.22	0.1
Shrinkage ‖ (%)	0.91	0.99	1.04	0.81	0.98
Warpage (%)	0.69	0.73	0.81	0.59	0.88

LKAB Minerals data from accredited external laboratory

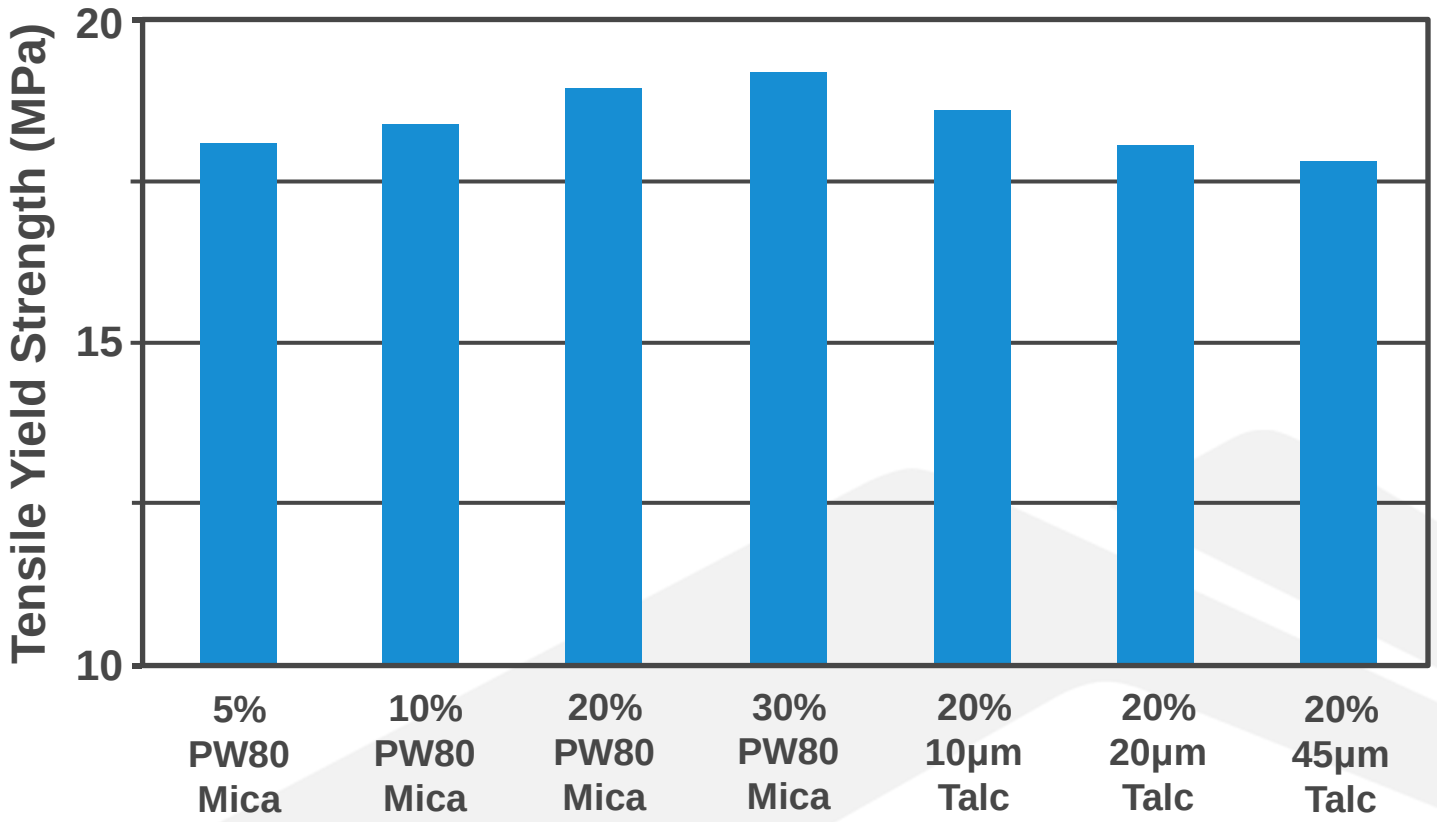
PHLOGOPITE MICAFORT – IN PP

VHAR MICAFORT VS HAR TALC



LKAB Minerals data from accredited external laboratory – PP Copolymer 65%, Impact Modifier 15%, Mineral 20%, Additives <1%

