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What's new in functional fillers?

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What's in it for me?

Lightweighting

Better Reinforcement

Quartz "Free"

Microwave Heating

Higher Impact

Radar Blocking

Thermal Conductivity

High Density

Toll Milling

Sub-micron

Preventing Wear

Ultra-low Moisture

Wollastonite Replacement

Renewable Content

Radiation Shielding

Reasons to use fillers

Innumerable different reasons to use fillers

- Raise heat resistance
- Increase stiffness
- Increase strength
- Reduce shrinkage
- Improve dimensional stability
- Reduce flammability
- Modify flow
- Increase lubricity
- Decrease permeability
- Increase degradability
- Improve processability
- Reduce creep
- *Change electrical properties*
- *Modify specific gravity*
- Improve abrasion resistance
- Improve impact resistance
- *Improve thermal conductivity*
- Improve moisture resistance
- Increase adhesion
- Appearance, opacity, gloss
- *Better scratch resistance*
- *Magnetic properties*
- Thermal property tuning
- *Radiation blocking*

World markets by filler (all polymers)

Huge volumes by value and tonnage

Filler Type	2017 Volume (tonnes)	Value (Million USD)
Carbon black	18,000,000	18,000
Precipitated silica	1,400,000	1,400
Fumed silica	110,000	600
Crystalline silica	300,000	<200
Precipitated calcium carbonate	275,000	165
Ground calcium carbonate	12,000,000	2,500
Talc	1,000,000	600
Kaolin	1,750,000	800
Calcined kaolin	175,000	<200
Wollastonite	150,000	<200
Barium sulfate	350,000	250
Natural fibers	350,000	NA
Others	250,000	NA
Total	**30,885,000**	**>2,750**

Courtesy of Rothon Consultants 2017

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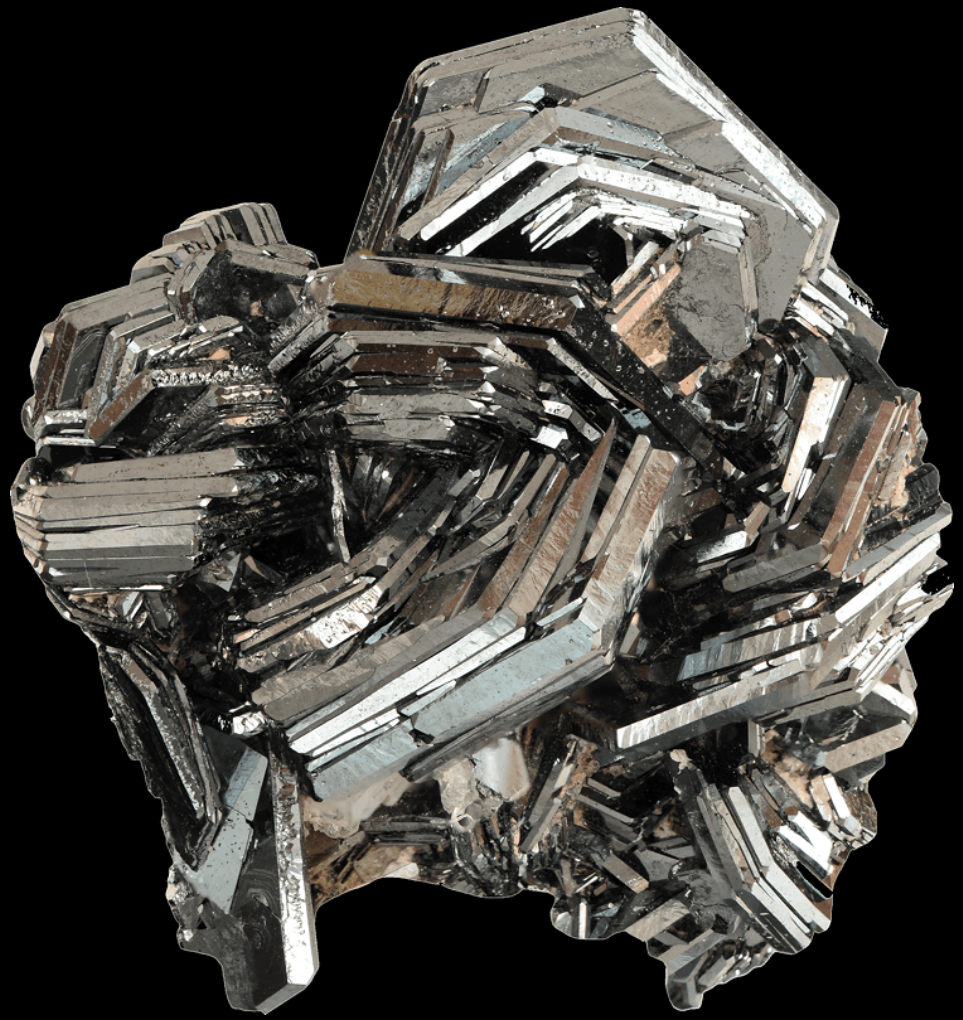


