THERMOPLASTIC ELASTOMERS • STRUCTURAL • WEAR

CONDUCTIVE • COLOR • FLAME RETARDANT

Tough or Strong?
Short or Long?
Dialing in Mechanical Properties

Karl Hoppe

Senior Product Development Engineer

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA

website: www.rtpcompany.com • **email:** rtp@rtpcompany.com • **Wiman Corporation** • +1 320-259-2554

ISO 9001

TELEPHONE:

U.S.A.	SOUTH AMERICA	MEXICO	EUROPE	SINGAPORE	CHINA
+1 507-454-6900	+55 11 4193-8772	+52 81 8134-0403	+33 380-253-000	+65 6863-6580	+86 512-6283-8383

Strength

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Stiffness

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Impact

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Structural Composites Formula

Resin + Additives = Change in Properties

Structural Additives: Foundation

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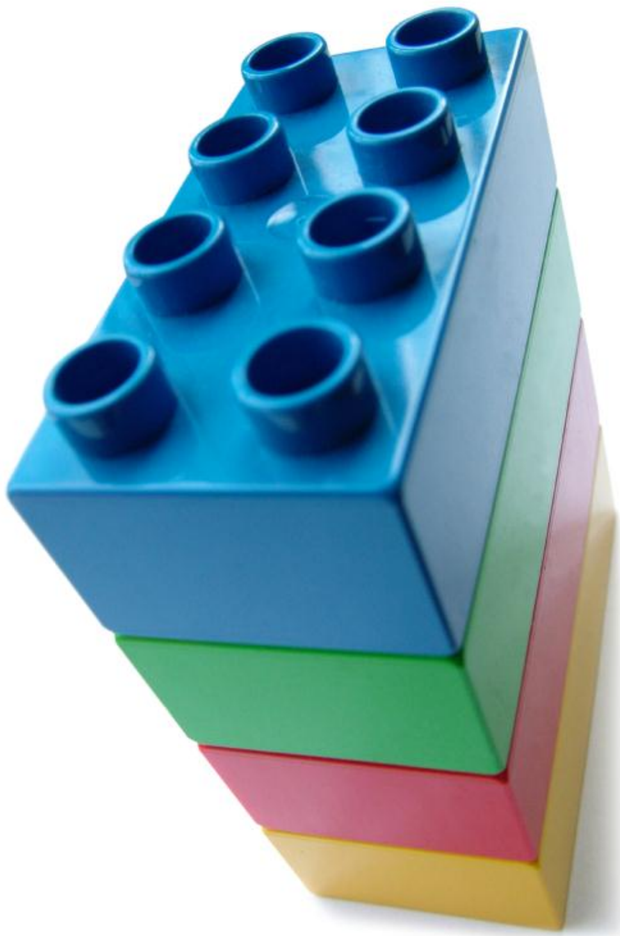

In this Presentation

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Modifiers

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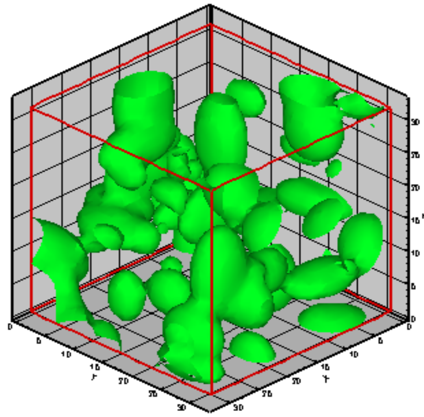
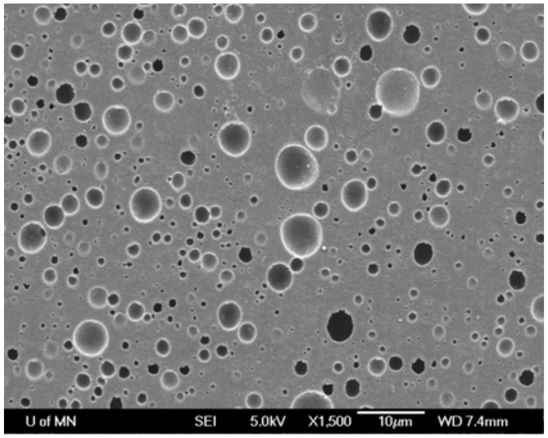
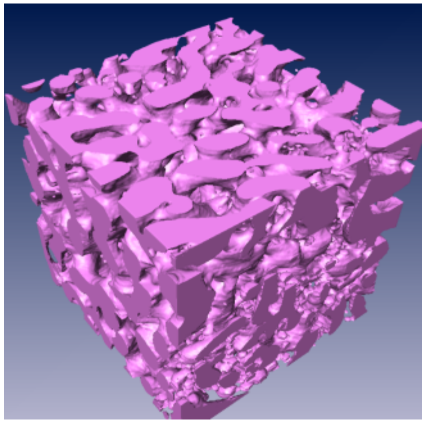
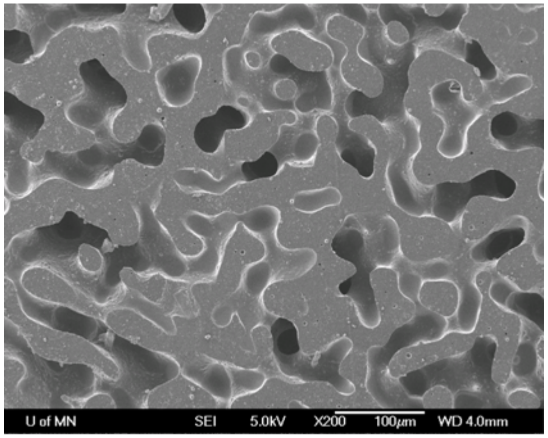
Polymer Blends
Impact Modifiers









PC / ABS → ABS brings
- Improved flow
- Chemical resistance
- Cost reduction

Nylon / PP → PP brings
- Improved flow
- Chemical resistance
- Cost reduction

PC /PBT → PBT brings
- Improved flow
- Chemical Resistance

Polymer Blends

PC / ABS → PC brings

- Toughness
- Strength

Nylon / PP → Nylon brings

- Strength
- Stiffness

PC /PBT → PC brings

- Toughness
- Dimensional stability

Polymer Blends

	PC	PC/ABS (RTP 2500 A)	ABS
Specific Gravity	1.19	1.15	1.05
Tensile Strength	59 MPa	59 MPa	45 MPa
Notched Izod Impact	850 J/m	740 J/m	250 J/m

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Polymer Blends

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Application: Housing for Hearing Tester

Problem: Toughness and chemical resistance

Solution: Polycarbonate/ABS Alloy

Benefit: Strength and toughness of PC with the added chemical resistance of ABS

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Modifiers

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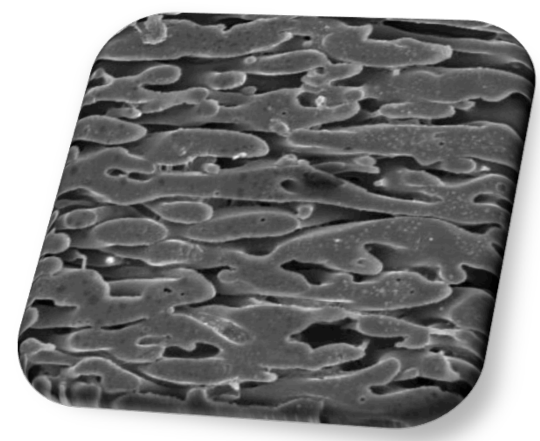
Impact properties

Impact Modifiers

Strength
Stiffness



Impact Modifiers

	PA 6/6	Impact Modified PA 6/6
Specific Gravity	1.14	1.08
Notched Izod Impact	55 J/m	900 J/m
Tensile Strength	80 J/m	45 J/m
Flexural Modulus	2.8 GPa	1.8 GPa

Impact Modified

Application: Housing for Wireless Workstation

Problem: Toughness and abrasion resistance

Solution: Impact Modified PA 6/6

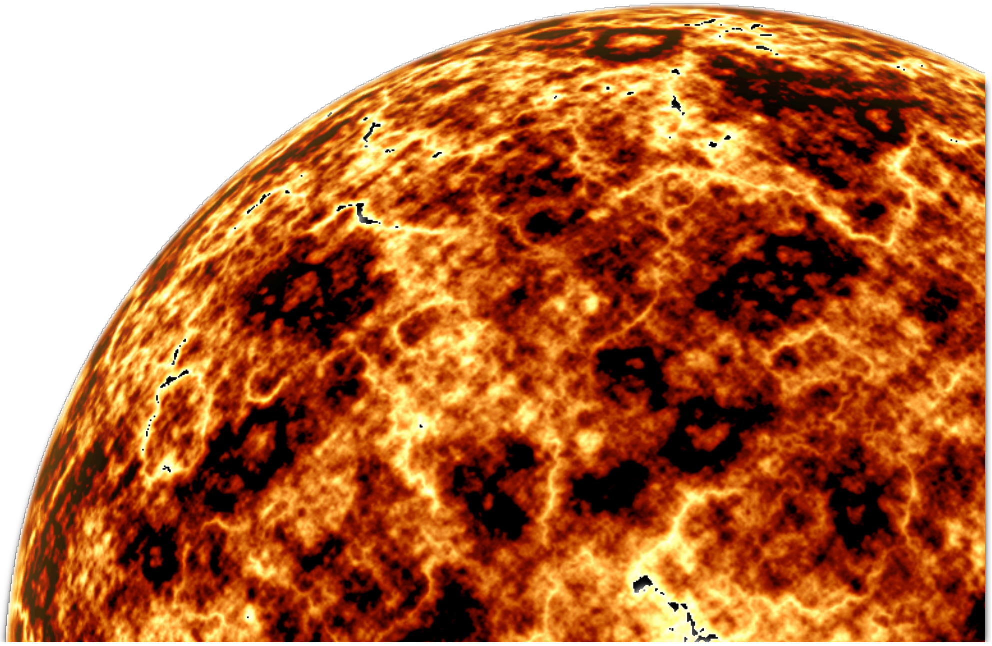
Benefit: Wear and abrasion resistance of Nylon 6/6 with added toughness from impact modifier