VHAR MICAFORT VS HAR TALC



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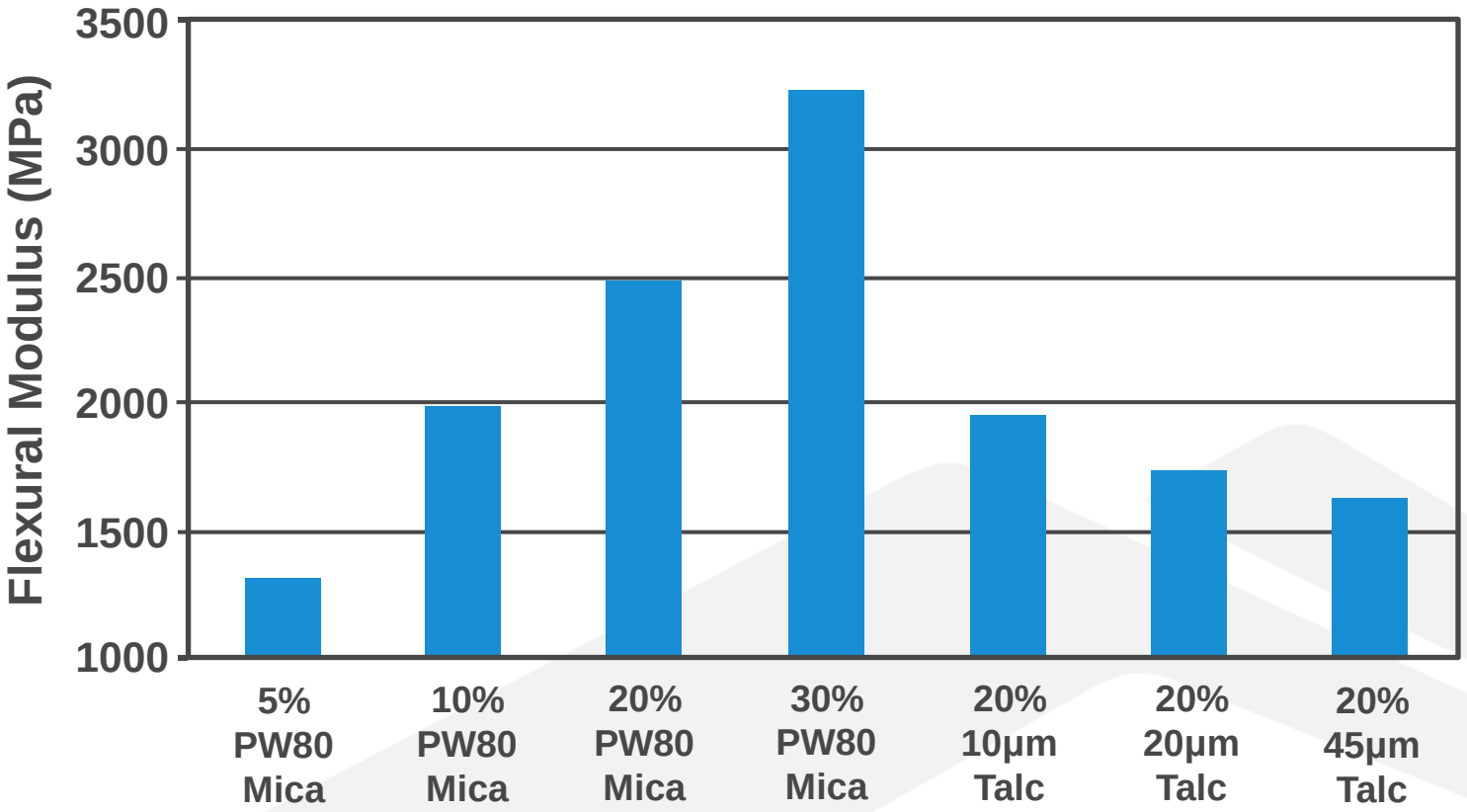