Hematite

Fe_2O_3 iron oxide

- Mohs Hardness 5.5-6
- Thermal conductivity high 12.5 W/m.K
- High volumetric specific heat capacity
- Electrical semi-conductor
- Density high 5.2 gcm^{-3}
- X-ray blocking
- Sound damping
- Radar absorbing
- Microwave heating

DenzFlex™

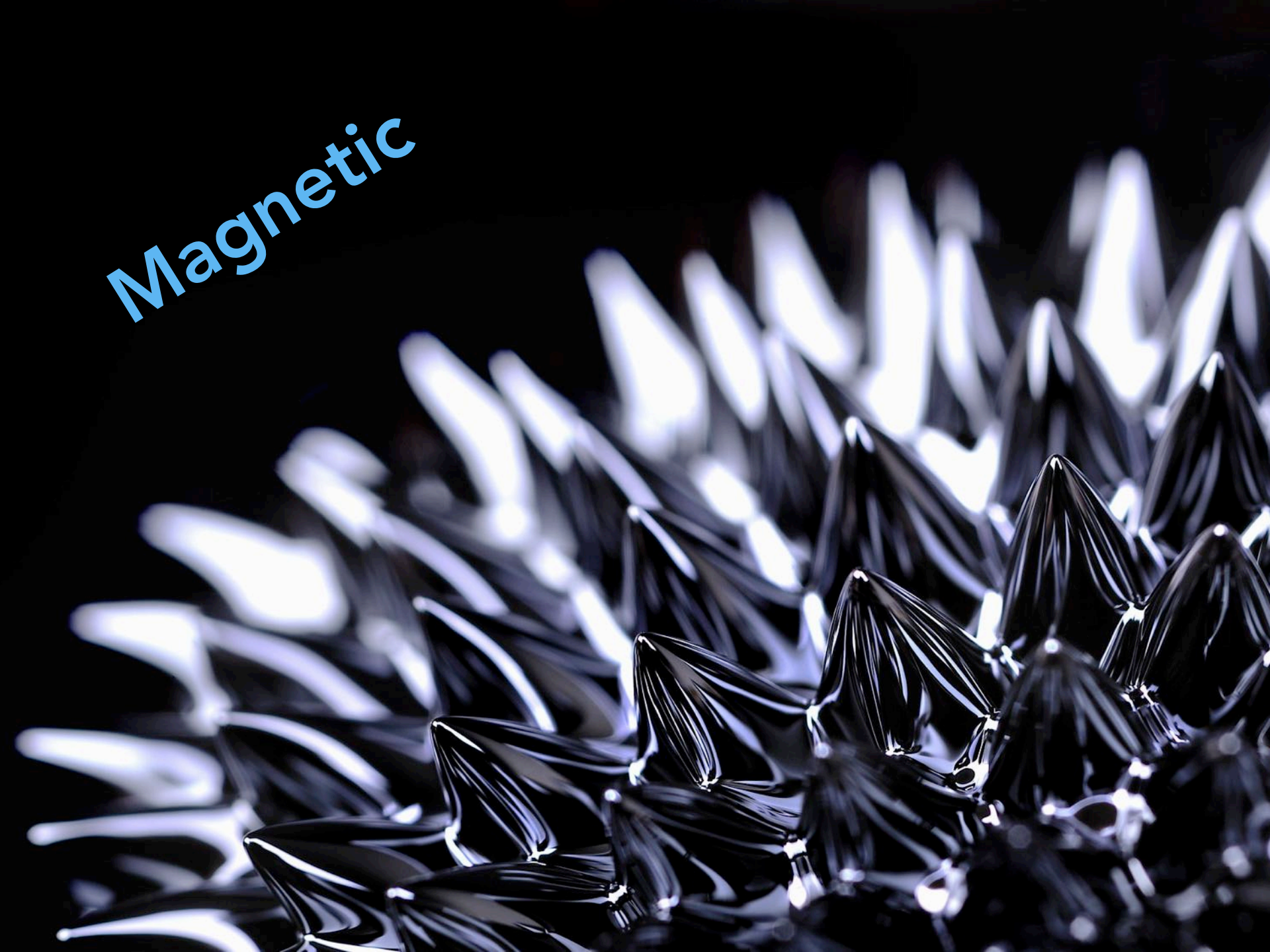
Reinforced easy to machine PEEK

Better mechanicals and allows machining of fine features or drilling minute holes

Magnetite

Fe_3O_4 iron oxide

- Mohs Hardness 5.5-6
- Thermal conductivity high 5.1 W/m.K
- High volumetric specific heat capacity
- Electrical semi-conductor
- Density high 5.2 gcm^{-3}
- X-ray blocking
- Sound damping
- Radar absorbing
- Microwave heating


Magnetic

Properties of magnetite

In contrast to common fillers

Property	Typical Mineral Filler	Magnetite
Color	White	Black
Density	2.5-3.0 g cm^{-3}	5.2 g cm^{-3}
Mohs Hardness	2-3	5.5-6
Attraction to a Magnet	No	Yes
Electrical conductivity	Insulator	Conductive
Chemical composition	Carbonates & silicates	Oxide
Volumetric heat capacity	2.1 kJ L^{-1} K^{-1}	3.8 kJ L^{-1} K^{-1}
Microwave heatable	No	Yes
Radiation blocking	No	Yes

Properties of FiberFlex™

Amorphous mineral fiber - similar properties to treated wollastonite