Impact Modifiers

- Limitations
  - Base resin
    - Lose Performance
    - Temperature
  - Environment
    - Chemical Resistance
    - UV Resistance

Stabilizers

- **Protect from**
  - UV
  - Heat aging



UV Stabilization

- **Hindered Amine Light Stabilizers (HALS)**
  - Protects polymer by stopping degradation reactions once they have started
- **UV Absorbers**
  - Protects polymer by absorbing harmful UV light before the degradation reaction has started

UV Stabilization Data

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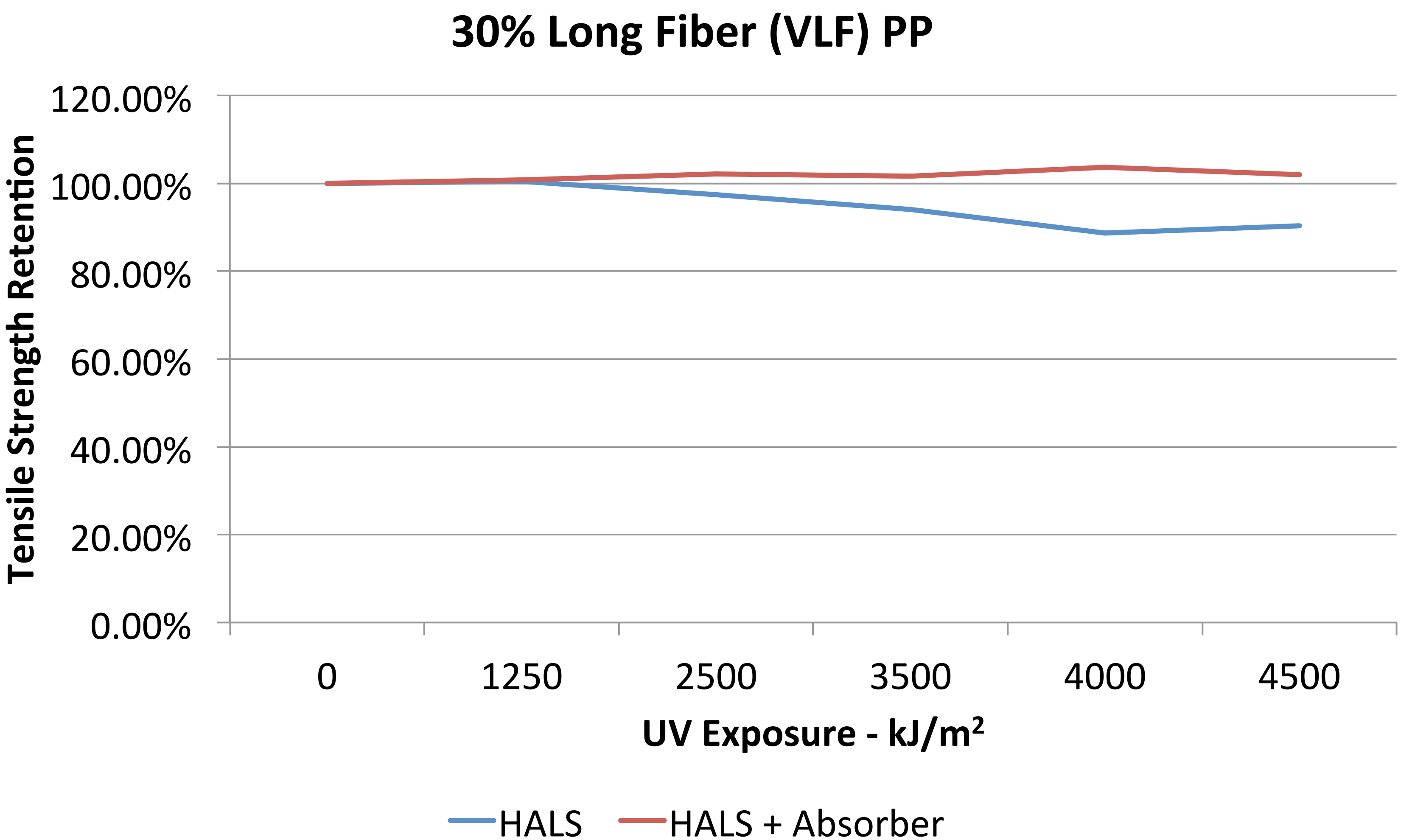

- **Heat stabilizers come in many forms**
  - Slow down the degradation reactions of the polymer caused by heat
  - Can be for process stability or Long Term Heat Aging (LTHA)

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Heat Stabilization Data

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40% VLF PP

1000 Hour Heat Aging

Temperature	Tensile Retention	Izod Impact Retention
140ºC	+5.7%	+9.9%
150ºC	-4.7%	-11.3%

Typical Automotive requirements are ~+/- 25%

In this Presentation

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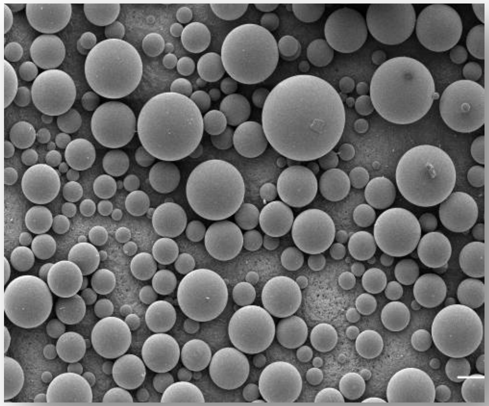
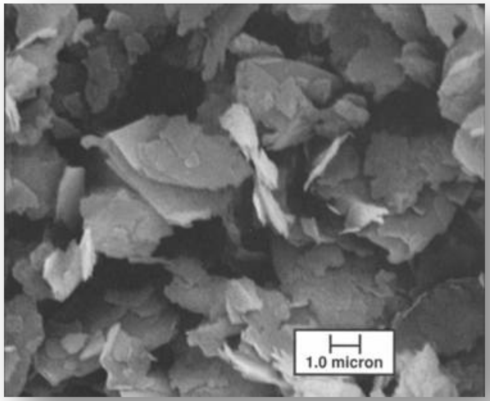
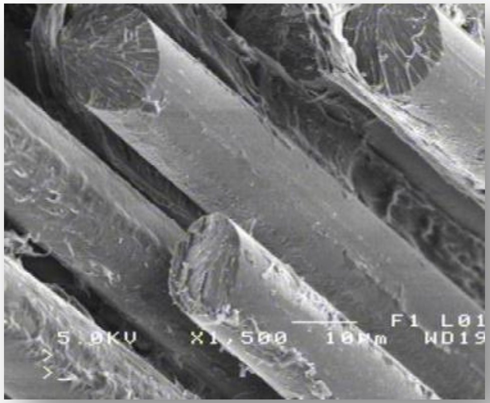
Fillers



Beads (Glass)
(photo: Potters, Inc.)

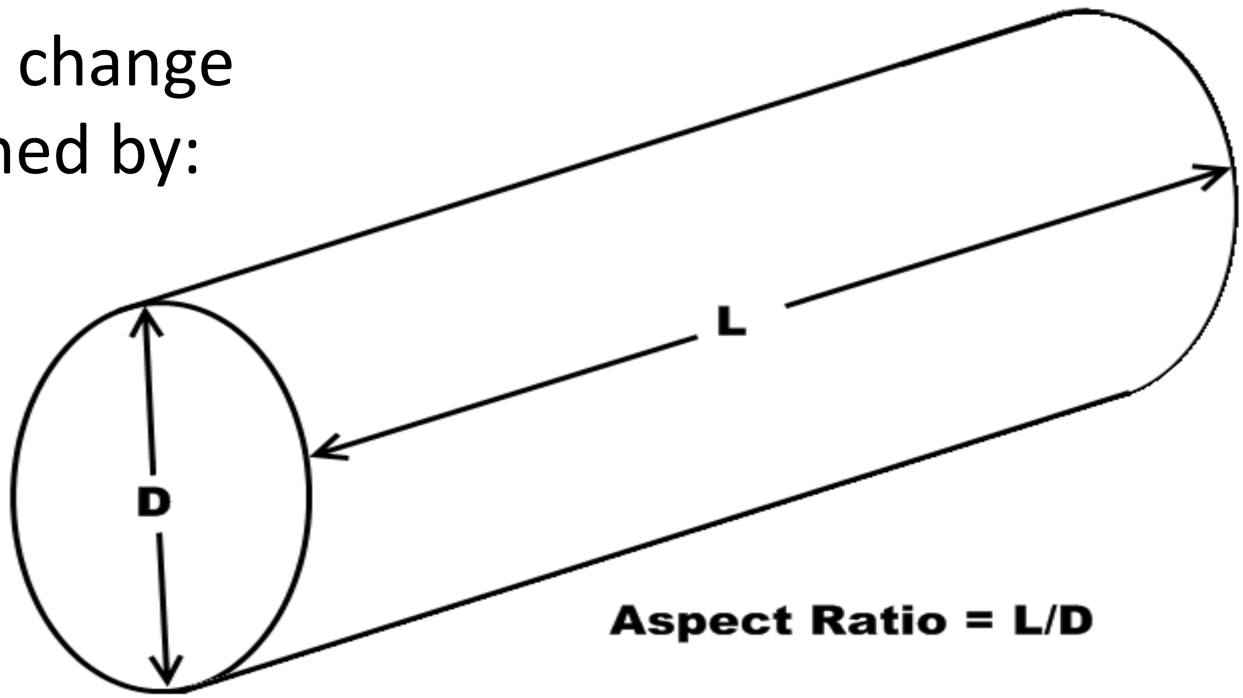


Minerals (Talc)