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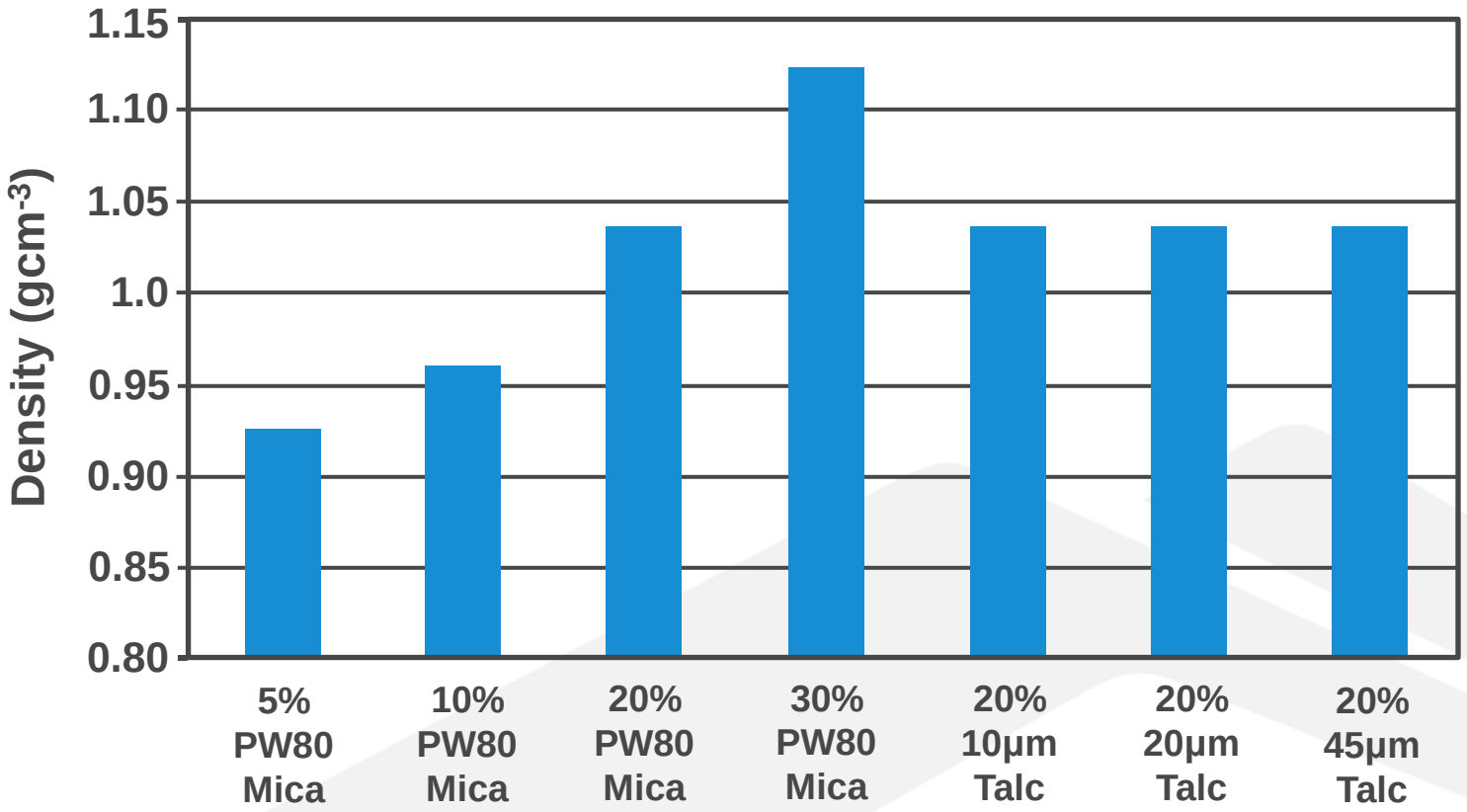