Property	Virgin PP	FiberFlex™ 10%	Wollastonite 10%	FiberFlex™ 30%	Wollastonite 30%
MFI (g/10min)	12.6	13.4	12.7	12.3	14.3
Density (g/cc)	0.90	0.964	0.963	1.127	1.134
Flexural secant modulus (psi)	131700	150800	148800	198200	210000
Flexural tangent modulus (psi)	144000	182000	185000	300500	318000
Flexural maximum strength (psi)	4140	4430	4440	4800	5100
Notched Izod RT (ft-lb/in)	1.2	0.75	0.75	0.61	0.75

FiberFlex™ is an experimental grade without surface treatment – wollastonite is a commercial, silane treated type

Oolitic Aragonite – renewable filler

Finally, a renewable filler that makes sense

Aragonite

$CaCO_3$ calcium carbonate

- Mohs Hardness 3.5-4
- Density 2.84 gcm^{-3}
- Needle-shaped crystals
- Newly deposited
- Deposited 10x faster than harvesting
- Therefore renewable material

Gives white calcium carbonate when milled to filler-sized particles (Hunter L value ~91)

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Toll milling

- 1-2MT trial run
- Match target PSD
- Qualify a sample
- Price quote
- Define COA
- Packaging options
- Warehousing & delivery
- Surface treatment options
- Sub-micron possible
- Low-moisture capability
- Huge mills = lower prices
- Mica, ATH, MDH, glass…

