Performance Comparison of Mineral Filled Olefins

Imerys Performance Additives, North America

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SPE INTERNATIONAL POLYOLEFINS CONFERENCE

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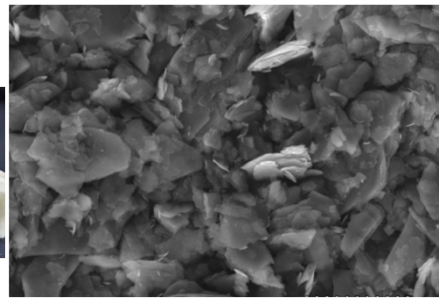
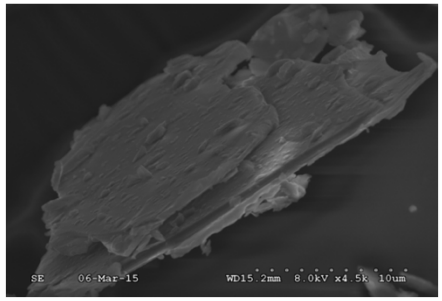
Outline

- IMERYS
- Minerals in Plastics/Automotive
  - Talc, Mica & Wollastonite
- Performances against Chopped Glass Fiber
- Screening Approach & Objectives
- Findings
  - Trends/Relationships
  - Case Studies
- Performance Comparison
- Conclusions

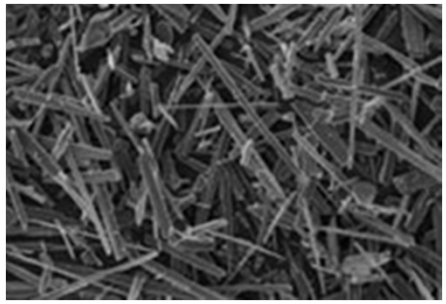
Talc



Mica



Wollastonite



IMERYS – Leading Global Supplier of Performance Minerals for Plastics

IMERYS

2015 Sales

€4,087 million

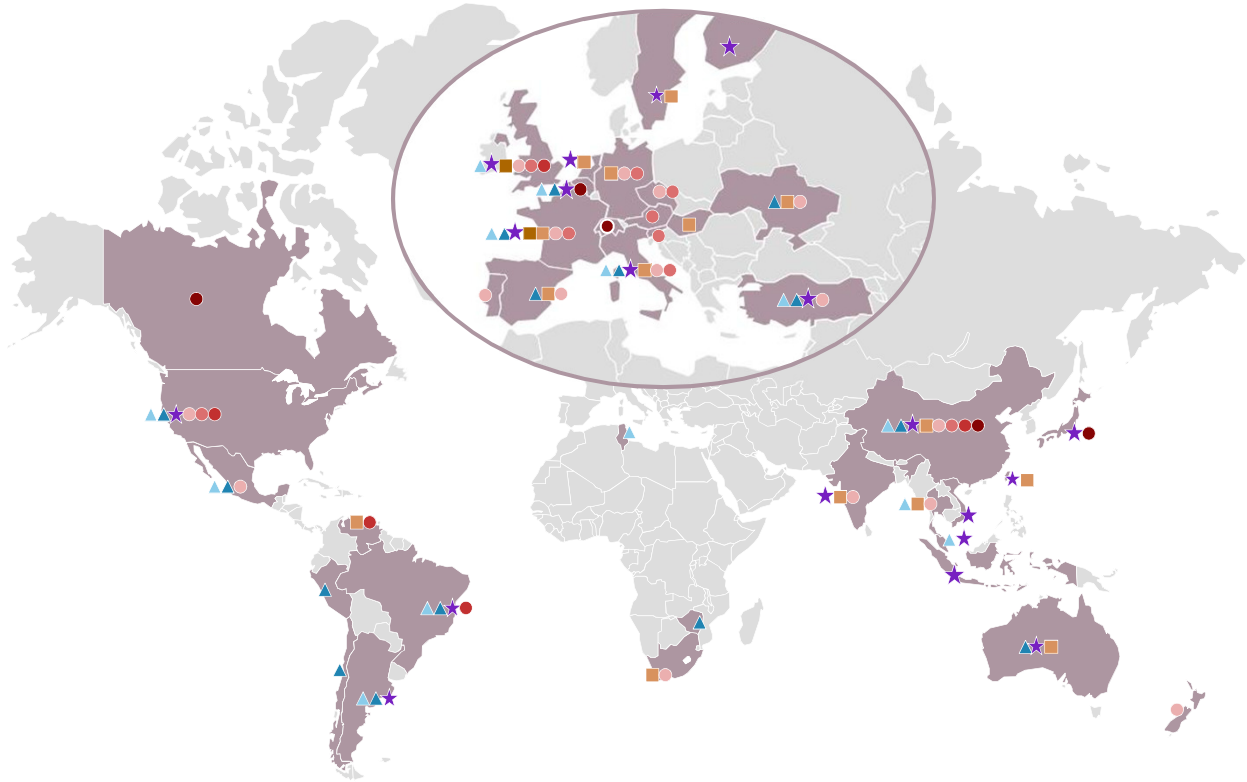
15,800

employees

in 50 countries

234

locations



Energy Solutions & Specialties	Filtration & Performance Additives	Ceramic Materials	High Resistance Minerals

Talc, Mica & Wollastonite

IMERYS

Imerys, North America

- Leading supplier of mineral products in North America:
  - 3 Talc, 2 Wollastonite & 2 Mica mines
  - 9 processing (milling, beneficiation, etc.) operations
  - Large portfolio of:
    - Purity, Particle Size & Morphology
  - Laboratory in San Jose, CA.
    - Processing
    - Testing
    - Analytical
    - Product Stewardship

Yellowstone, MT

Argonaut, VT

Penhorwood, ONT

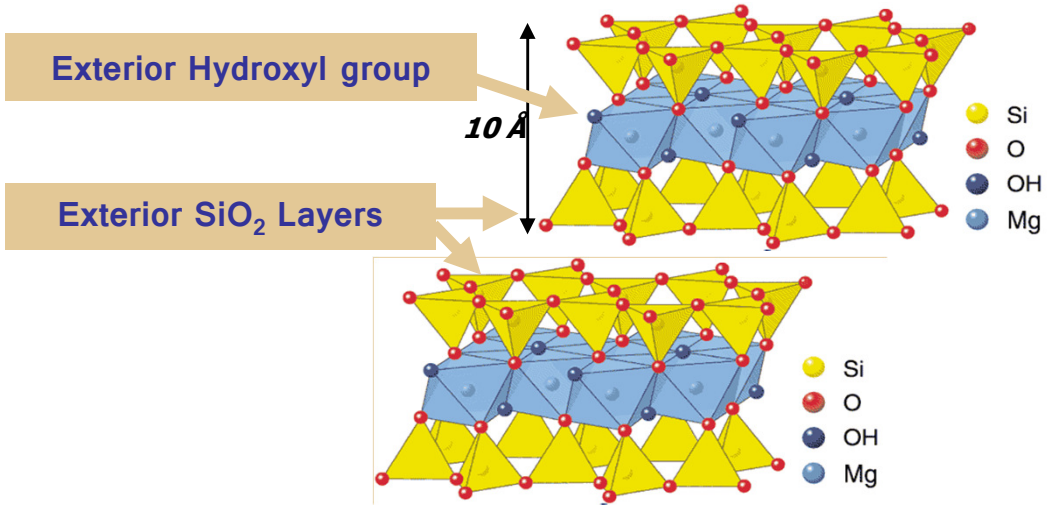
Mica Mines, Boucherville QC

Kings Mountain, NC

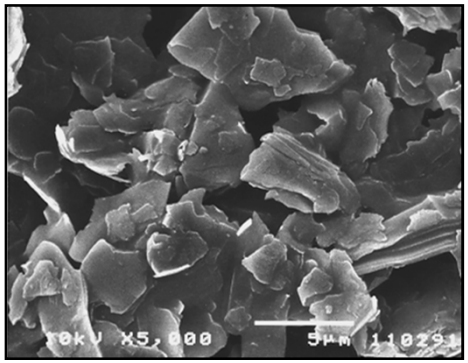
Wollastonite Mine, Oakhill, NY

Talc Properties & Structure

- Hydrated magnesium silicate: $Mg_3Si_4O_{10}(OH)_2$
  - Naturally occurring
  - Softest mineral; 1 on Mohs scale
  - Platy crystalline structure
  - Hydrophobic exterior; relatively inert
  - Delaminating
  - Contains other minerals/impurities (Chlorite, Dolomite, Magnesite, etc.)
- Talc Parameters:
  - Purity
  - Morphology
  - Particle Size



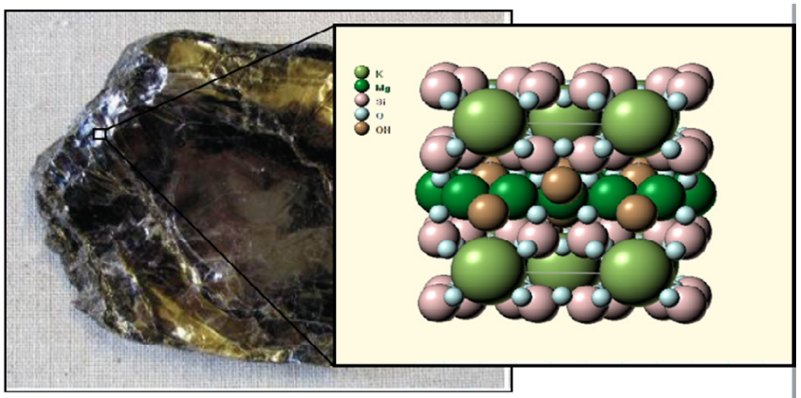
Macro-crystalline



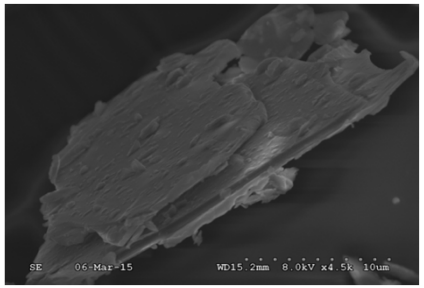
Micro-crystalline

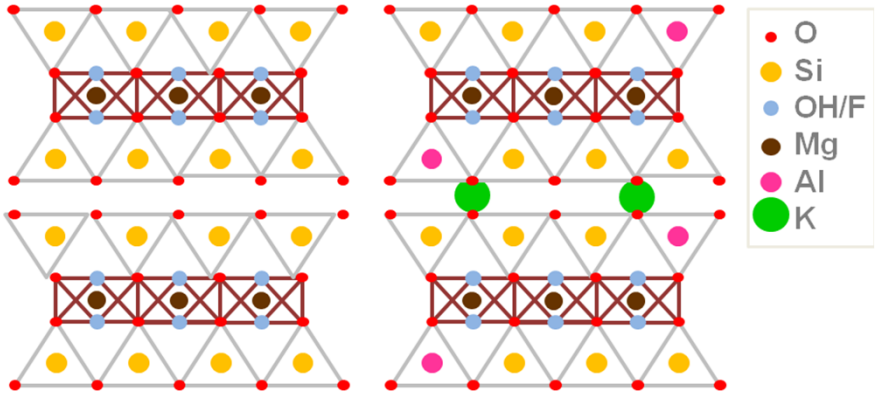
Mica Properties & Structure

- Chemistry/Type
  - Phlogopite & Muscovite
  - Similar to Talc
    - Si substitution with Al
    - Interlayer ionic bond
  - Ionic interlayer interaction; more difficult to delaminate
  - Mohs hardness of 3
- Morphology - Platy
- Delamination possible but more difficult than talc.
- Surface modification possible