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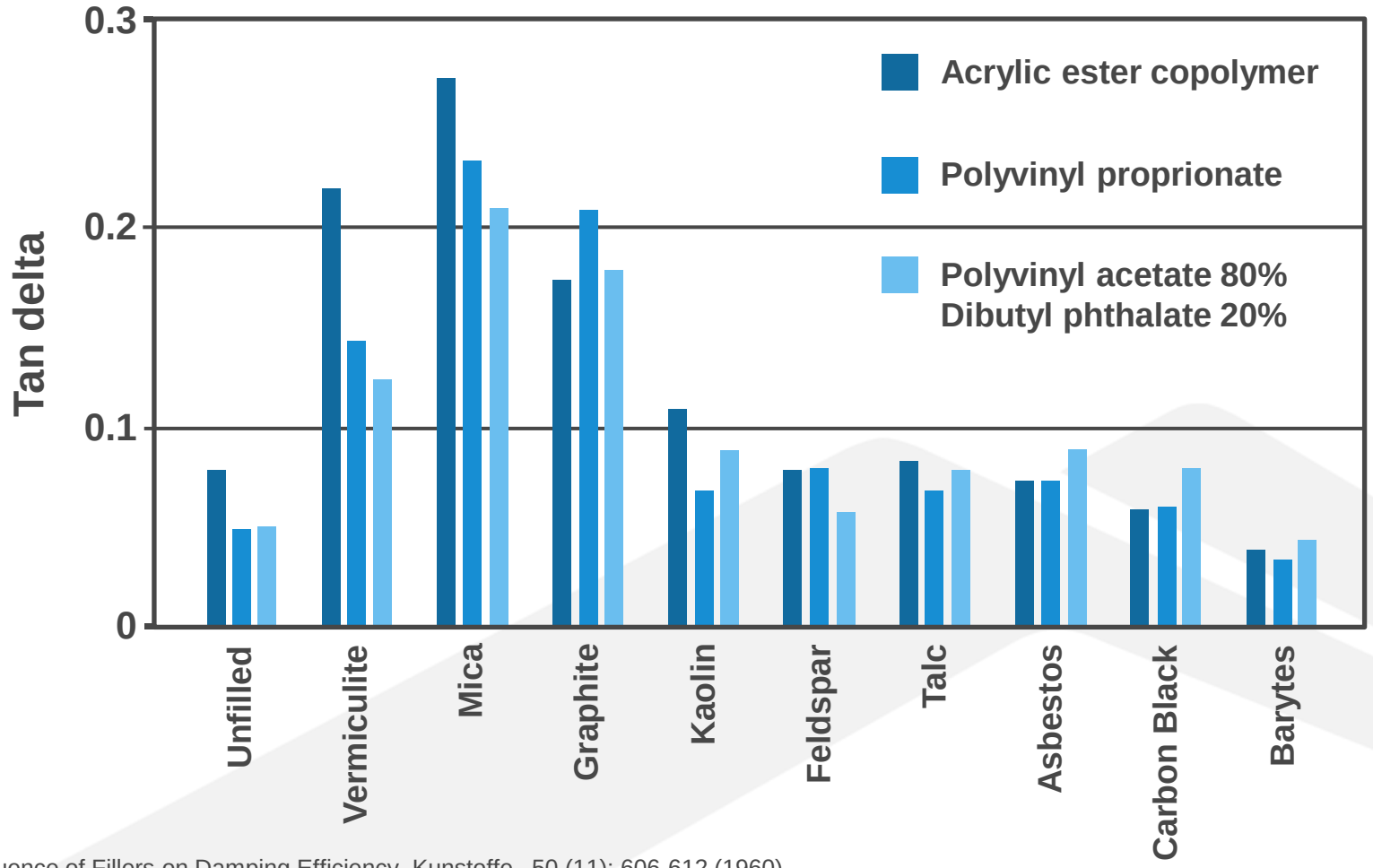
MICA FOR SOUND DAMPING



Influence of Fillers on Damping Efficiency, Kunstoffe, 50 (11): 606-612 (1960).

VHAR PHLOGOPITE MICAFORT

- Very 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, scratch resistance and sound damping are other key advantages