Arctic Minerals LLC

Toll milling of minerals & fine chemicals

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Services

Milling technologies & services

- *Milling capabilities using cutting edge equipment & processes*
- *Sub-micron & high aspect ratio capability*
- *In-line surface treatment optional*
- *Custom sieving*
- *In-house QC on every batch*
- *Two sites for security of supply*
- *USA warehousing network*

Testimonials

"We were blown away by the packaging"

"Fast turn around"

"Great value"

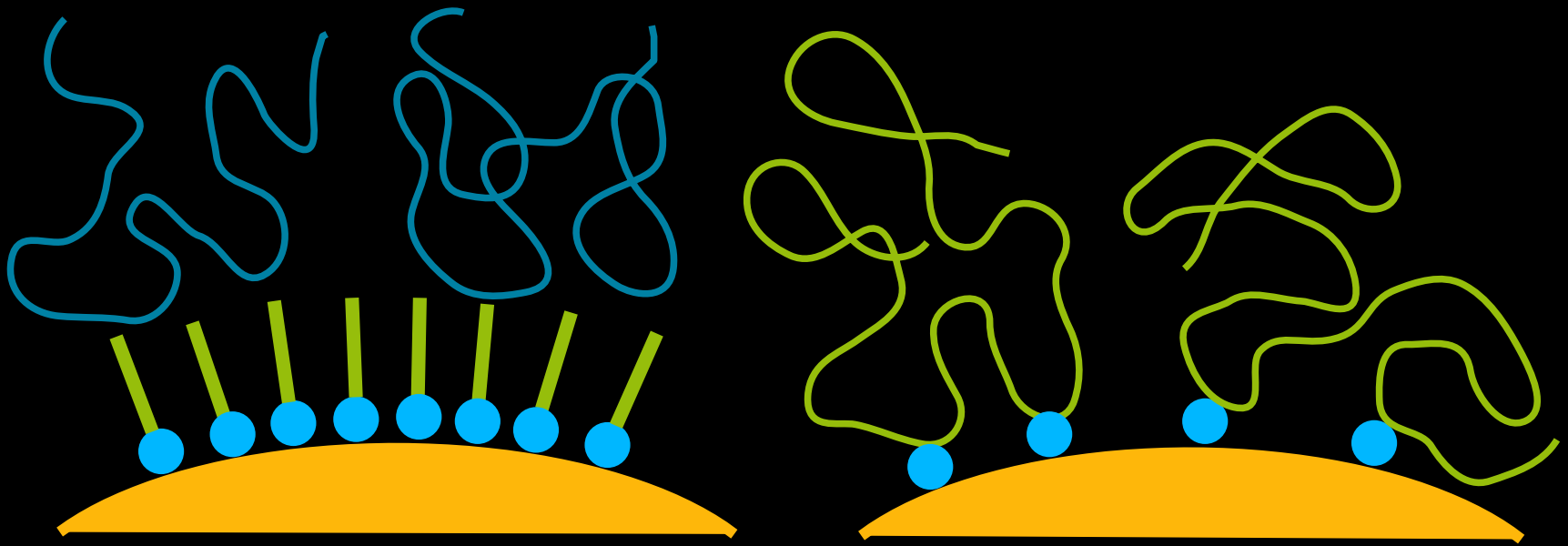
About Us

Key points

ISO 9001 certified
Decades of experience
Large capacity
Family owned

Surface treatment types

Dispersants improve impact resistance & coupling agents for strength



Dispersant

Coupling Agent

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Mica for better reinforcement & lightweighting

Phlogopite mica outperforms the best talc

Particle Dimensions (microns)	Wollastonite	Talc	HAR Talc	Mica
D_{50}	3.5	12	15	40
D_{90}	13	40	50	150
Aspect Ratio	10:1	20:1	40:1	100:1

- Aspect ratio determines stiffness, strength, HDT, barrier and CLTE
- Phlogopite mica can achieve much higher aspect ratio than talc
- Less phlogopite is needed to achieve equivalent mechanicals

Mica for better reinforcement & lightweighting

Phlogopite mica outperforms every mineral (in PA 6,6)