$KMg_3(Si_3Al)O_{10}(F,OH)_2$
Suzorite, Quebec

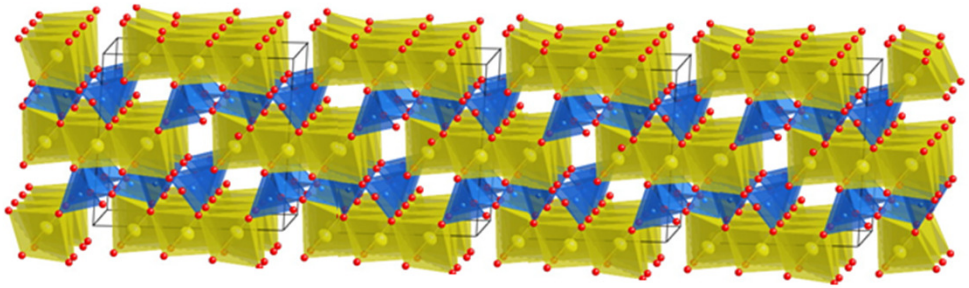




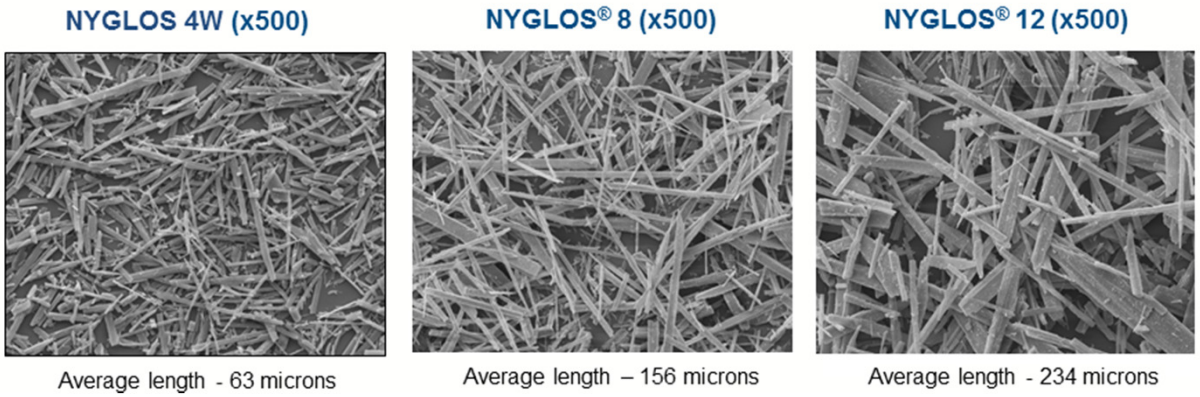
Talc: $Mg_3Si_4O_{10}(OH)_2$ Phlogopite: $KMg_3(AlSi_3)O_{10}(OH/F)_2$

Wollastonite Properties & Structure

- Chemistry
  - Calcium Silicate ($CaSiO_3$)
- Naturally occurring white mineral
- Morphology: Acicular
- Mohs hardness = 4.5
- Surface modification possible



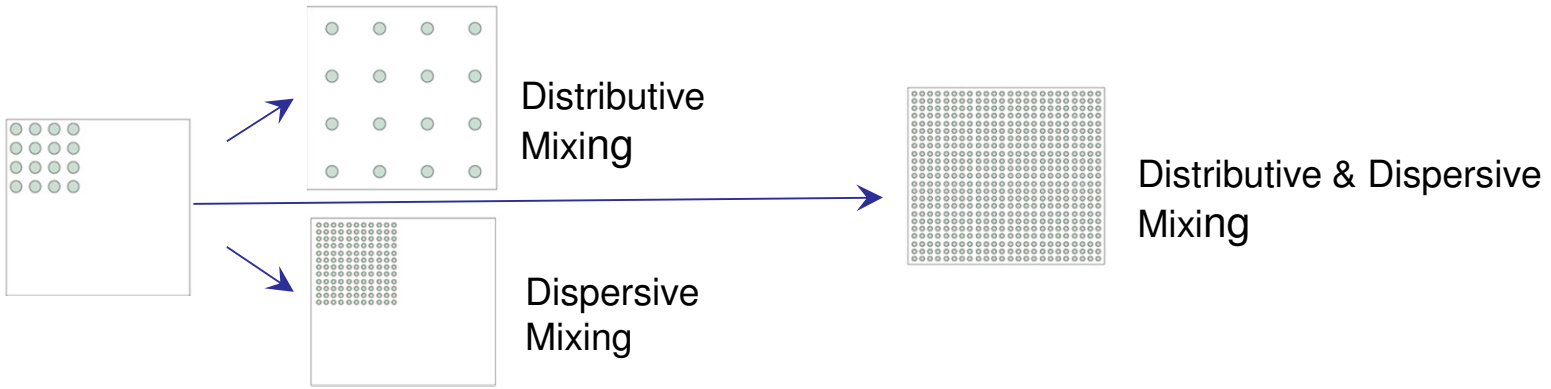
Si – blue, O – red, Ca - yellow



Processing Optimization (Compounding)

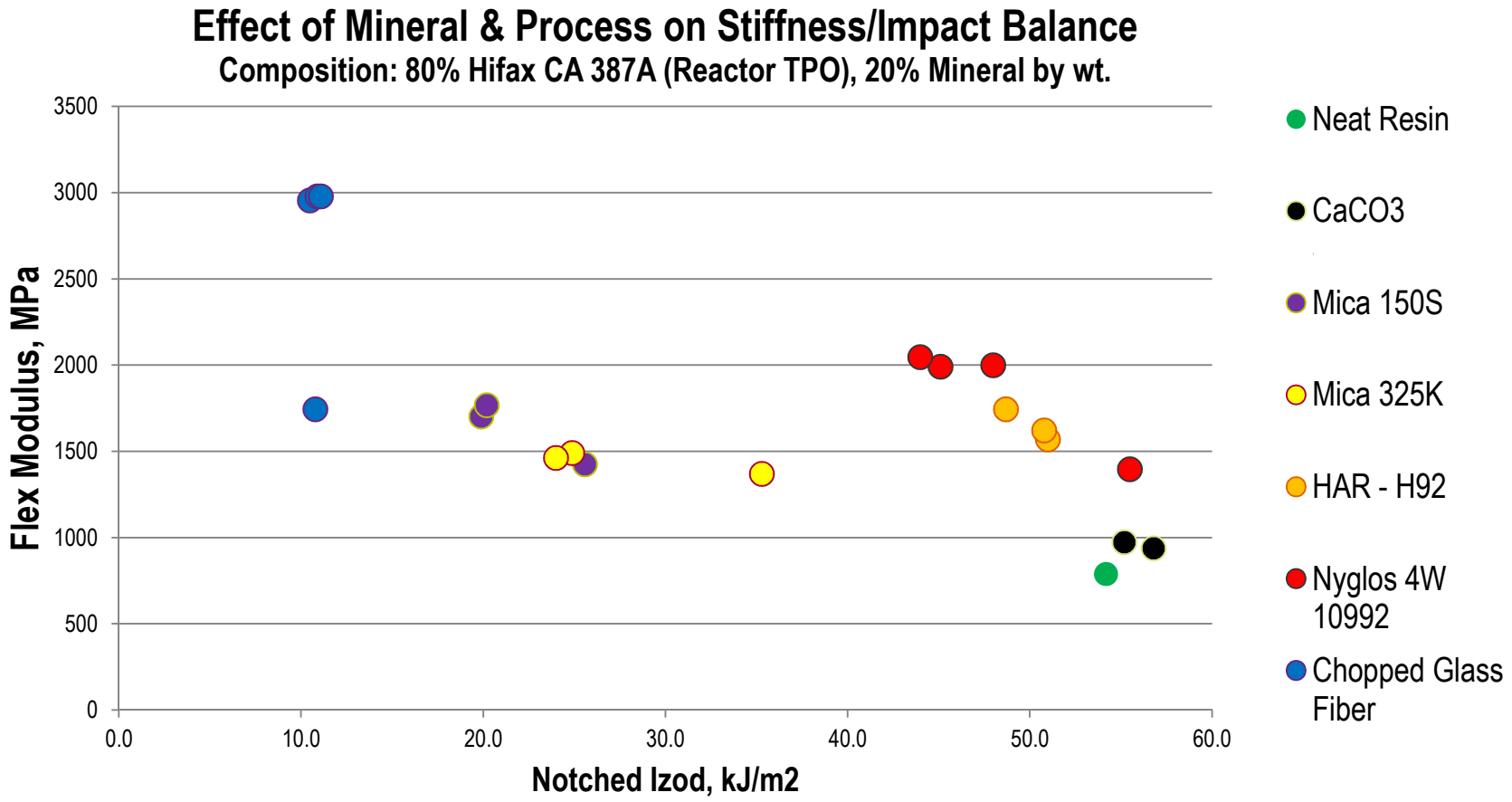
Critical processing parameters include

- Extruder type & L/D
- Screw design & RPM
- Throughput; SME
- Feed location; side or upstream
- Processing temperature
- Resin & rheology
- Screen Pack



Processing parameters critical in achieving optimal end performance

Processing Optimization: Various Minerals



Melt compound on 25mm co-rotating/intermeshing TSE (46:1, L/D)
ISO test specimen prepared on Arburg 66T Injection molding