ULTRACARB – NATURE'S OWN FLAME RETARDANT

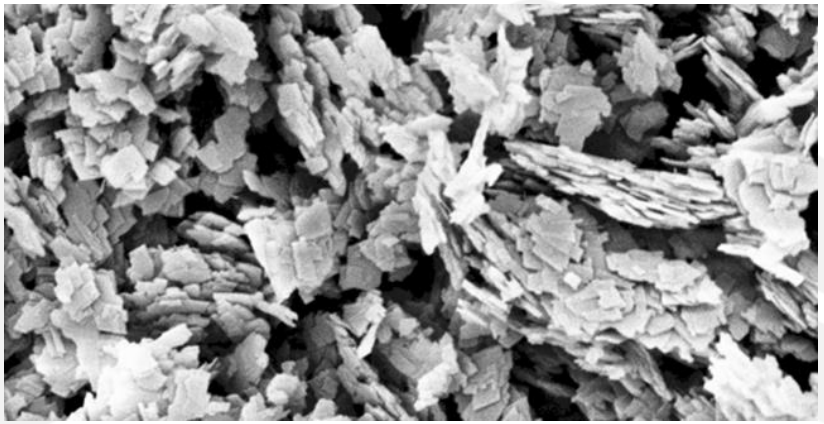
HMH: A BLEND OF TWO MINERALS

huntite:
magnesium calcium carbonate

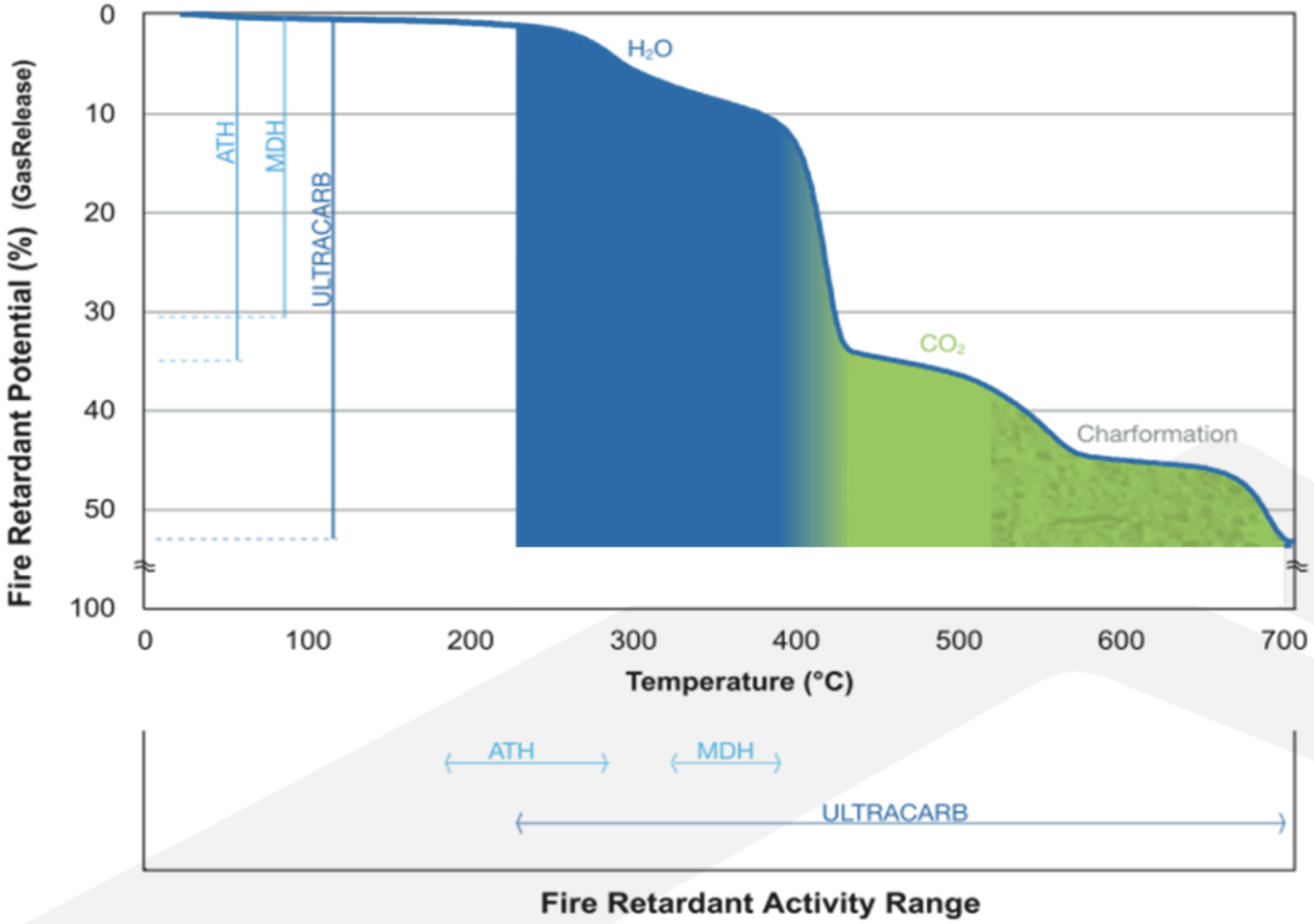
$Mg_3Ca(CO_3)_4$ + 1 kJ/g
→ 3MgO + CaO + $4CO_2$