Property	Mica 40%	$CaCO_3$ 40%	Wollastonite 40%	Glass Beads 40%	Clay 40%
Flexural Modulus (GPa)	10.6	4.55	5.45	4.24	6.96
Flexural Strength (MPa)	179	114	53.1	109	163
Ultimate Tensile Stress (MPa)	105	72.4	33.1	67.6	75.2
Break Strain (%)	140	144	144	165	195
Break Strain (%)	2.7	2.9	3.0	3.2	2.5
Unnotched Charpy (Jm^{-1})	433	513	502	294	657
Notched Charpy (Jm^{-1})	30	25	30	20	15
Shrinkage (%)	0.3	1.2	0.9	1.1	0.4
HDT @ 1.82 MPa (°C)	238	198	221	208	199
Thermal Expansion (10^{-5}/°C)	1.2	1.5	1.4	1.5	1.4

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

Mica for better reinforcement & lightweighting

Phlogopite mica outperforms every mineral with glass fiber (in PA 6)

Property	GF 25% Talc 15%	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

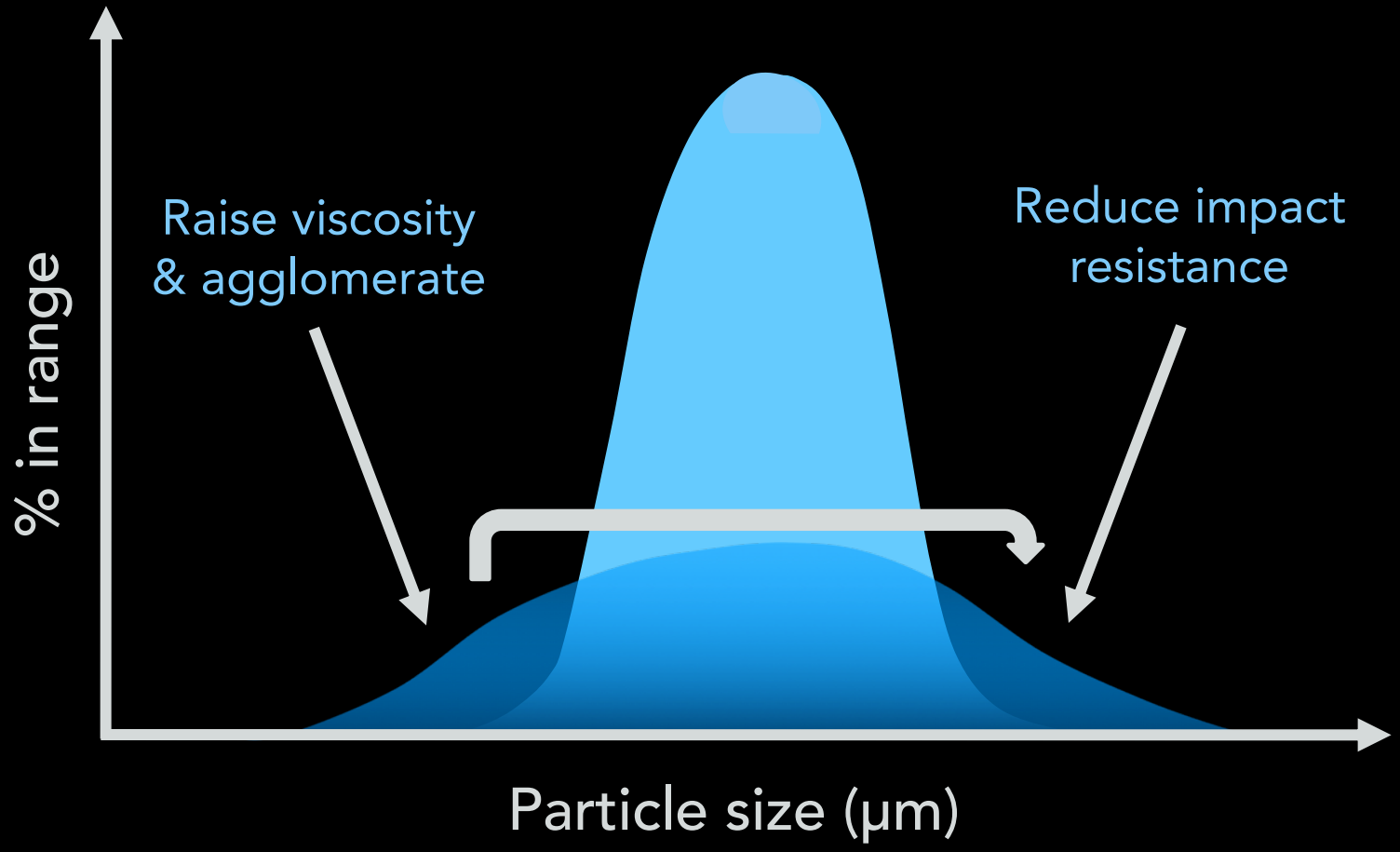
Phlogopite mica next generation reinforcement