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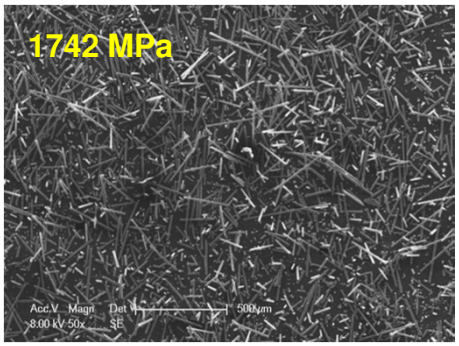
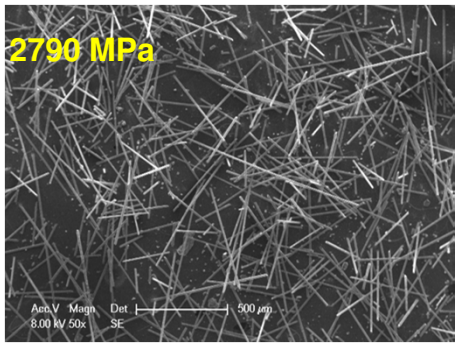
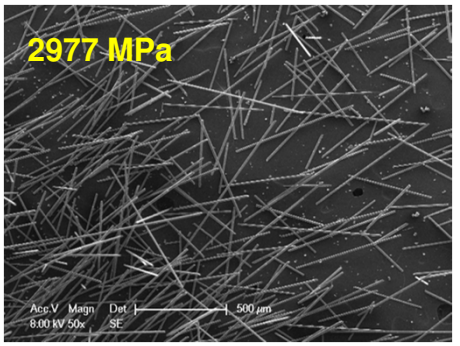
Processing Optimization: Various Minerals

Effect of Process on Morphology and Stiffness

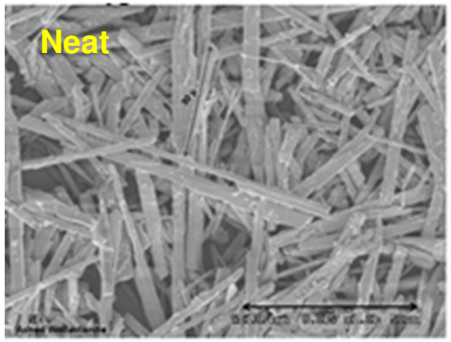
Chopped Glass Fiber

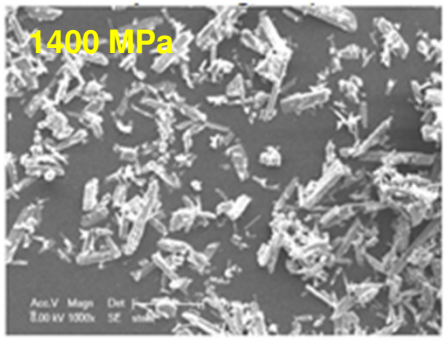


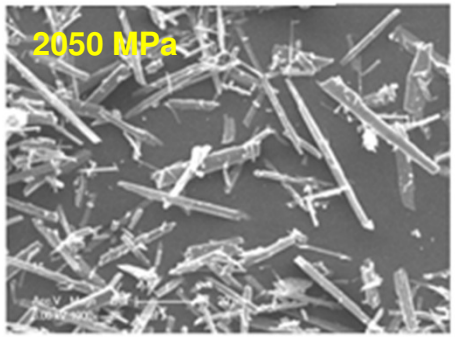




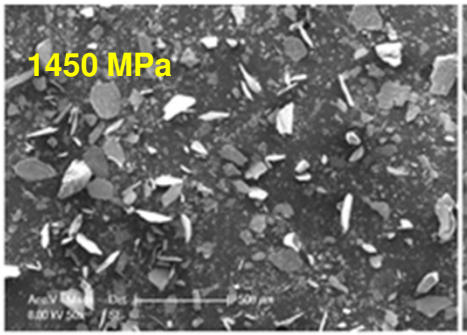
Nyglos 4W

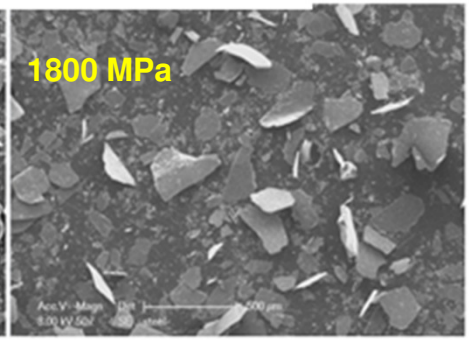




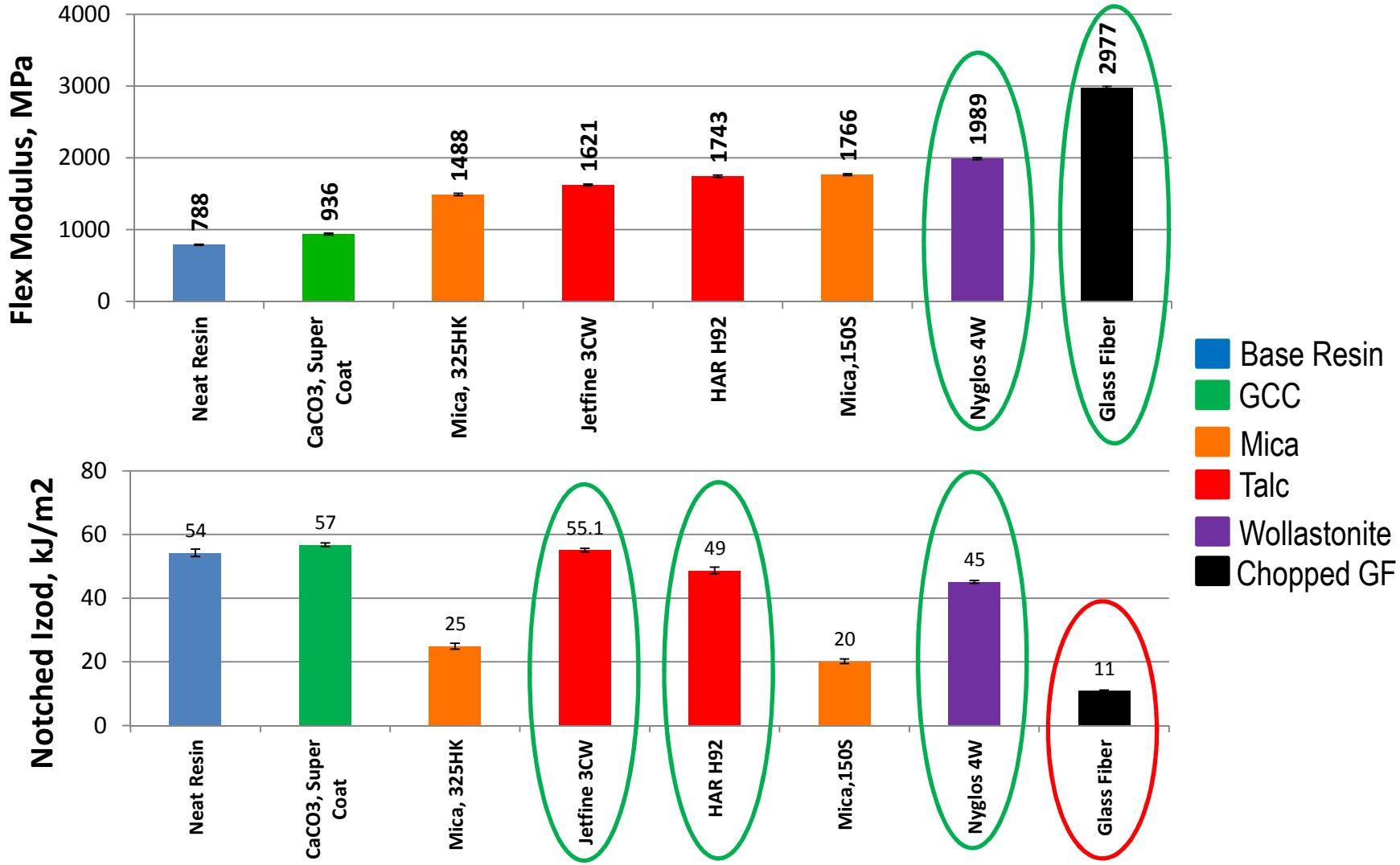


Mica 150S



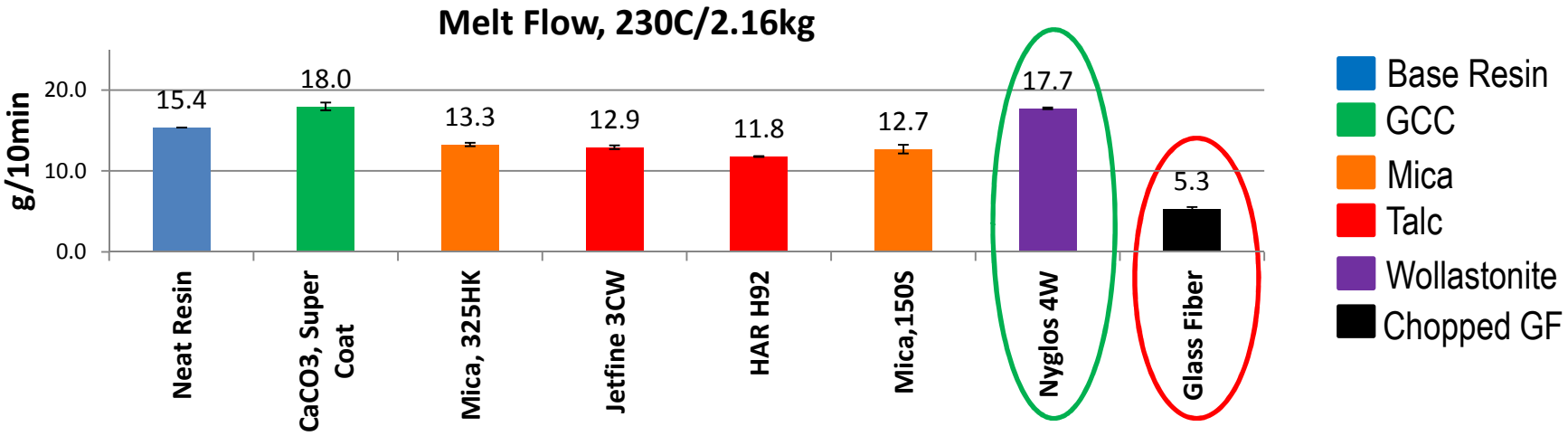


Results: Performance Comparison



Composition: 80% Hifax CA 387A (Reactor TPO), 20% Mineral by wt.

Results: Performance Comparison



Composition: 80% Hifax CA 387A (Reactor TPO), 20% Mineral by wt.