hydromagnesite:
hydrated magnesium carbonate

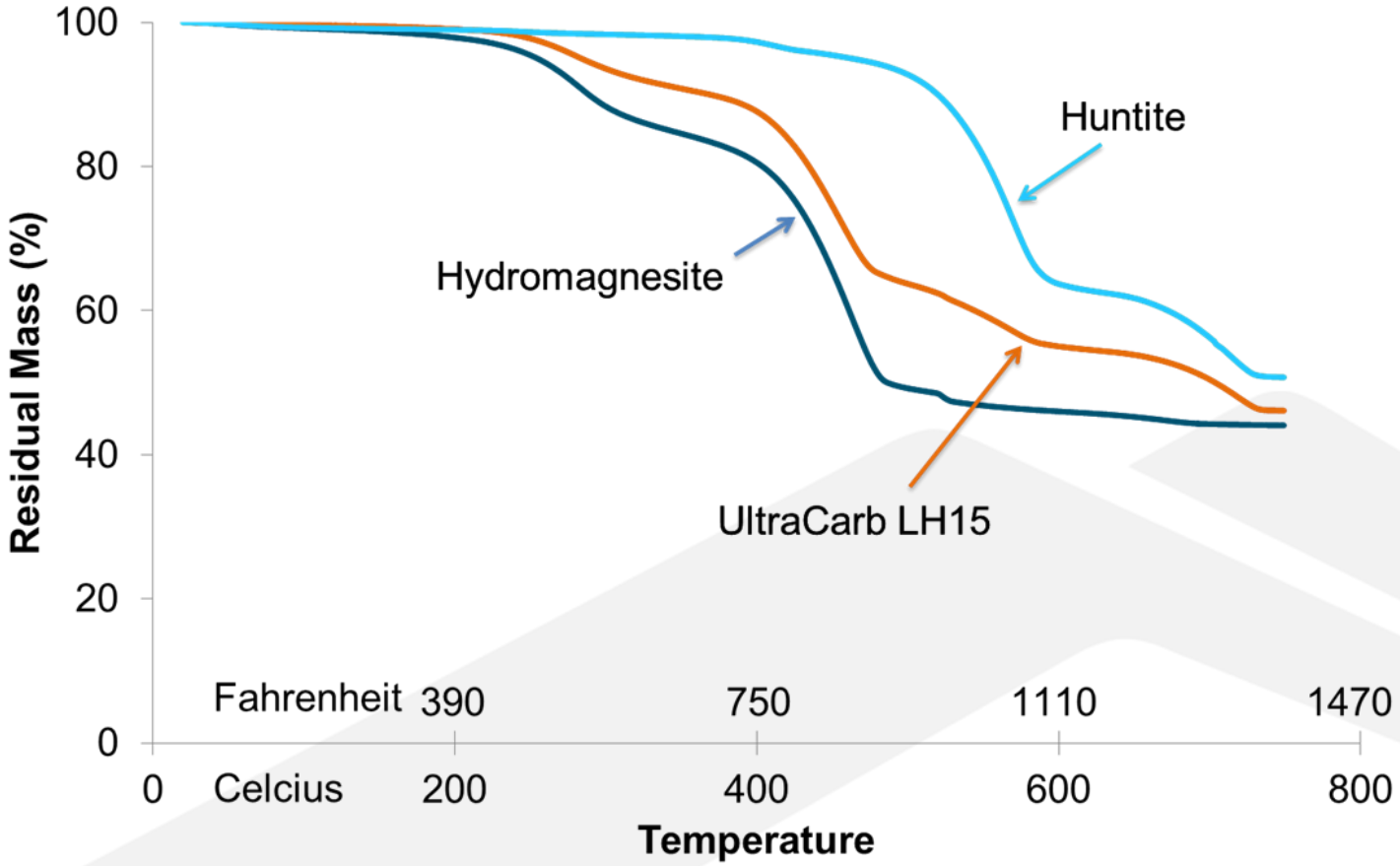
$Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$ + 1 kJ/g
→ 5MgO + $4CO_2$ + $5H_2O$