Fibers (Glass)

Property change determined by:



↑ Aspect Ratio

↑ Reinforcing

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Low Aspect Ratio

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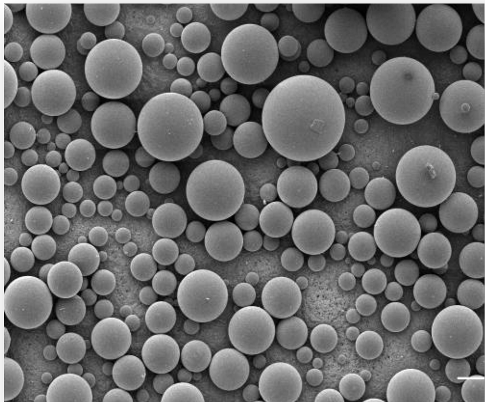
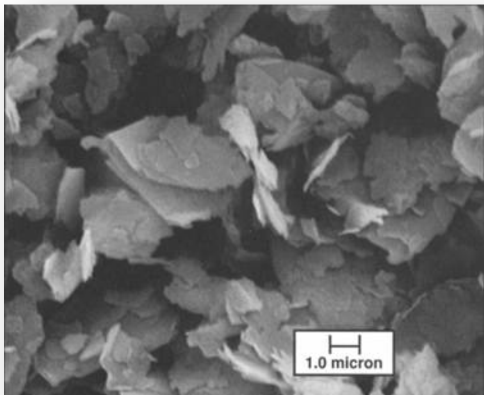


Beads (Glass)
(photo: Potters, Inc.)

Aspect Ratio = 1

	PC	PC + 10% Glass Beads	PC + 30% Glass Beads
Specific Gravity	1.19	1.27	1.42
Tensile Strength	59 MPa	55 MPa	48 MPa
Notched Izod Impact	850 J/m	100 J/m	80 J/m
Flexural Modulus	2.4 GPa	2.6 GPa	3.4 GPa

Low Aspect Ratio



Minerals (Talc)

Aspect Ratio = 2-50

	PP	PP + 20% Talc	PP + 40% Talc
Specific Gravity	0.91	1.05	1.25
Tensile Strength	32 MPa	32 MPa	30 MPa
Notched Izod Impact	47 J/m	45 J/m	34 J/m
Flexural Modulus	1.5 GPa	2.5 GPa	3.8 GPa

Warp Control

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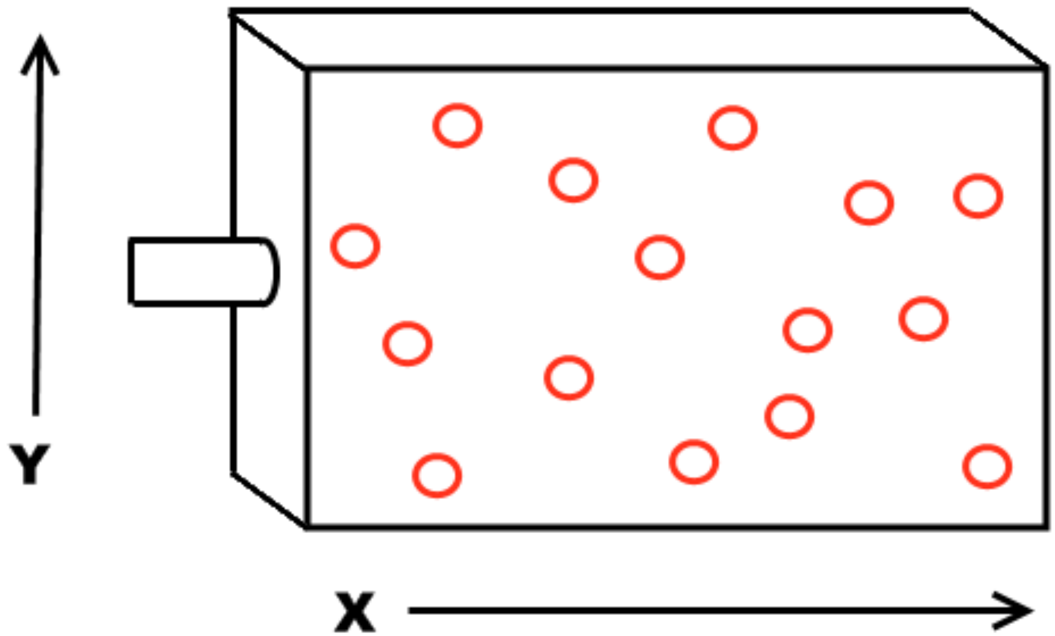


Shrink Rate x = Shrink Rate y → Flat Part

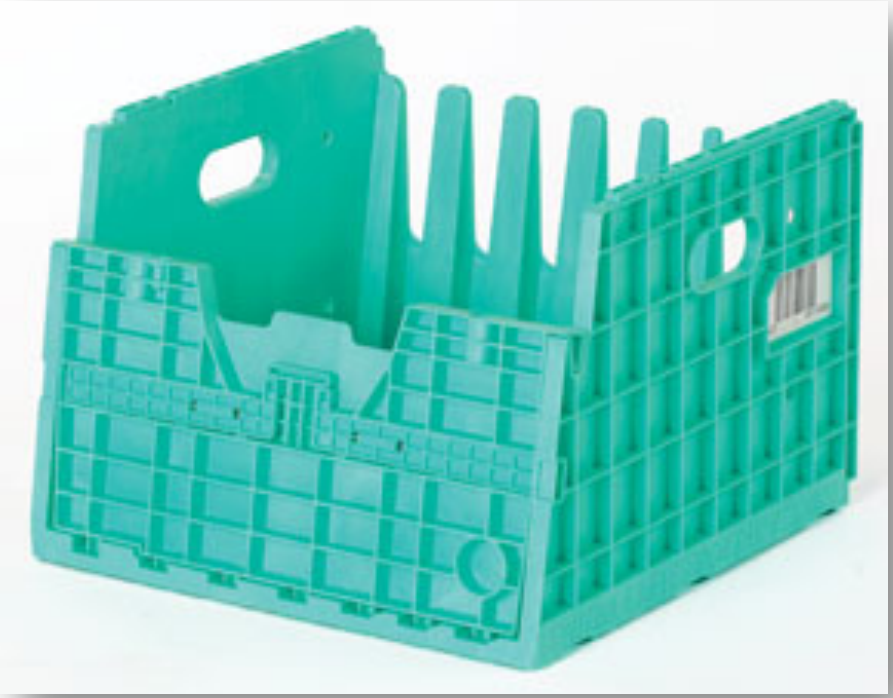
Low Aspect Ratio

Application: Reusable Handling Container

Problem: Dimensional stability

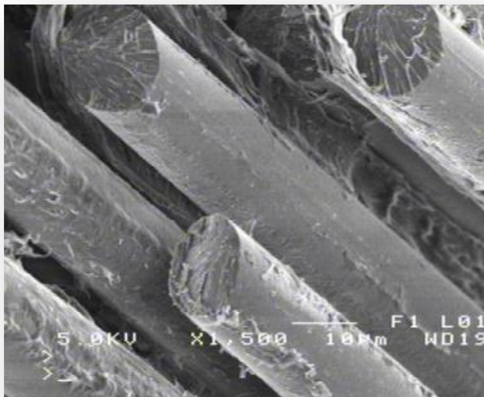
Solution: Mineral filled Polypropylene

Benefit: Low warpage



High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



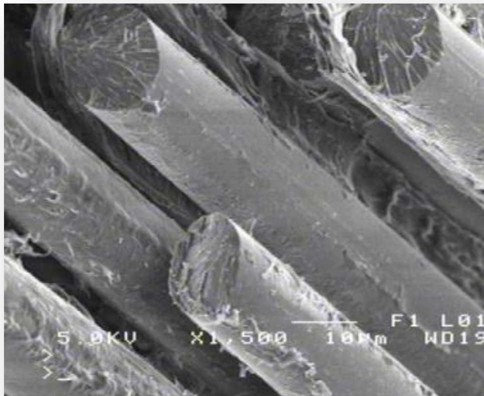
Fibers (Glass)

Aspect Ratio = 50-250

	PC	PC + 30% Glass Beads	PC + 30% Glass Fiber
Specific Gravity	1.19	1.42	1.42
Tensile Strength	59 MPa	48 MPa	124 MPa
Notched Izod Impact	850 J/m	80 J/m	160 J/m
Flexural Modulus	2.4 GPa	3.4 GPa	7.6 GPa

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Fibers (Glass)

Aspect Ratio = 50-250

	PP	PP + 40% Talc	PP+ 40% Glass Fiber
Specific Gravity	0.91	1.25	1.22
Tensile Strength	32 MPa	30 MPa	85 MPa
Notched Izod Impact	47 J/m	34 J/m	108 J/m
Flexural Modulus	1.5 GPa	3.8 GPa	6.9 GPa