Higher aspect ratio leads to better performance

- Higher aspect ratio means better stiffness, strength, HDT and barrier with lowest CLTE, shrinkage and warpage
- 12% ThermaFlex™ mica to replace 20% talc with the same properties
- Well proven in PA6, PA6,6 and PP for over 30 years
- ThermaFlex™ - no detectable quartz (safe, non-abrasive)
- Full range of sizes available
- Custom sieved grades for better impact
- Cost-effective silane treatments upon request

Particle size distribution

Particle size & impact resistance



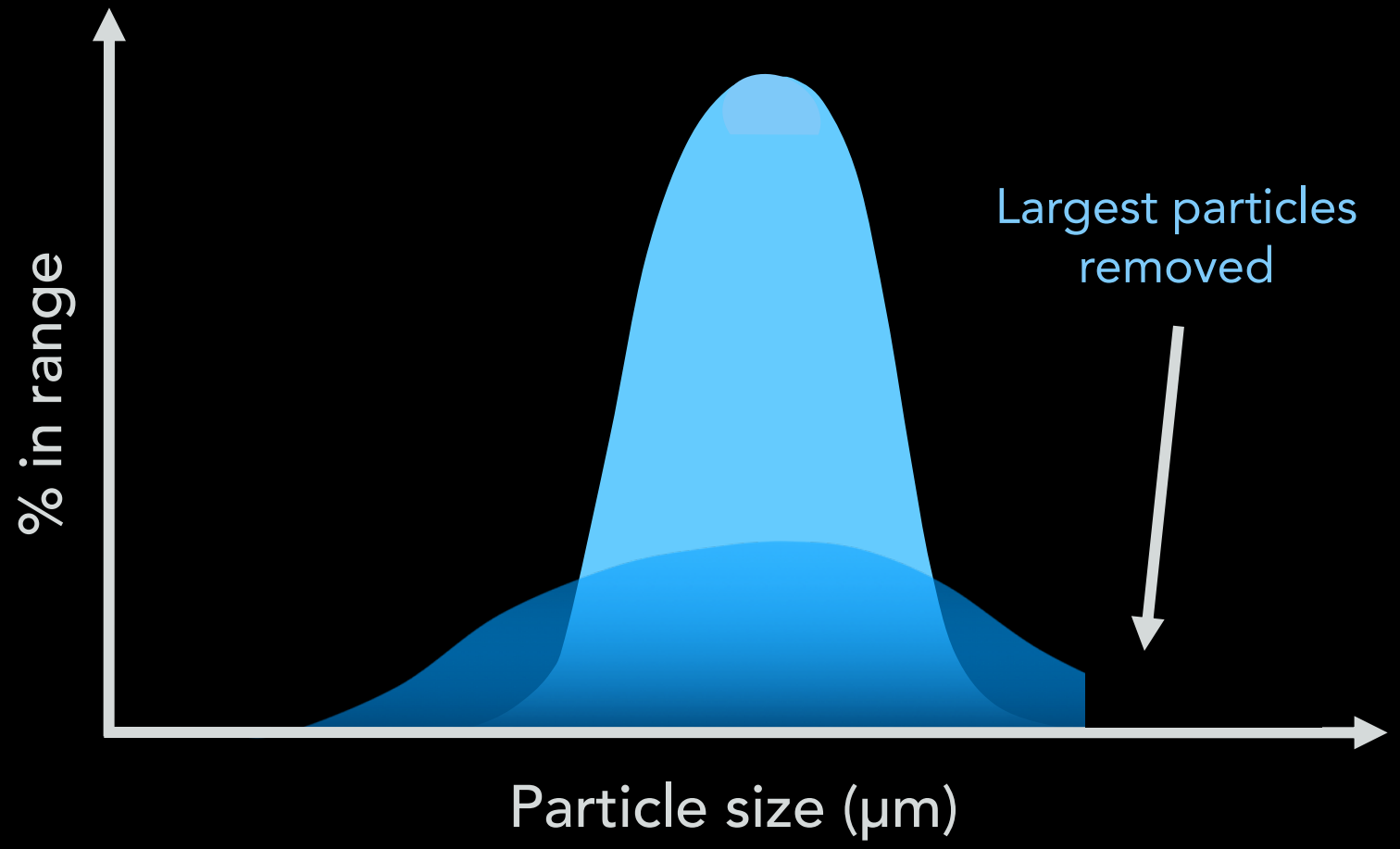
Effect of particle size on dispersibility