Findings

- Superior attributes with Chopped GF in Modulus (Strength, HDT and Shrinkage) but inferior in other properties:
  - Impact retention (both Notched Izod & Multiaxial Impact)
  - Flow
  - Anisotropic
  - Warpage
  - Surface finish/aesthetic
  - Equipment wear

Balance of Properties often Critical

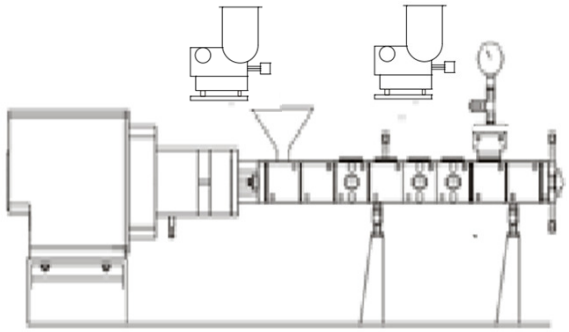
Screening Objectives/Approach

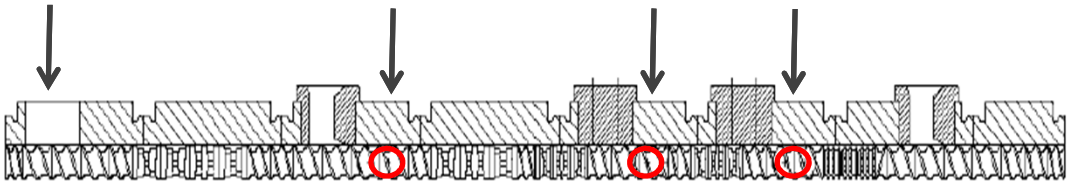
Objectives

- Evaluate commercial Talc, Mica & Wollastonite grades in PP Copolymer at 20% by wt. loading
- Identify performance space, trends/relationships

Approach

- Melt compound via 25mm co-rotating/intermeshing TSE (46:1, L/D)





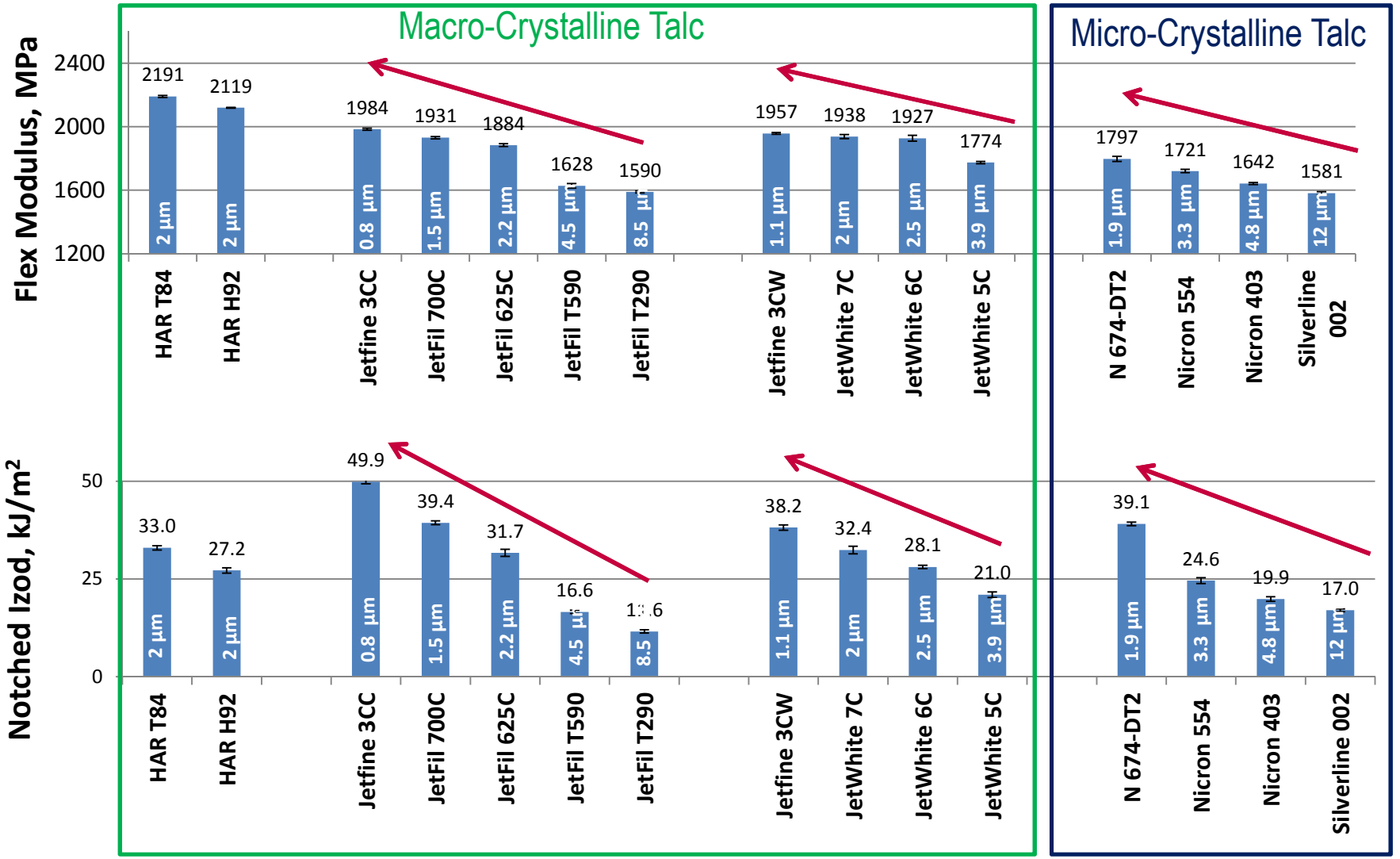
Screw Design

Profile at 15kg/hr & 200/450 screw RPM, Atmospheric Vent

Materials

- Resin: Braskem PP Copolymer # T16200Q4
- Minerals: Talc (15 grades), Mica (10 grades) and Wollastonite (4 grades - neat & surface treated)

Test Results - Talc

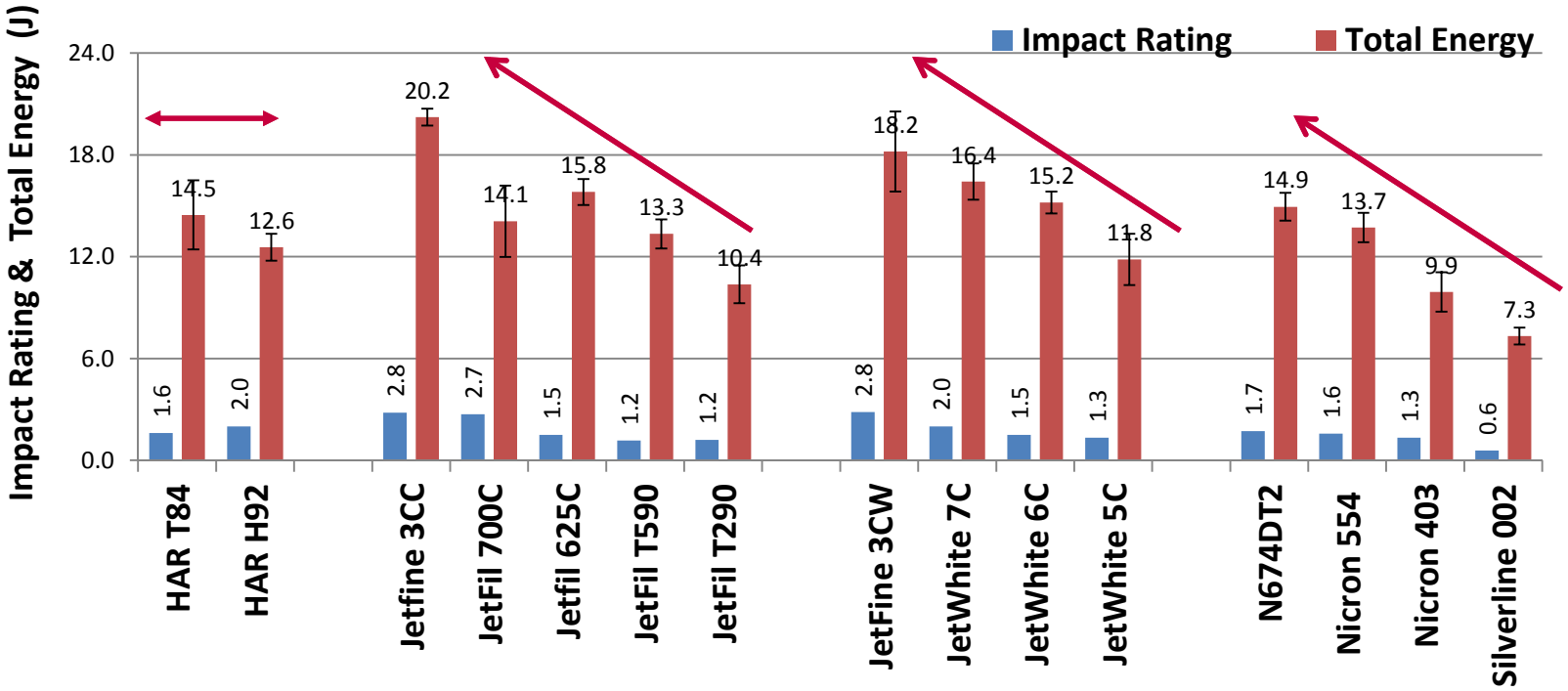


Composition: Braskem PP Copolymer & 20% Mineral by wt.