High Aspect Ratio

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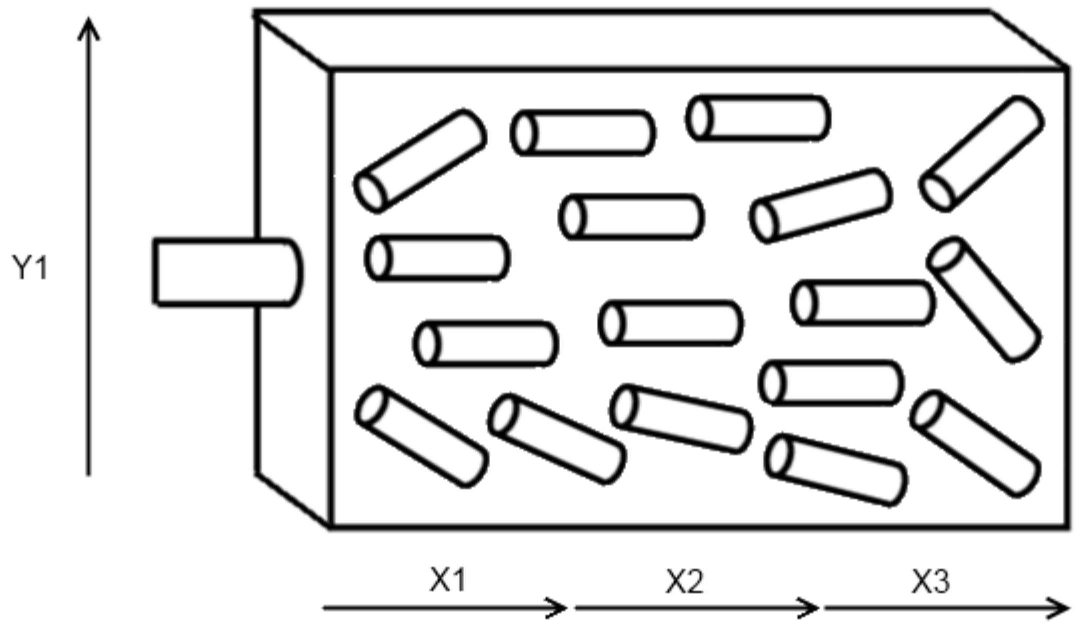
Application: Surgery Drill Guide

Problem: Stiffness and dimensional stability

Solution: Glass fiber reinforced Polycarbonate

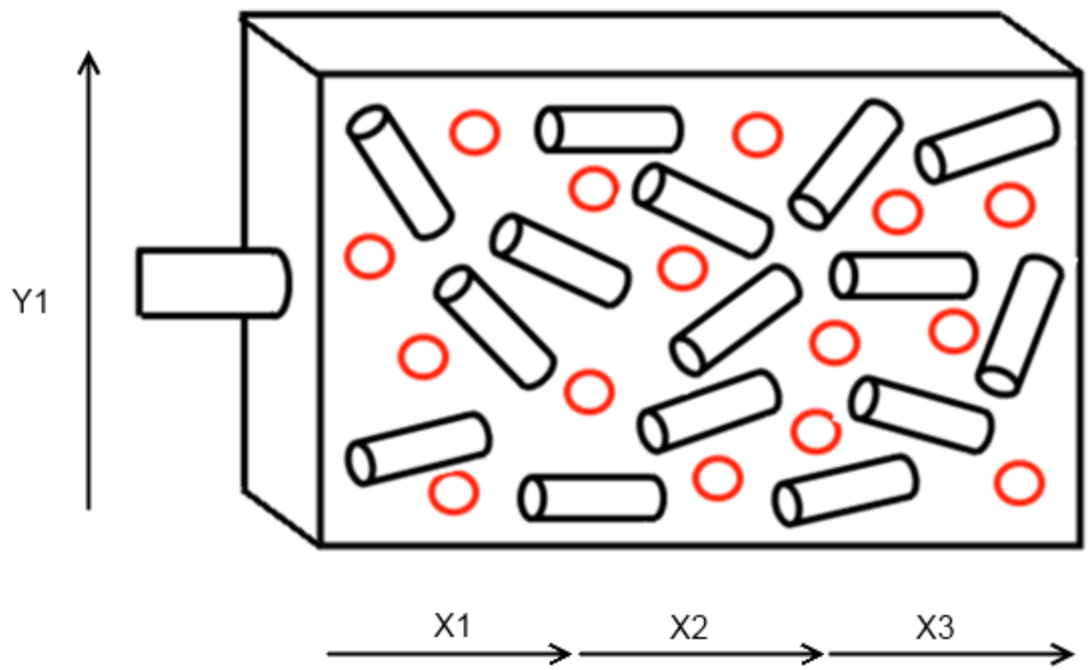
Benefit: Rigidity and tight tolerances

Non-Uniform Shrink = Warp



Shrinkage X1 & X2 ≠ X3 ⟶ Warp

Strength & Warp Control



Shrinkage X1 = X2 = X3 → Flat Part

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VLF Manufacturing Process

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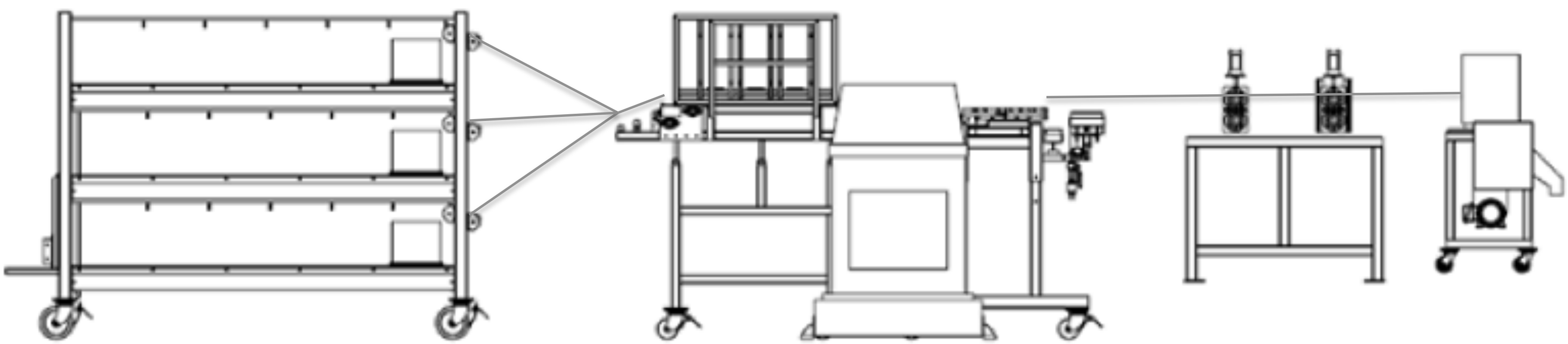
Fiber Extruder/Die Puller Pelletizer



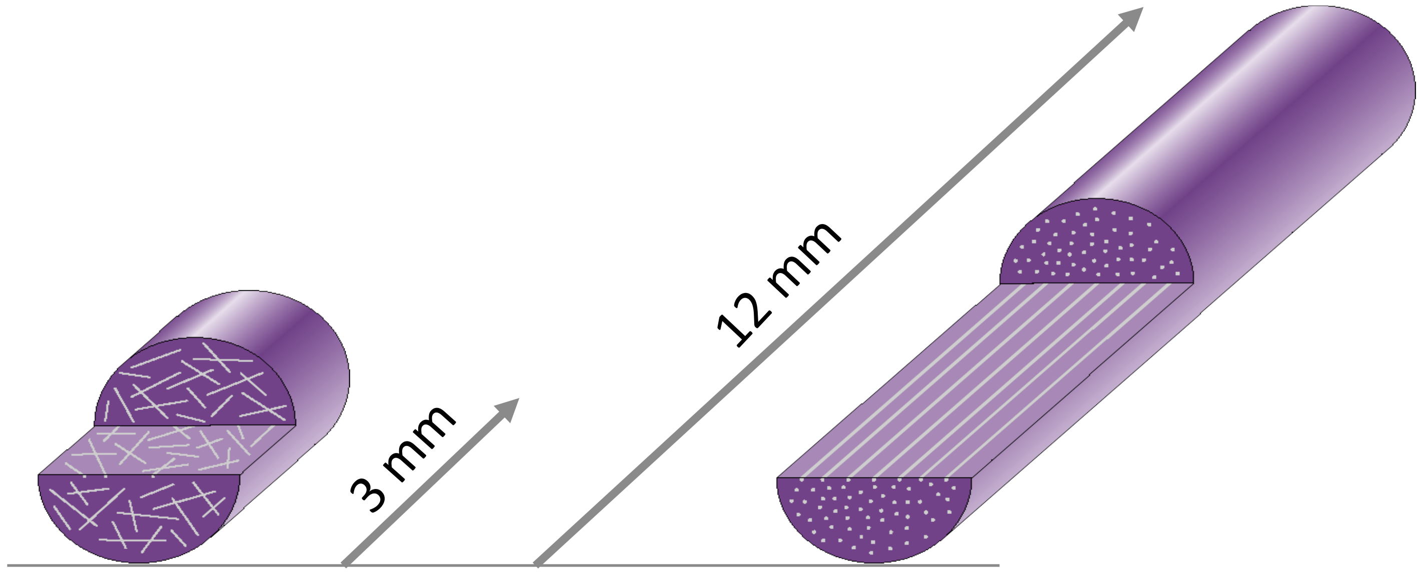
Extreme Aspect Ratio

Long Glass Fiber

Aspect Ratio = 300+

	PP+ 40% Short Glass	PP + 40% Long Glass
Specific Gravity	1.22	1.22
Tensile Strength	85 MPa	118 MPa
Notched Izod Impact	108 J/m	228 J/m
Flexural Modulus	6.9 GPa	7.7 GPa

Extreme Aspect Ratio



Short Fiber | **Long Fiber**

Fiber Length

~ 1-2 mm | **12 mm**

Secret to Success: The Skeleton

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PA 66 + 60% VLF
Seat Belt Tensioner Housing