A few larger particles ruin impact and elongation

D_{50} 0.85 micron, D_{98} 5 microns

Particle size distribution

"T - GRADES" are custom sieved to remove the coarser particles



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Filler properties & why quartz matters

Quartz relates to safety but also machine wear & abrasion

- Must be insoluble and inert
- Colour consistency
- Abrasion (Quartz impurities dominate)
- Electrical Properties (Traces of soluble salts)
- Stability (Transition metals can attack polymers - Cu, Fe, etc.)
- Health (Quartz, asbestos)

Quartz “free” mineral range

Calcium Carbonate

Calcined Calcium Sulfate
TiO_2 Extender

Talc

Blanc Fixe
Barium Sulfate

Hollow Glass Spheres

FiberFlex™
Wollastonite Replacement

DenzFlex™ Fe_2O_3
Iron Oxide

BriteFlex™ Muscovite Mica
(Under Development)

ThermaFlex™
Phlogopite Mica

Expandable Polymer Spheres

Quartz “free” means <0.1 weight%, i.e. below the detection limit

Conclusions

Lots new in the world of fillers

- ThermaFlex™ mica for better reinforcement to replace talc and save weight
- DenzFlex™ iron oxide for sound damping and x-ray blocking
- FiberFlex™ amorphous mineral fibers to replace wollastonite
- CalciFlex™ renewable calcium carbonate from the ocean
- Quartz “free” mineral range for better safety and lower machine wear
- Toll milling and mixing of chemicals and minerals
- New continuous silane treatment technology for improved output and far better economics

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Experience

Leading consultant, innovator, speaker, author

- Over 25 years of experience innovating in industry: Cookson, Institute for Surface Chemistry (YKI), Electrolux (Frigidaire), BASF, Hybrid Plastics, Applied Minerals, LKAB Minerals, Phantom Plastics, Kish Company / Arctic Minerals
- Expert in plastics, filled plastics, mineral fillers, specialty chemicals, materials and consultant to the Fortune 500 (P&G, Total, CBS, Apple, HP, Exxon etc.)
- Serial innovator: over 30 registered inventions, 15 patents & 6 Innocentive open innovation awards totaling > $50 000 (top 0.01% of registered innovators)
- Articles (40), book chapters (9), presentations (40), workshops (50)
- Fellow of the Royal Society of Chemistry & Chartered Chemist
- Awards for speaking, Frost & Sullivan Award, R&D 100 Award
- Voted #1 plastics expert world-wide out of over 14 000 peers