Baseline Braskem PP Copolymer Fex modulus: **850 Mpa,** Notched Izod – **No Break**

Test Results - Talc

Multiaxial Impact at 0°C, 4.4 m/s (ISO 6603)

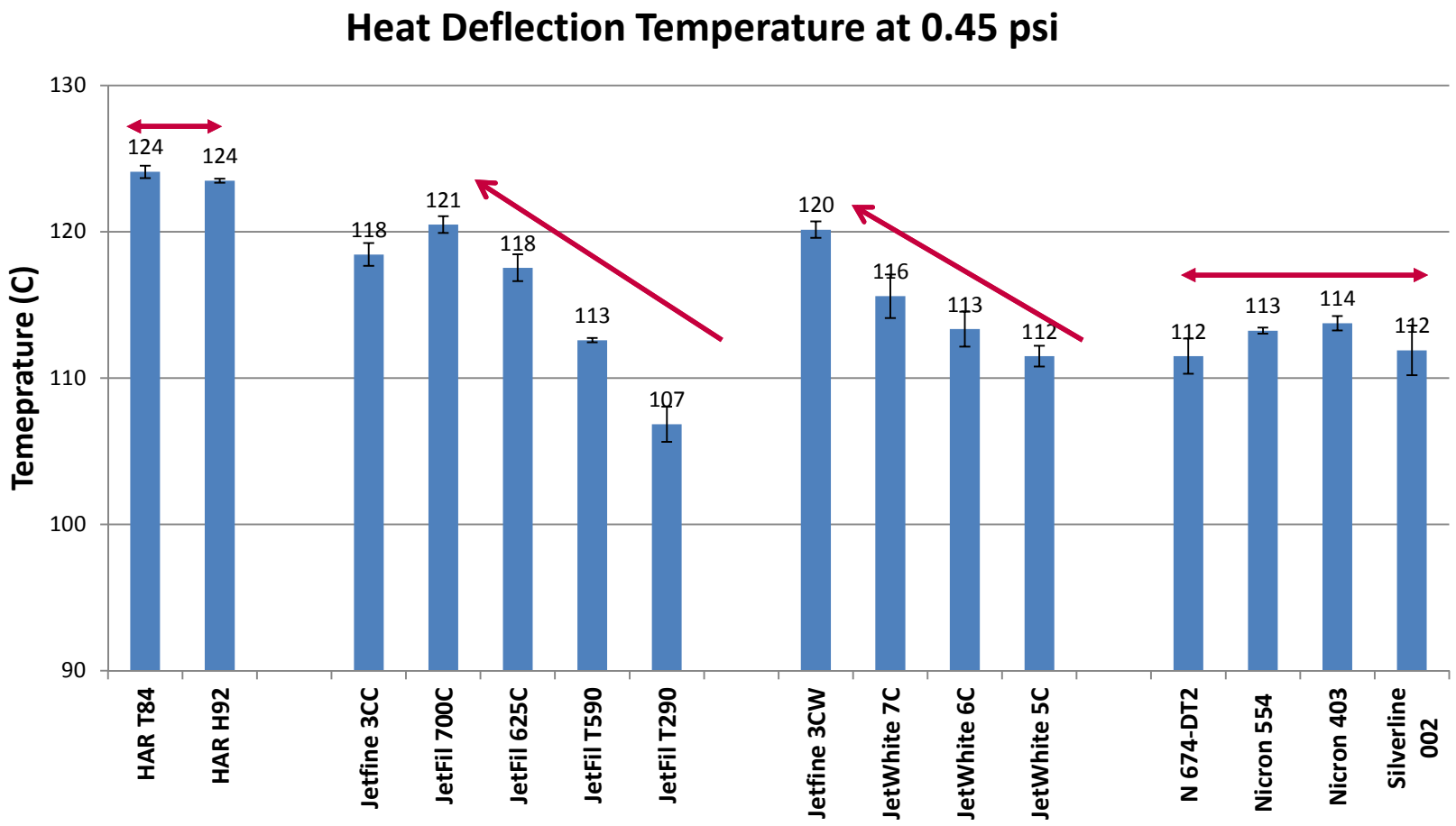


Impact Rating
3 – Extended Ductile
2 – Ductile
1 – Semi - Ductile
0 – Brittle

Finer d50 psd = Superior Impact Retension

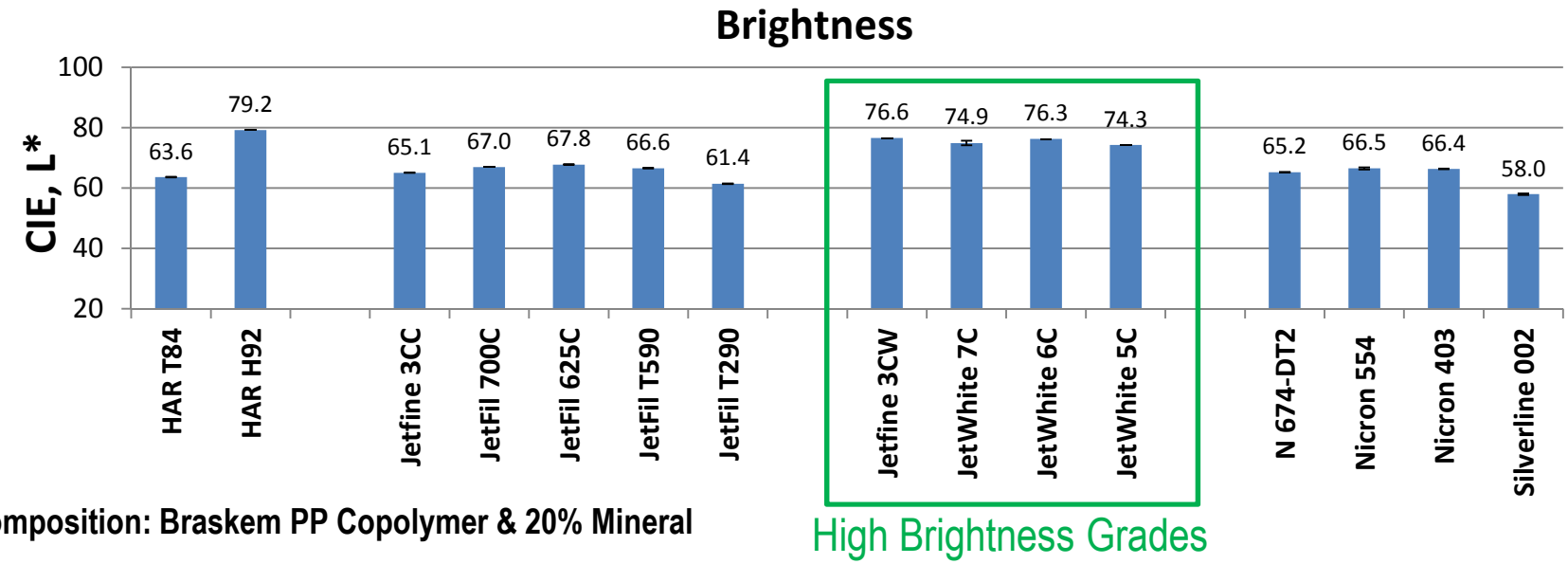
Composition: Braskem PP Copolymer & 20% Mineral by wt.

Test Results - Talc



Composition: Braskem PP Copolymer & 20% Mineral by wt.

Test Results - Talc

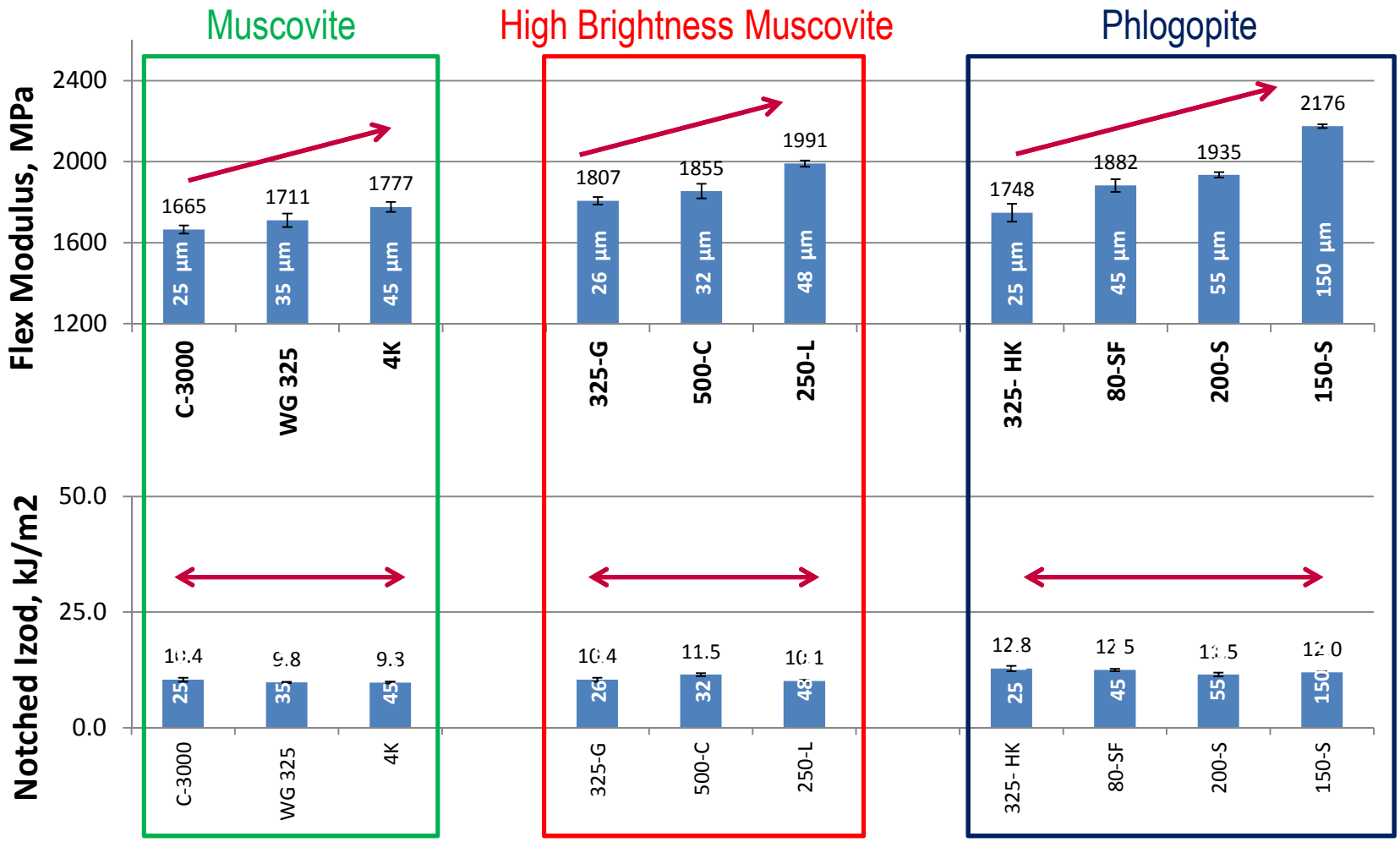


Composition: Braskem PP Copolymer & 20% Mineral

Talc Findings

- HAR – Best reinforcing talc
- Particle size:
  - ↓ Particle size results in ↑ Modulus & ↑ Impact retention; finer particles are generally better
- Purity influences Brightness (↑ Purity ↑ Brightness)
- Macro-crystalline generally superior in mechanicals vs. Micro-crystalline