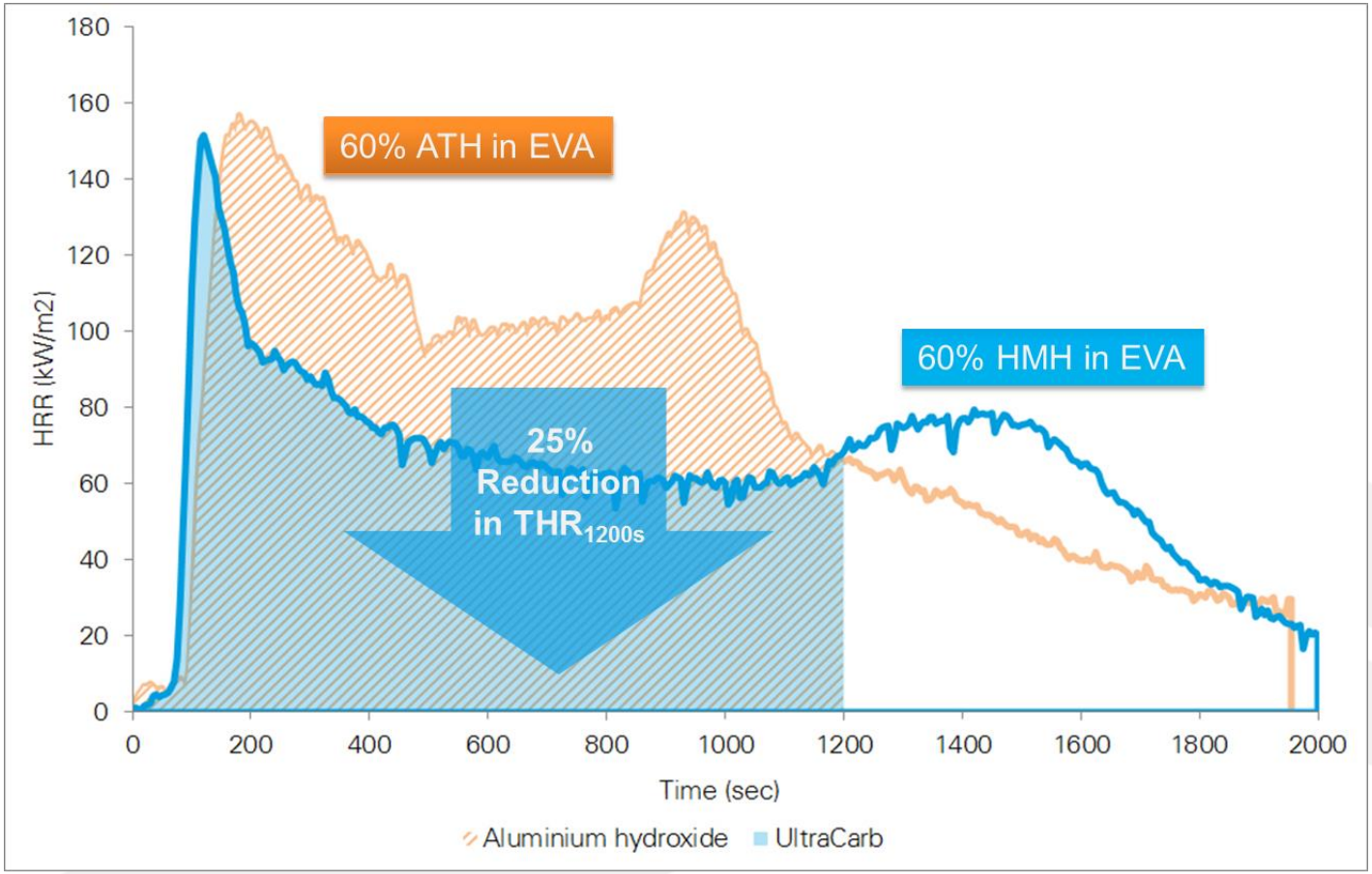
THE THREE STAGE FR MECHANISM OF HMH



HYDROMAGNESITE & HUNTITE DECOMPOSITION

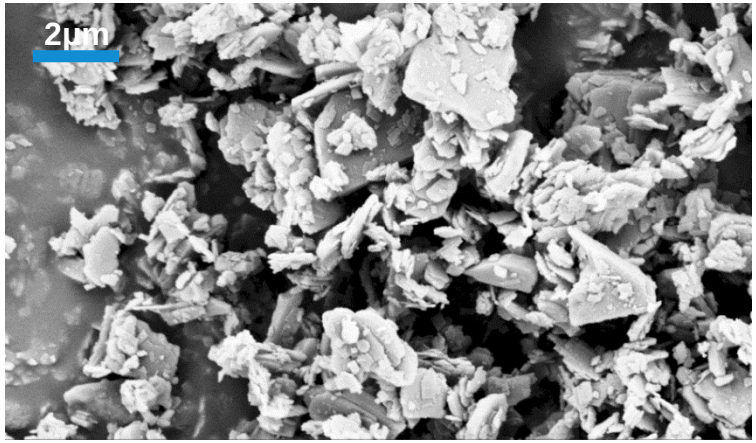


TOTAL HEAT RELEASE OF HMH AND ATH

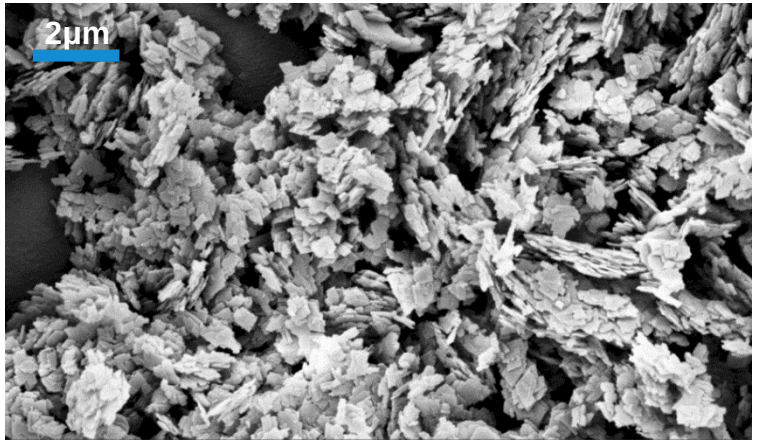


Data retrieved from 50kW cone calorimeter

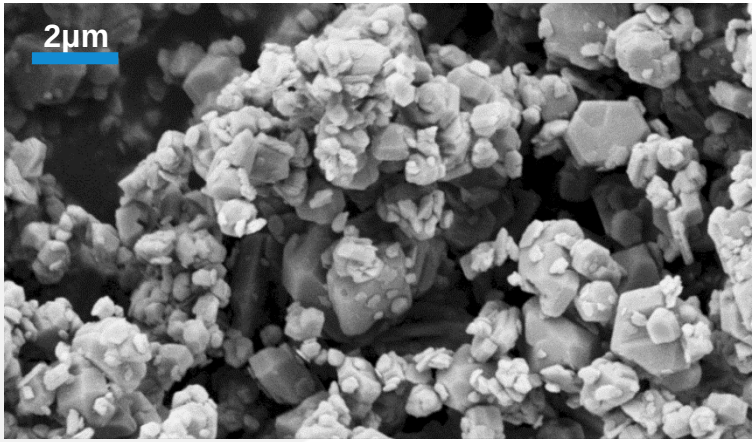
PARTICLE MORPHOLOGY



HMH



Huntite



ATH

NATURAL HMH VERSUS SYNTHETIC ATH

	HMH	ATH
Shape	Platy	Spherical
FR activity range	220°C – 700°C	180°C – 280°C
Evaporation enthalpy	-1000 kJ/kg	-1000 kJ/kg
Water release	>220°C	>180°C
Cementicious char	Yes	No
Bulk density (at feeding)	0.3g/cm³ (0.3g/cm³)	0.6 g/cm³ (0.4g/cm³)
BET surface	10m²/g (15m²/g)	4m²/g (7m²/g)
Processing temperature	<220°C @ 1 bar	<180°C
High shear kneading	**Yes**	**No**

EVA + ULTRACARB LH3 + PLASTOMER

Ingredients

20.0% Elvax 265 A (EVA)

6.5% Lucene LC180 (Plastomer)

3.75% Compoline CO/LL (MAH)

6.5% Eltex PF6130 AA (LLDPE)

1.5% Silmaprocess AL 1142A (Processing aid)

0.75% Silmastab AE 1527 (Stabilizer)

61.00% UltraCarb LH3

Tensile Strength:	15 MPa
Elongation @ Break:	276%
Dispersion:	very good
LOI:	32.5

Instructions

Feed polymers, additives and processing aids in the first hopper of a Buss Co-Kneader MX-30 and split feed the UltraCarb LH3 in port 1+2 and let it run at 600rpm and 15kg/h.

CONCLUSIONS

- Specialty minerals allow new levels of performance
- Magnetite has been used for decades but its full potential has not yet been tapped
- Established minerals like mica can still be innovative and are especially suited to automotive applications
- UltraCarb HMH is greener, less expensive and in some ways better than ATH and MDH
- One needs new ingredients to make better compounds!

CUSTOMER FEEDBACK

“It’s magic”

President of coatings company

“It blew everything else out of the water”

PhD scientist at leading engineering plastics company

“Significantly better than everything else”

Fortune 100 company

“I’m in awe of what this stuff can do”

PhD scientist at leading aesthetic products company


"A ship is safe in harbor, but that's not what ships are for."
— William G.T. Shedd
GBR7207T

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?