Polyamide 6/6 – 40% Glass Fiber

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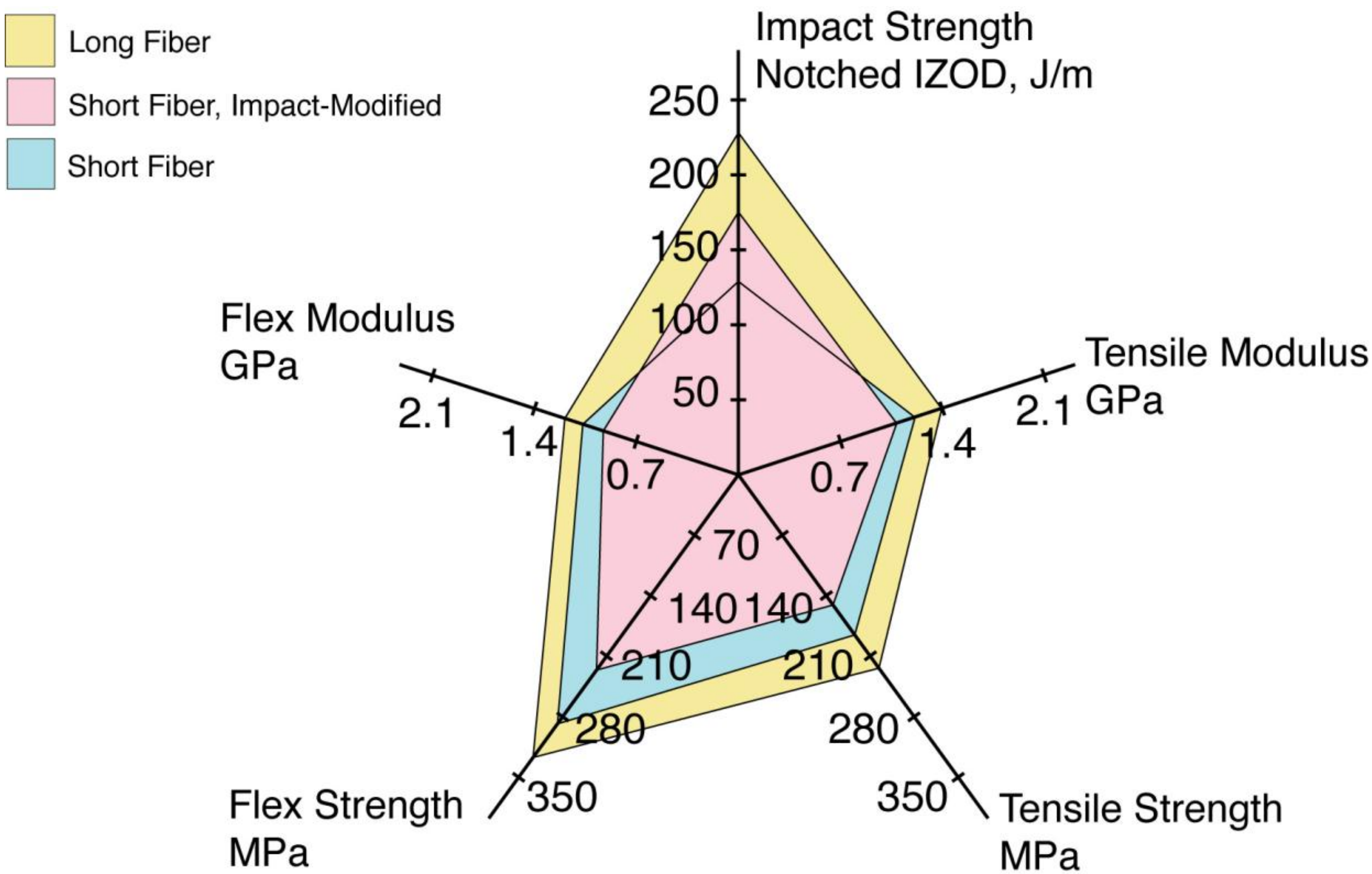

High Aspect Ratio

Carbon Fibers

Aspect Ratio = 50-250

	PEEK	PEEK + 40% Glass Fiber	PEEK + 40% Carbon Fiber
Specific Gravity	1.30	1.61	1.45
Tensile Strength	93 MPa	186 MPa	265 MPa
Notched Izod Impact	53 J/m	133 J/m	91 J/m
Flexural Modulus	3.8 GPa	13.8 GPa	30.3 GPa

High Temperature Application

Application: Brake Rotor Measuring Probe

Problem: Casting replacement

Solution: Carbon fiber reinforced PPA

Benefit: High strength and stiffness

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High Temperature Polymers

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Amorphous	Semi-Crystalline
Polyetherimide (PEI)	Polyetheretherketone (PEEK)
Polyethersulfone (PES)	Polyphenylene Sulfide (PPS)
Polysulfone (PSU)	Polyphthalamide (PPA)
Polycarbonate (PC)	Polyethylene Terephthalate (PET)
Acrylonitrile Butadiene Styrene (ABS)	Polybutylene Terephthalate (PBT)
Styrene Acrylonitrile (SAN)	Polyamide (PA/Nylons)
Polystyrene (PS)	Acetal (POM)
High Impact Polystyrene (HIPS)	Polypropylene (PP)
Acrylic (PMMA)	Polyethylene (HDPE, LDPE, LLDPE)