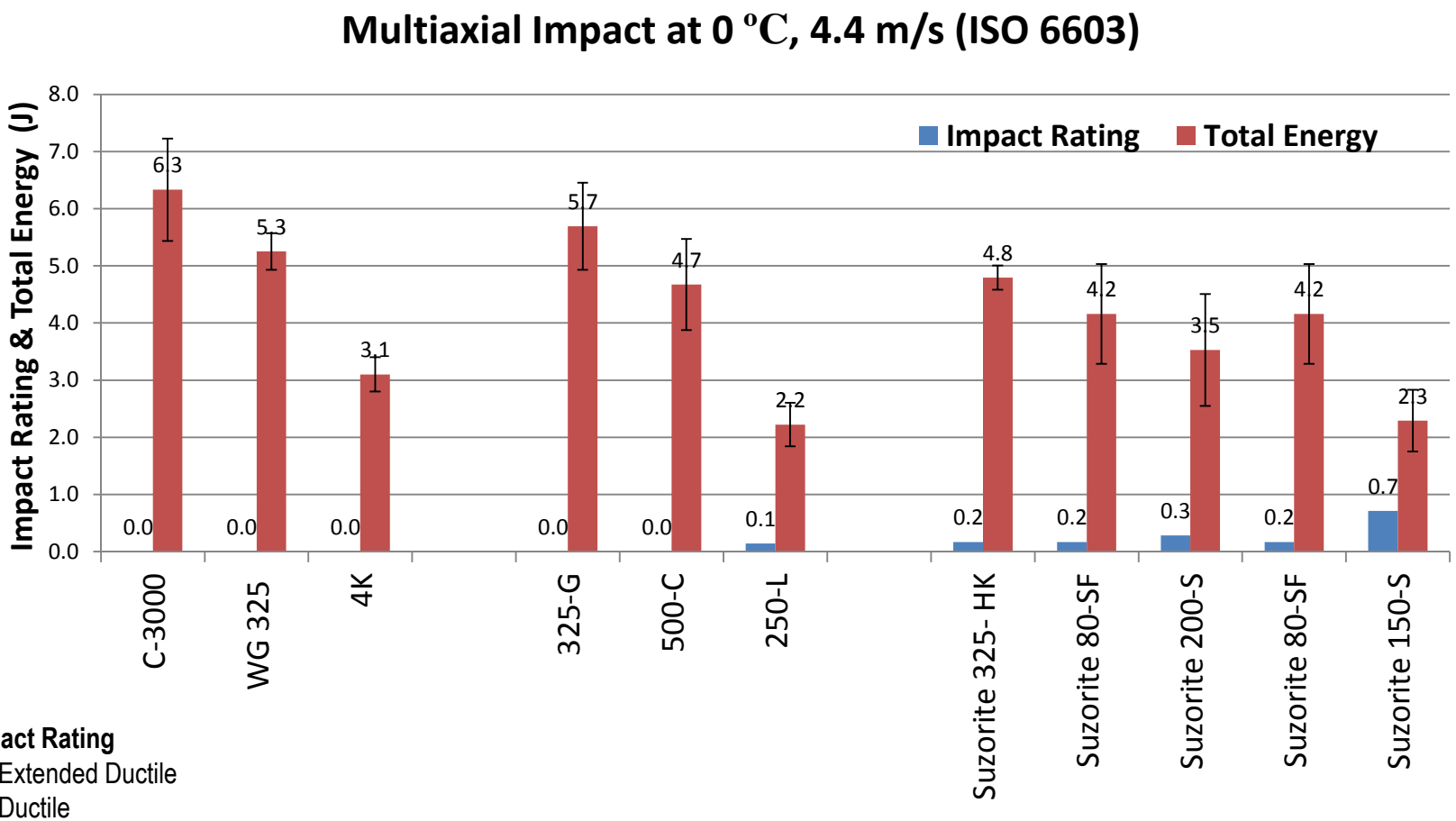
Test Results - Mica



Composition: Braskem PP Copolymer & 20% Mineral

Baseline Braskem PP Copolymer Fex modulus: **850 Mpa,** Notched Izod – **No Break**

Test Results - Mica

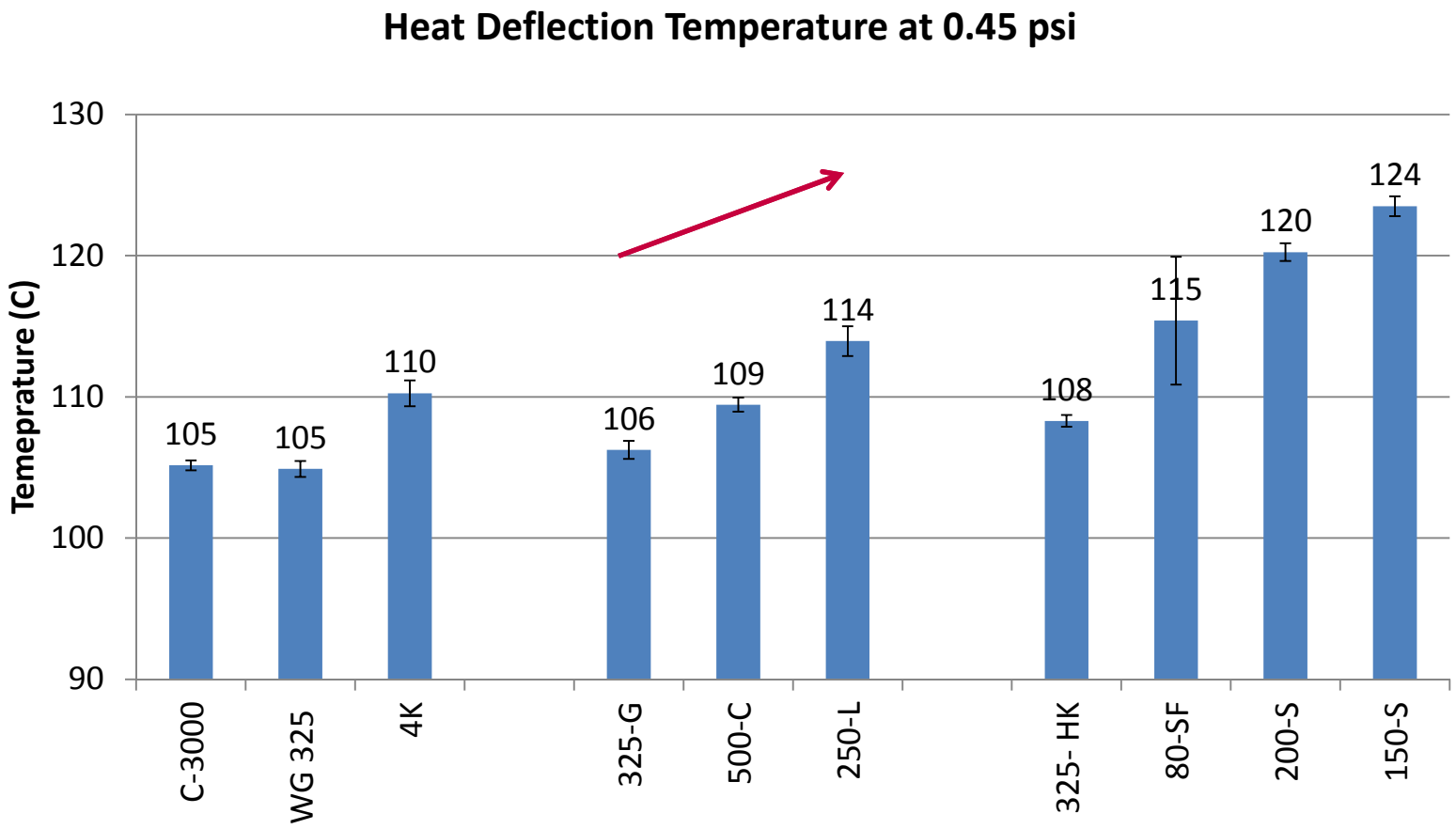


Impact Rating
3 – Extended Ductile
2 – Ductile
1 – Semi - Ductile
0 – Brittle

All Mica grades exhibit Brittle Failure

Composition: Braskem PP Copolymer & 20% Mineral

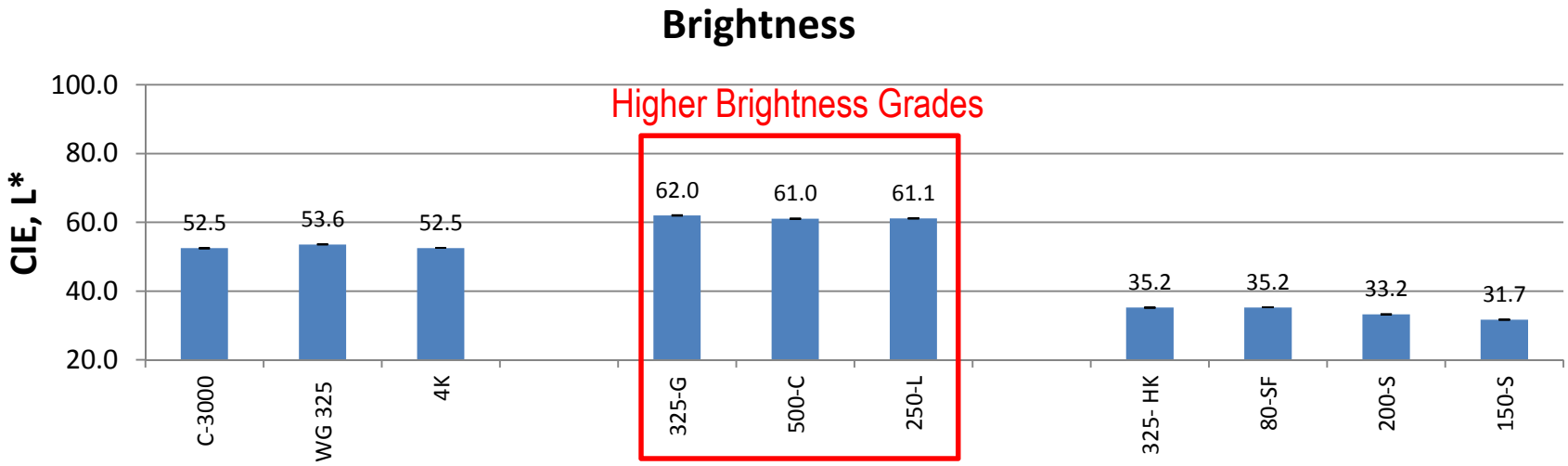
Test Results - Mica



Coarser Mica Grades yield Superior HDT

Composition: Braskem PP Copolymer & 20% Mineral

Test Results - Mica

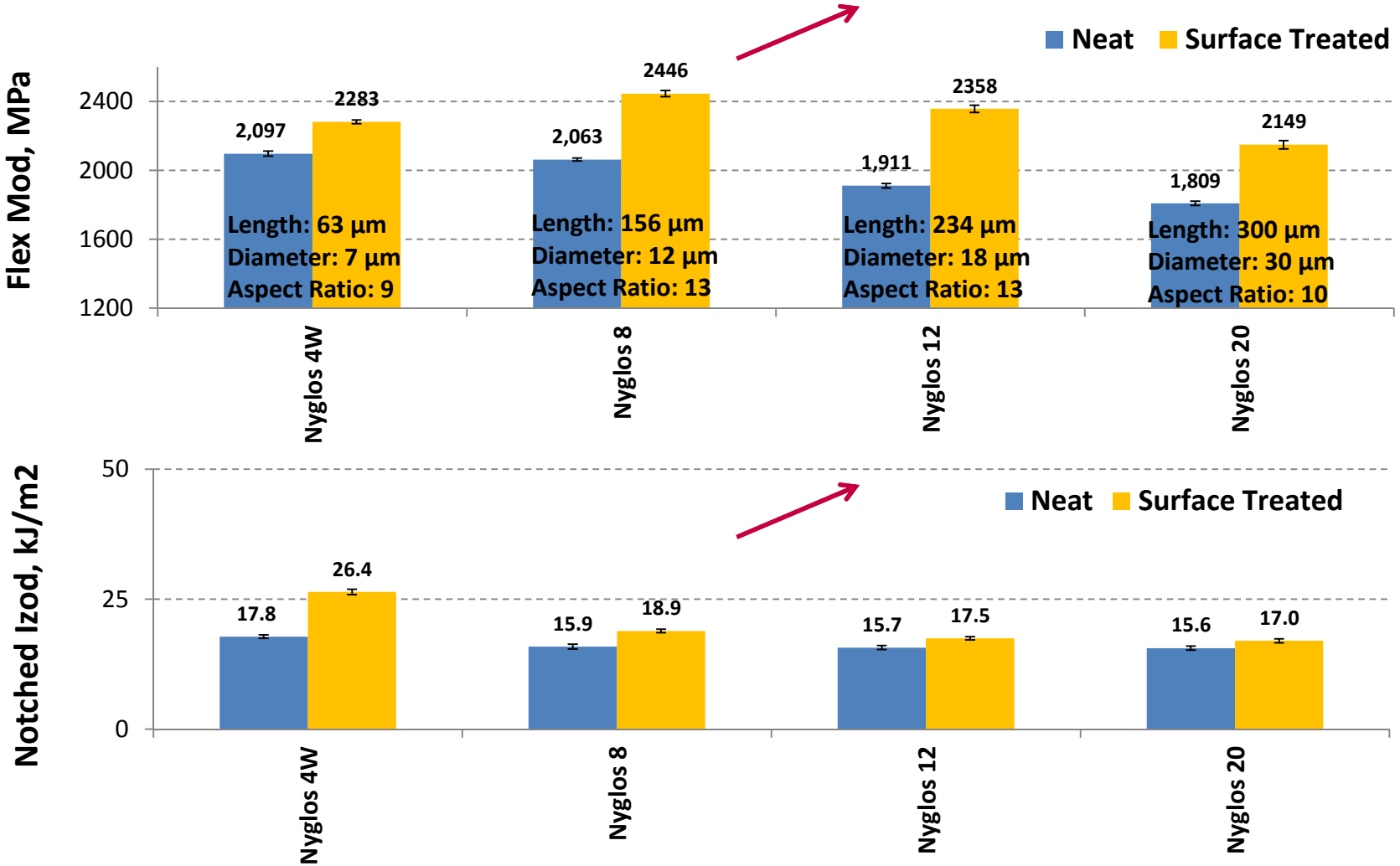


Composition: Braskem PP Copolymer & 20% Mineral

Mica Findings

- Coarse grade, Mica 150-S best reinforcing (similar to HAR talc); both at 2200 MPa
- Effect of Particle size (opposite to talc):
  - ↑ Particle size provides↑ Modulus.
  - Impact retention generally poor (killer variable)
- Purity influences Brightness (↑ Purity ↑ Brightness)
  - Overall lower L* value than talc

Test Results - Wollastonite



Composition: Braskem PP Copolymer & 20% Mineral

Baseline Braskem PP Copolymer Fex modulus: **850 Mpa,** Notched Izod – **No Break**

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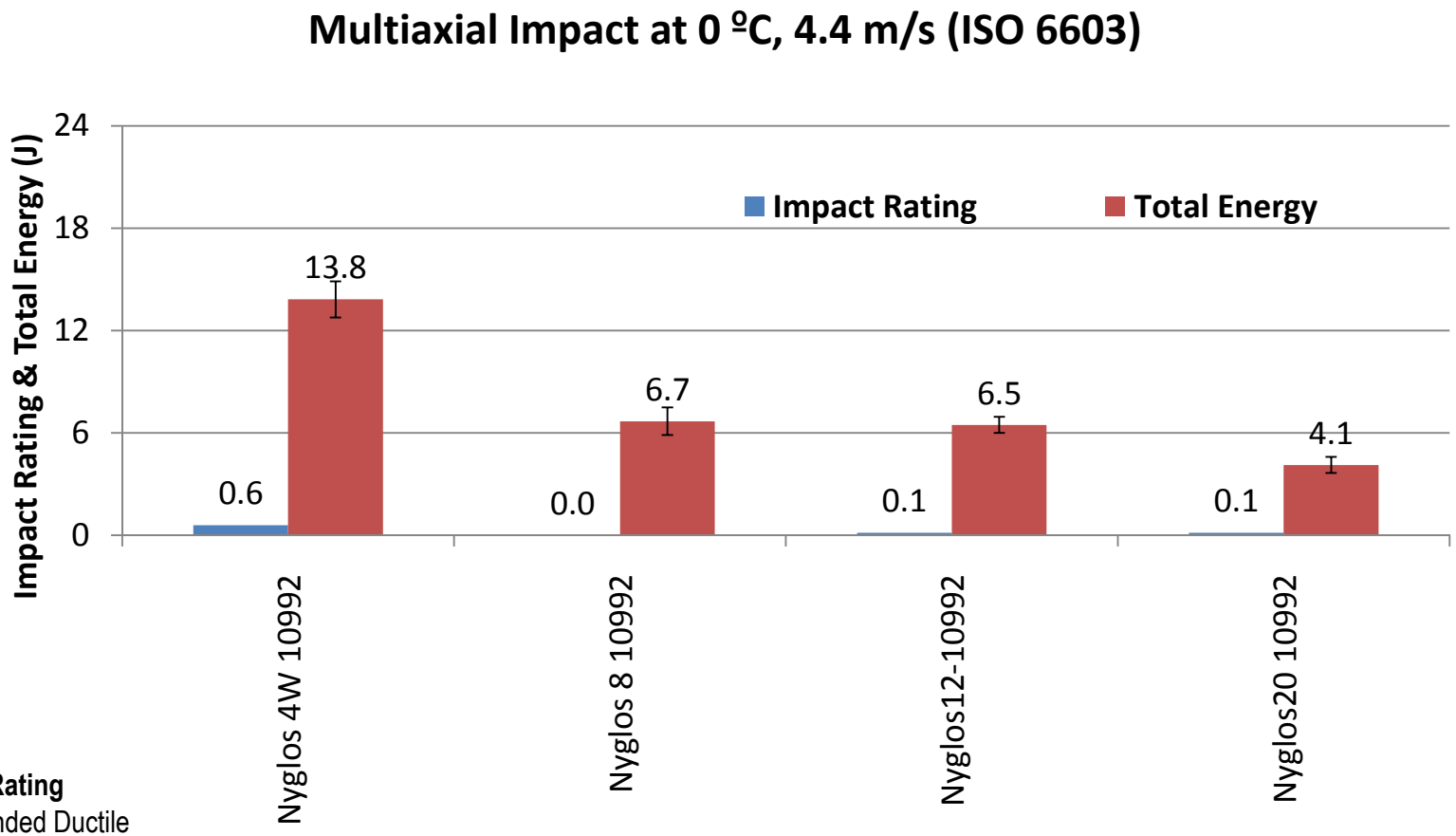
Test Results - Wollastonite