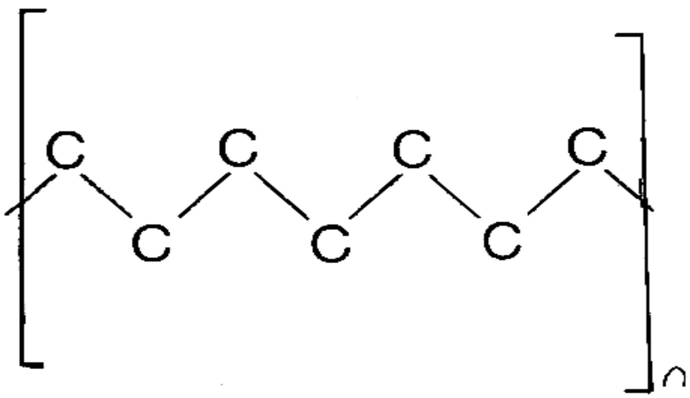
Thermal & Cost Increases

High Performance Engineering Commodity

Chemical Structure

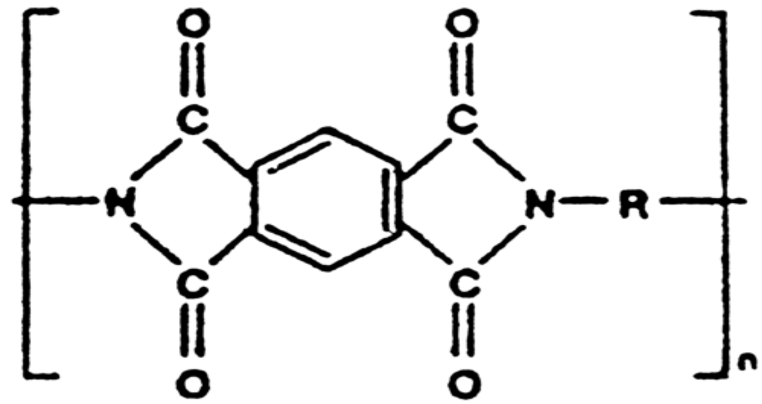
Polyethylene

T_g -5 °F

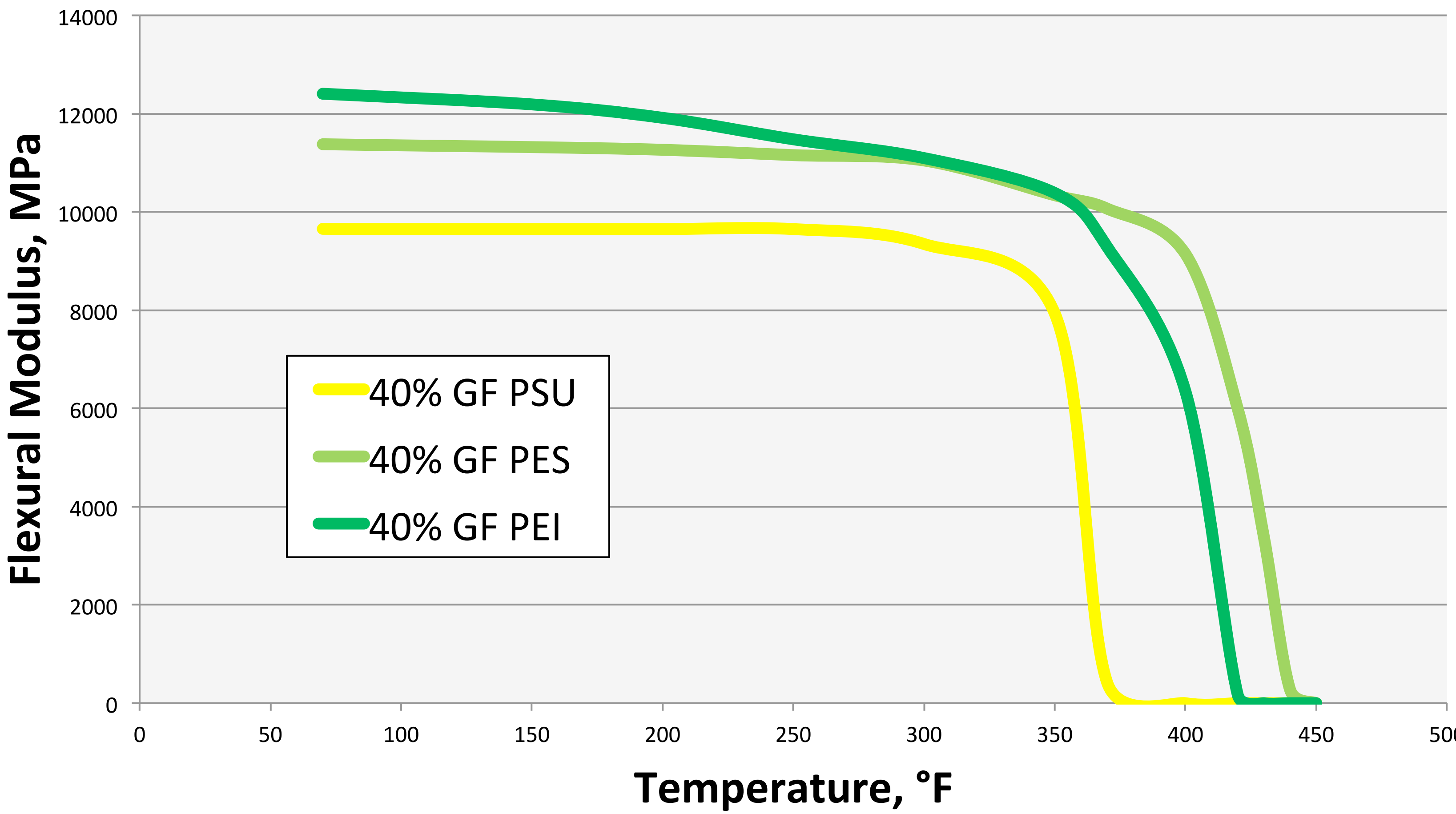


Polyimide

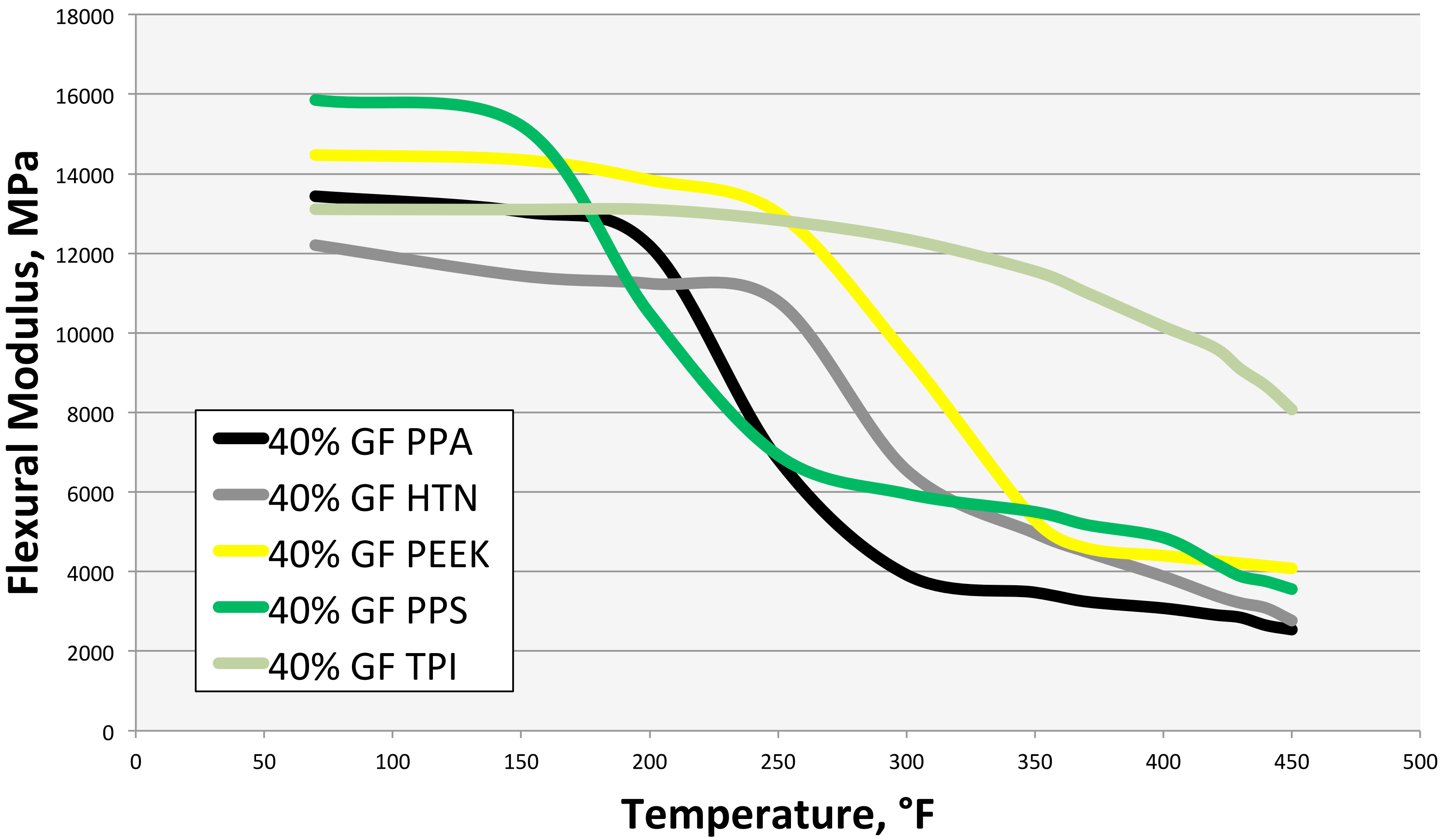
T_g 482 °F



Flexural Modulus Vs. Temperature



Flexural Modulus Vs. Temperature



Elevated Temp Properties

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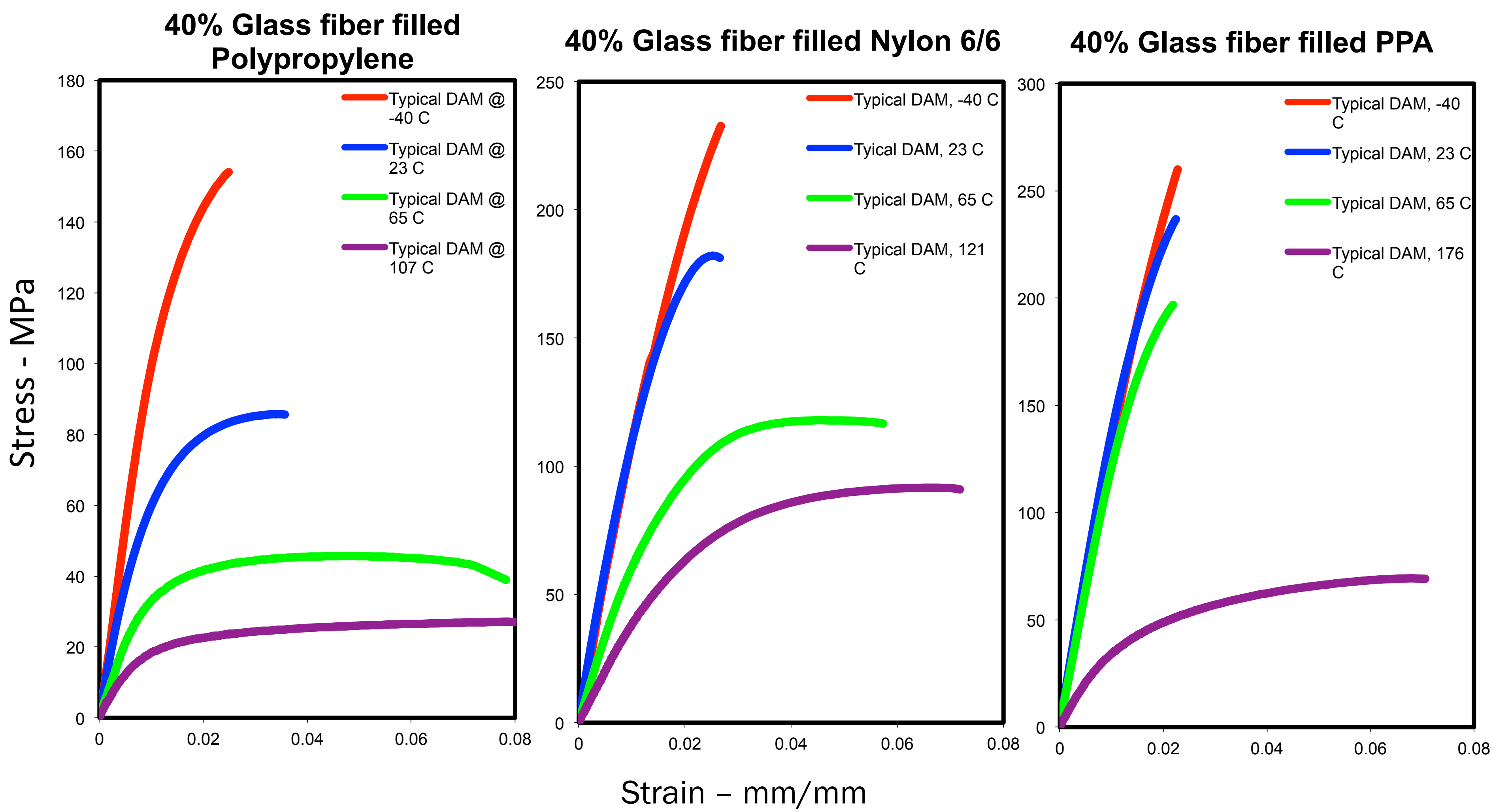
Multiple Temperature Tensile Stress/Strain



High Temperature Application

Application: Copier Bushings

Problem: High temperature (>445°F)

Solution: Aramid fiber reinforced TPI

Benefit: Wear resistance

Flexural Modulus

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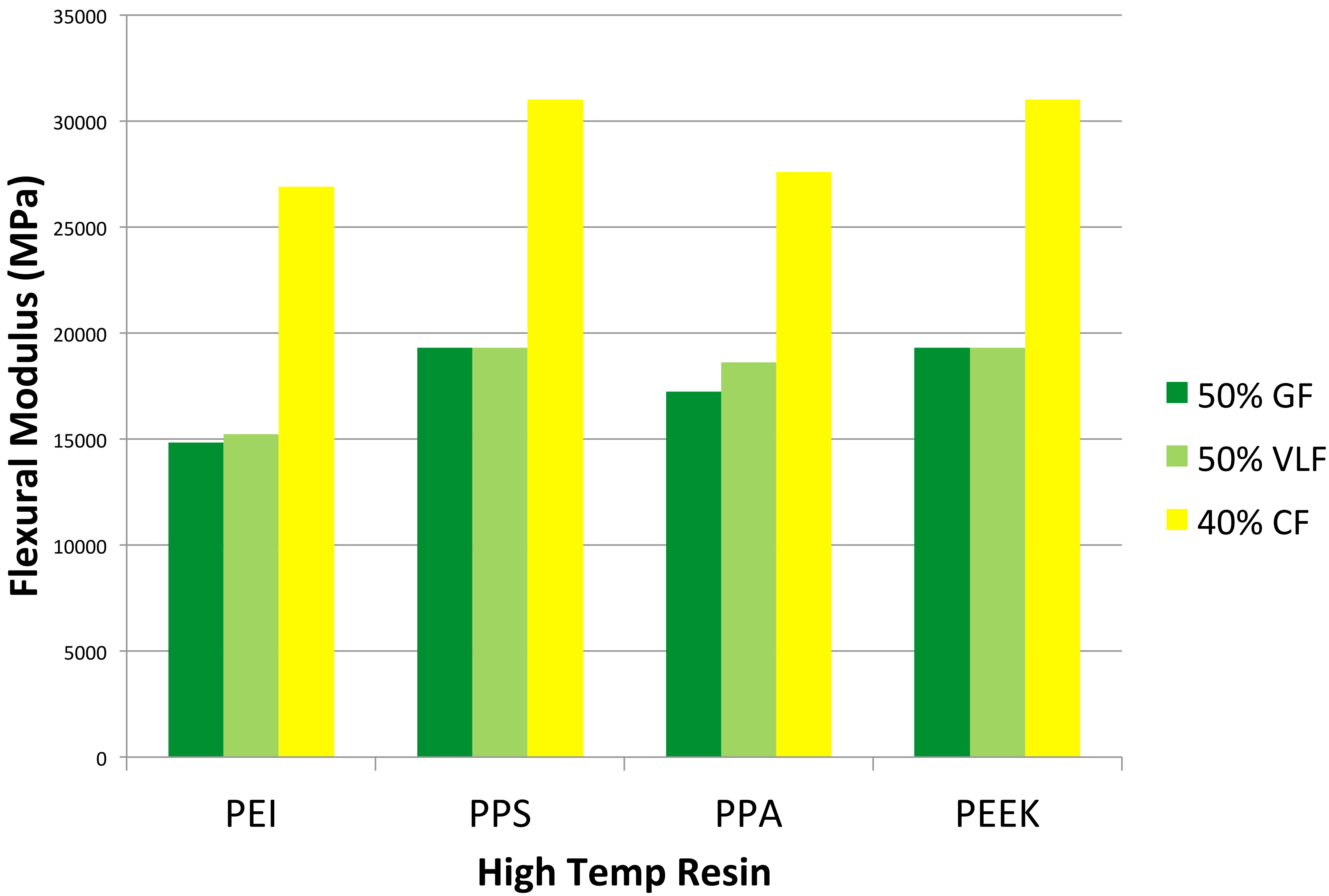

Impact – Izod Notched

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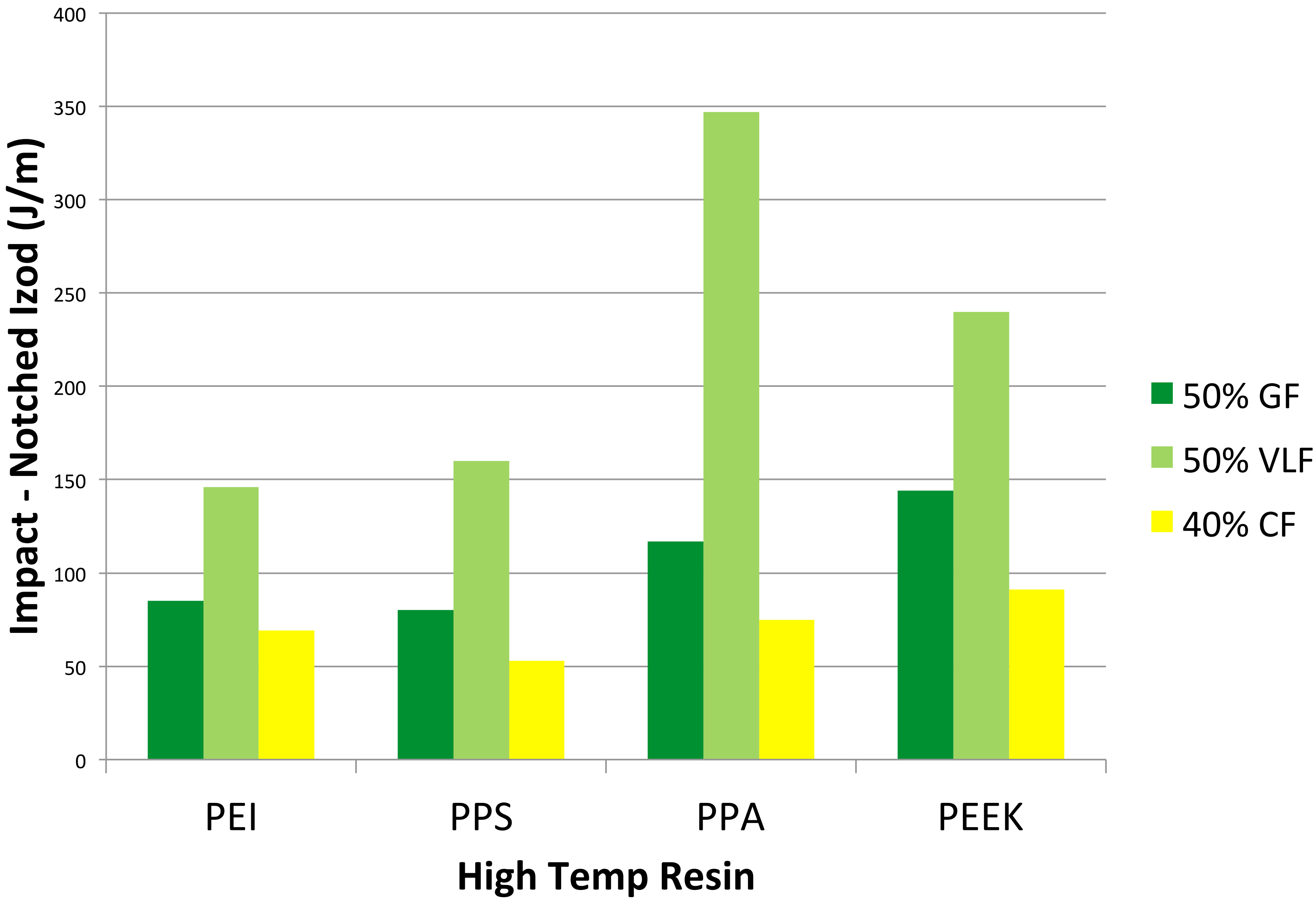

High Temperature Applications

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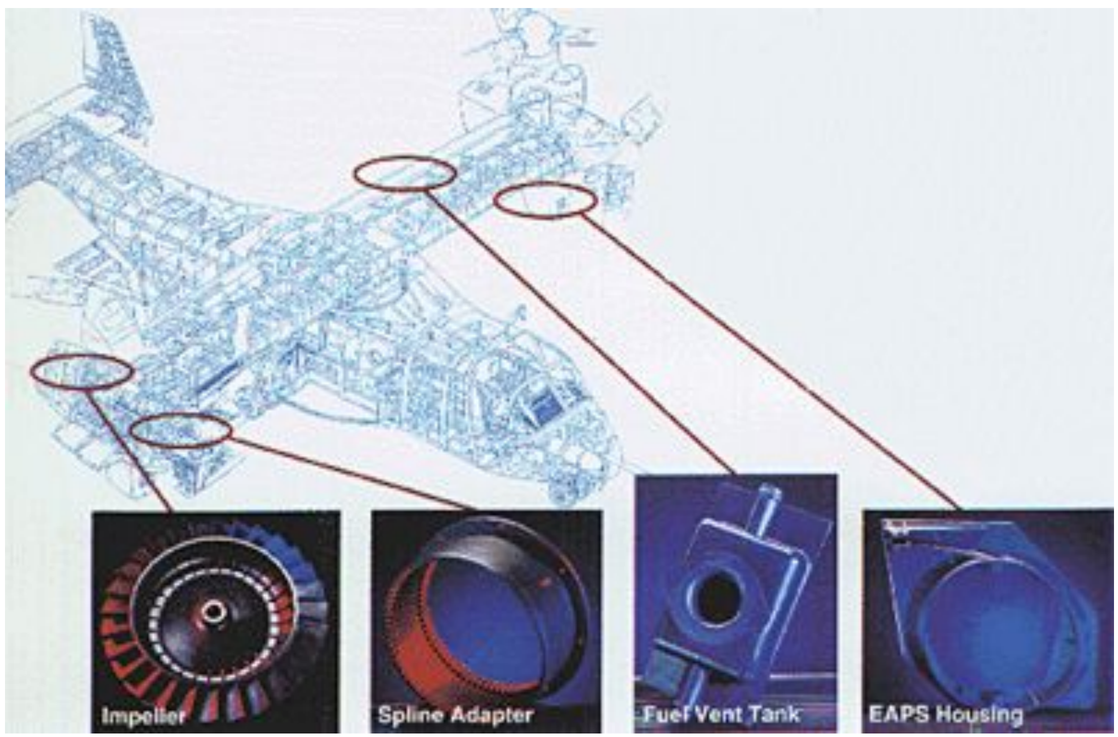
Application: Multiple Components on V-22 Osprey