Impact Rating
3 – Extended Ductile
2 – Ductile
1 – Semi - Ductile
0 – Brittle

Brittle Failure; slightly better than Mica but inferior to Talc

Composition: Braskem PP Copolymer & 20% Mineral

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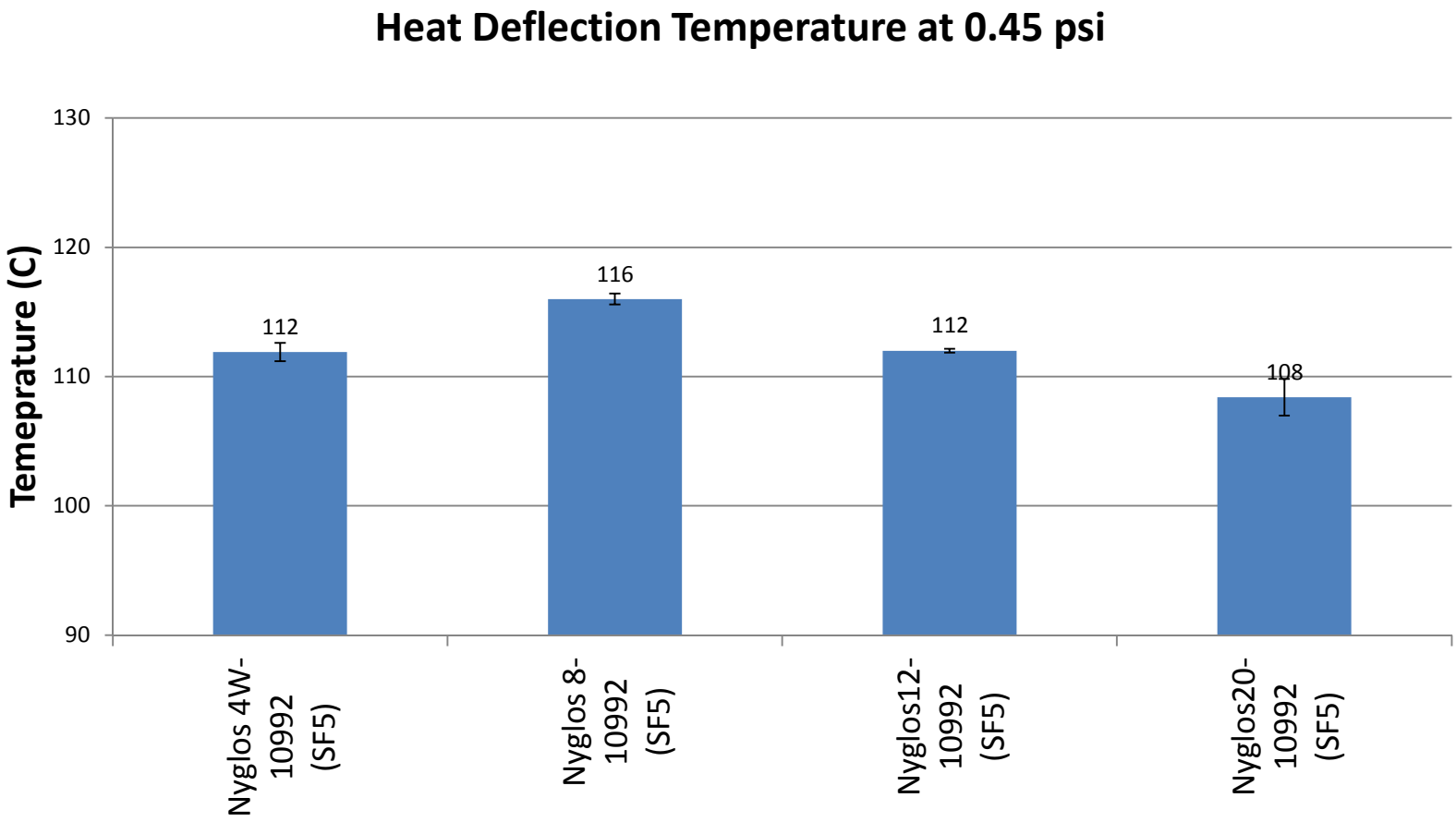
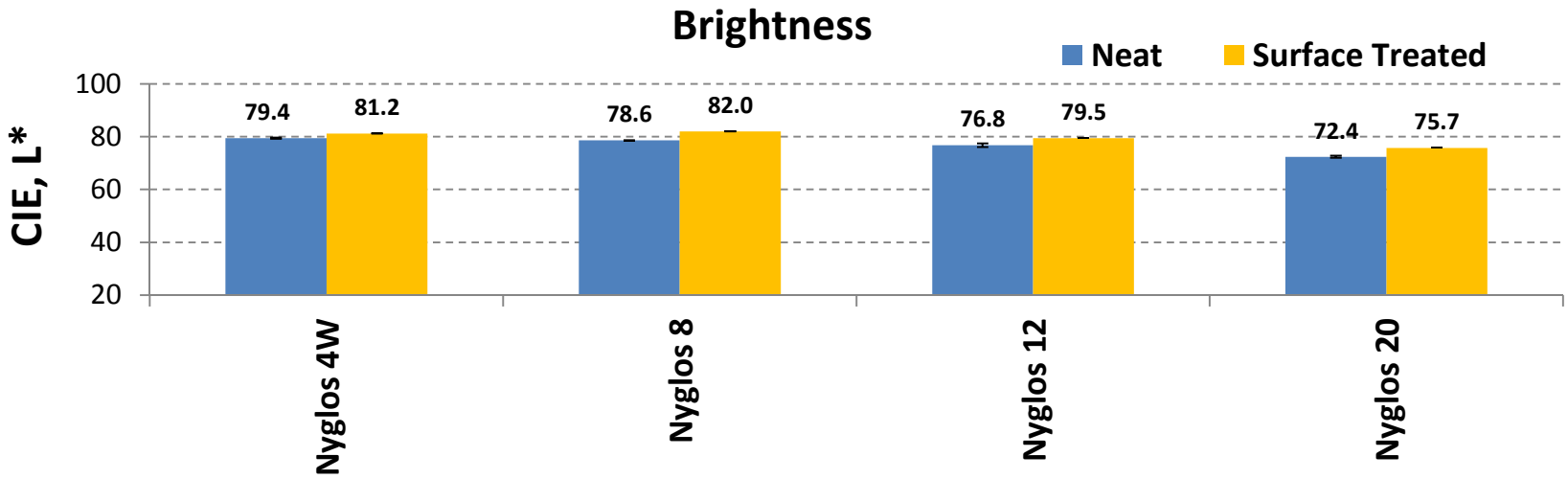
Test Results - Wollastonite



Composition: Braskem PP Copolymer & 20% Mineral

Test Results - Wollastonite

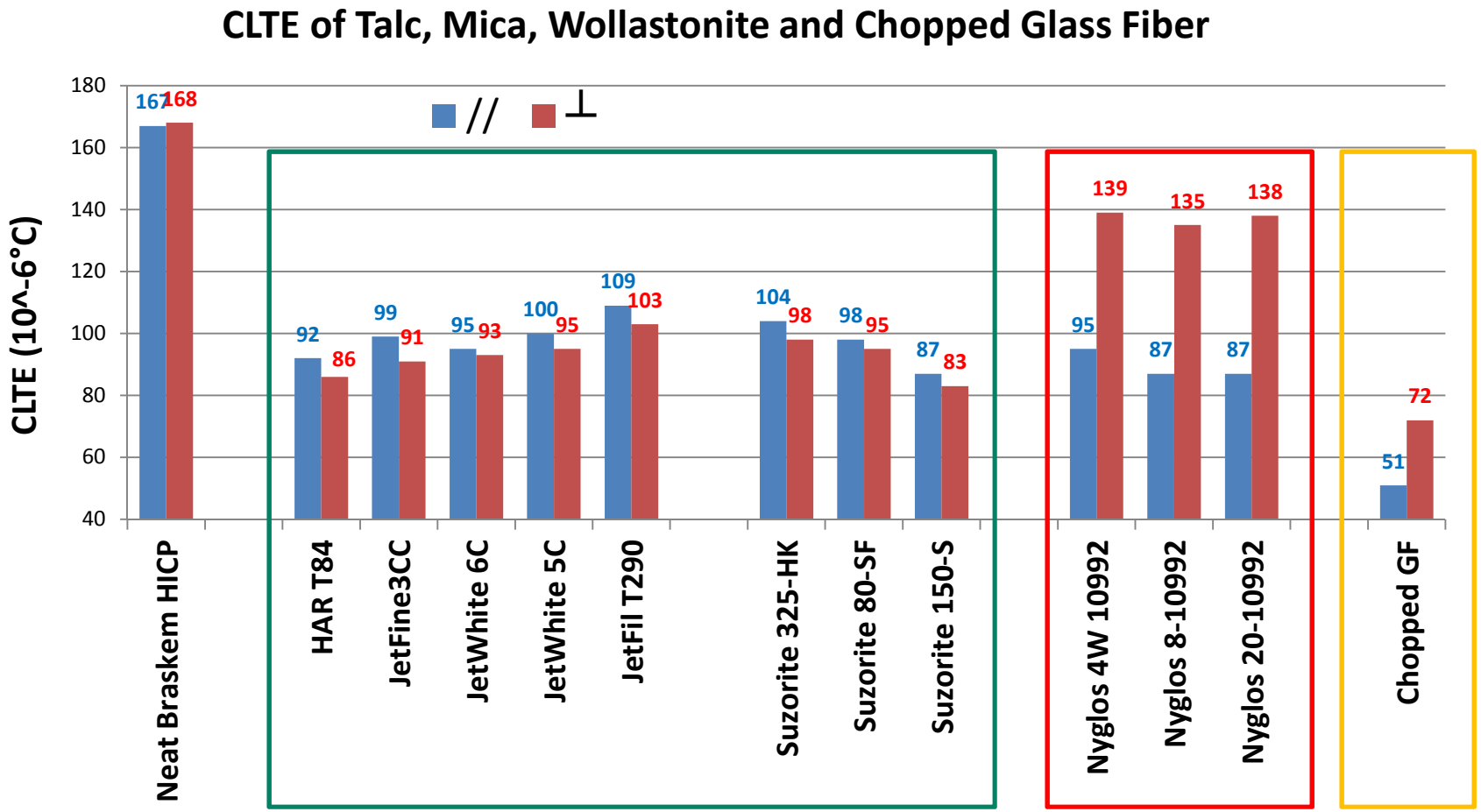


Composition: Braskem PP Copolymer & 20% Mineral

Wollastonite Findings

- Increase in reinforcement & impact strength with surface treatment (↑ by 10-19% & 50% respectively)
- Effect of aspect ratio (for surface treated grades)
  - ↑ higher aspect ratio yields ↑ Modulus.
- Higher reinforcement (↑ 10%) compared to talc or mica (2450 vs. 2200 Mpa)
- Impact decreases with increase in particle length/diameter (coarser products); overall inferior to talc
- Superior brightness
  - Boost with surface treatment
  - Finer grades overall better

Test Results - CLTE



Composition: Braskem PP Copolymer & 20% Mineral

Performance Comparison (Talc/Mica/Wollastonite/GF)

- Mineral selection/grade largely dependent on CTQ, end performance requirements along with price (overall cost to performance)
- Talc, generally mineral of choice if stiffness/impact balance is key; commonly used with olefins/automotive formulations
- Mica & Wollastonite more prevalently used with engineered resins (PA6, 6/6)
- Each mineral has its own unique strengths/weaknesses

Performance Grid for 20% Mineral in 20MFI PP Copolymer

Property	Talc	Mica	Wollastonite	Chopped GF
Modulus/Stiffness	++	++	++½	++++
Impact – Notched Izod	++++	++	+++	+
Impact – Multiaxial Impact	++++	+	+++	++
Rheology – Melt Flow	+++	++	++++	+
Color/Brightness	+++	++	++++	
HDT	++½	++½	++	++++
Shrinkage	+++	+++	++	+++½
CLTE	+++	+++	++	+++½
Scratch Resistance	++½	+	++	+++
Nucleation of PP	+++		++	
Surface Treatment	+	+++	+++	+++

This Study
Prior Study/Knowledge

Conclusions

- Various Talc, Mica, Wollastonite grades evaluated versus chopped glass fiber
- Process Optimization – Critical to establish for each mineral
- Chopped Glass Fiber – Highest reinforcement
  - Best modulus/strength; workhorse in many applications in which impact is less critical
  - Does have limitations/challenges (impact, flow, wear, surface aesthetic, etc.)
  - Stiffness/Impact balance inferior to talc & Wollastonite
- Talc – Excellent stiffness/impact balance
  - Best performance with finer grades (Increase in stiffness/impact with lower psd)
  - Color influenced by ore body & purity
    - **HAR** for maximum stiffness & low shrinkage/CLTE
    - **Jetfine 3CW** for optimum balance of stiffness/impact & impact ductility at -30°C
    - **Jetfine 3CC** for optimum scratch resistance & stiffness/impact balance
    - **JetWhite** for color sensitive high bright applications
    - **Nicron 674** for moderate reinforcement

Conclusions

- Mica – High reinforcement/inferior impact retention
  - Highest reinforcement with coarser grades (increase in stiffness with higher particle size)
  - Impact considerably lower than talc or Wollastonite
    - Grades available for maximum stiffness & high brightness
    - Surface treatment possible (but not evaluated in study)
- Wollastonite – Excellent reinforcement, highest brightness (exceeds talc/mica), impact inferior to talc;
  - Best stiffness/impact with surface treated product
  - Good flow & high brightness
    - Surface treated **Nyglos 4W** – for good reinforcement & impact retention
    - Surface treated **Nyglos 8, 12 and 20** – for maximum reinforcement; some loss in impact

Thank you for your attention !

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