Problem: Environment

Solution: Carbon fiber reinforced TPI and PEEK

Benefit: Flame retardant, temperature resistance, strength/stiffness



Tensile Strength

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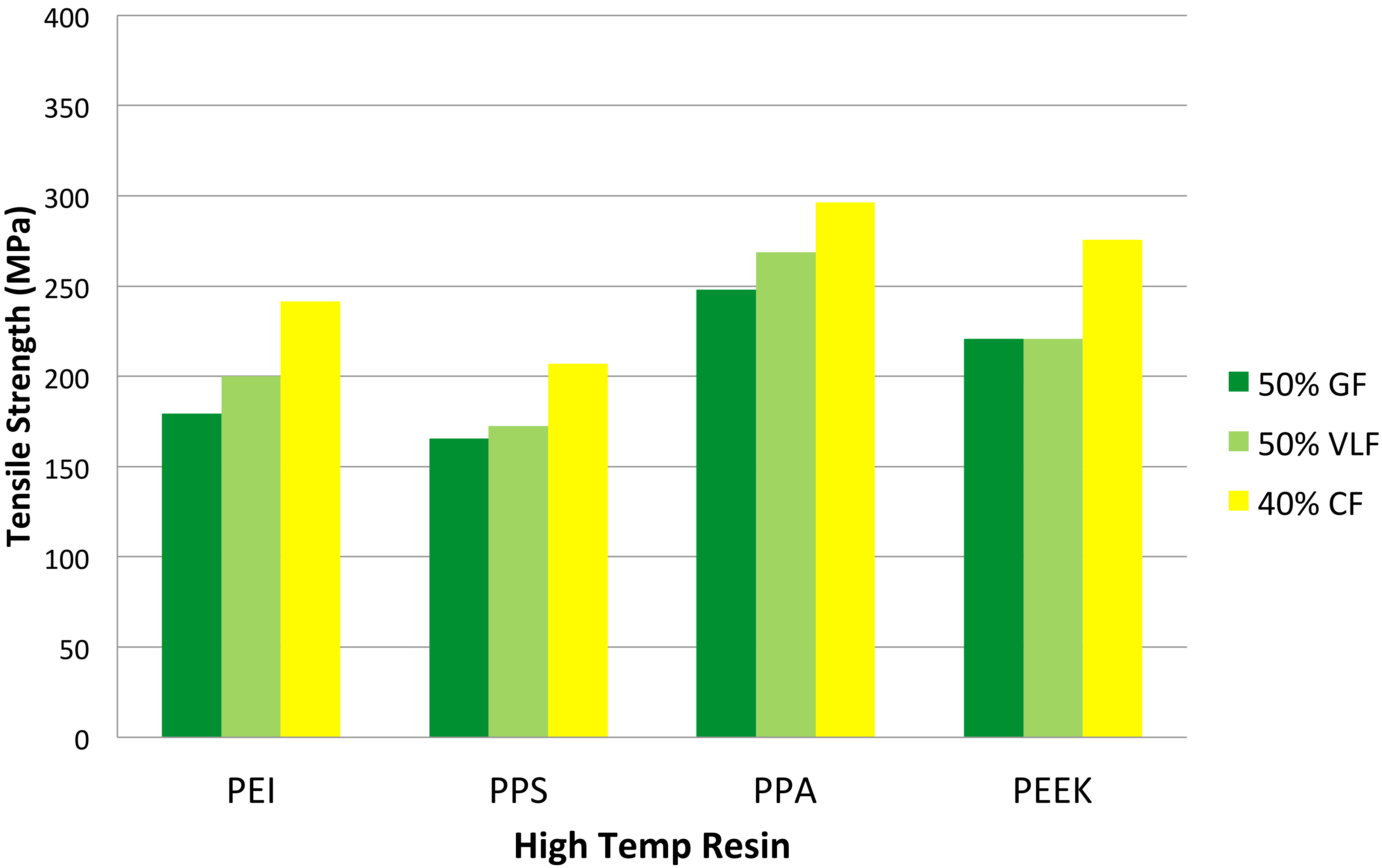

Tensile Strength

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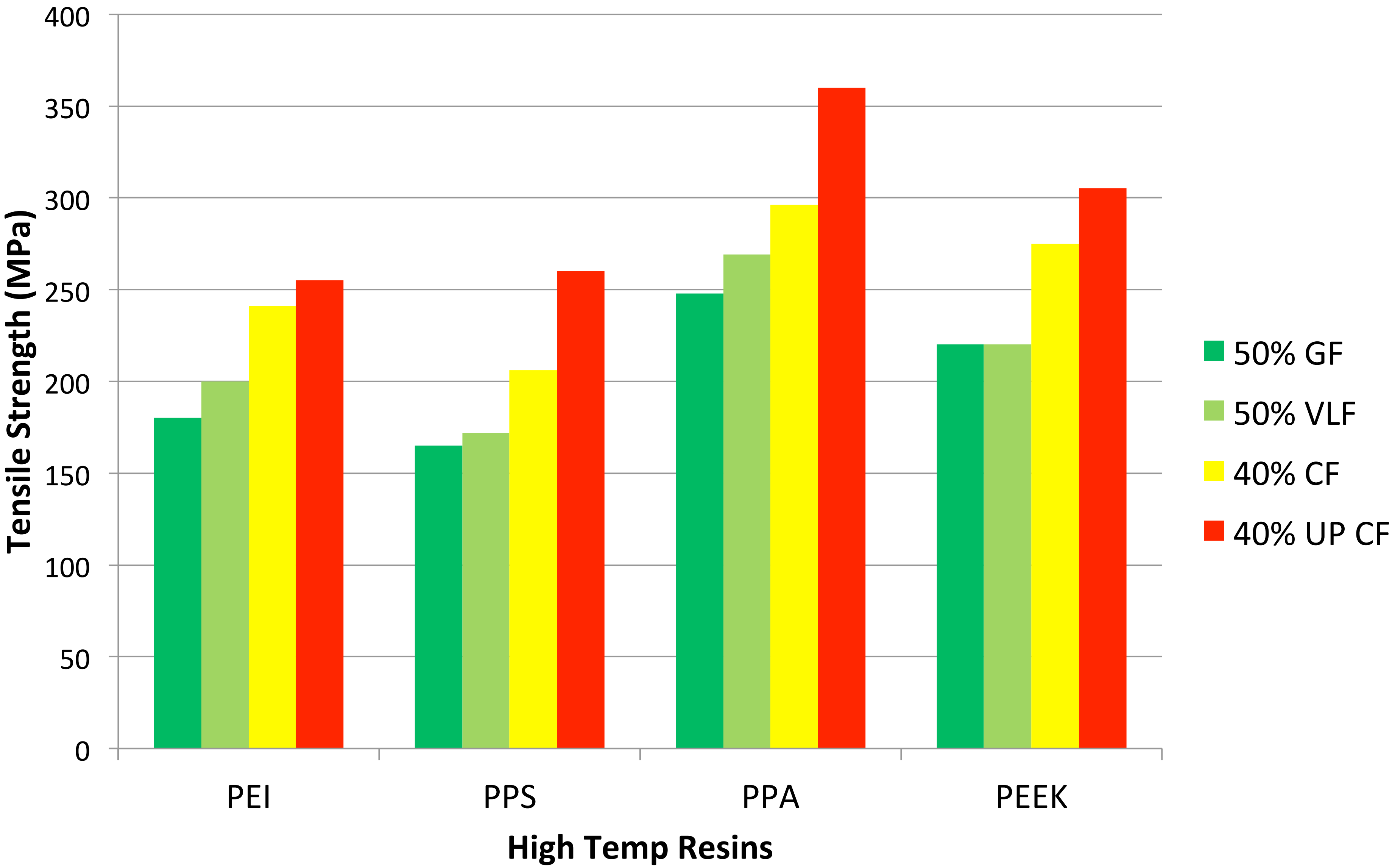

Summary

- Modifiers
  - Polymer Blends: overcome morphology deficiencies
  - Impact Modifiers: increase impact but reduction in strength/stiffness
  - Stabilizers: protect polymer
- Fillers
  - Performance driven by aspect ratio
  - Very Long Fiber: increases impact and retains stiffness/ strength
- High Temperature
  - Wide range of polymers with varying performance
  - Understanding environment and stress levels is key to success

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CONDUCTIVE • COLOR • FLAME RETARDANT

Questions?

Karl Hoppe

khoppe@rtpcompany.com

RTP Company Corporate Headquarters • 580 East Front Street • Winona, Minnesota 55987 USA
website: www.rtpcompany.com • email: rtp@rtpcompany.com • Wiman Corporation • +1 320-259-2554

TELEPHONE:

U.S.A.	SOUTH AMERICA	MEXICO	EUROPE	SINGAPORE	CHINA
+1 507-454-6900	+55 11 4193-8772	+52 81 8134-0403	+33 380-253-000	+65 6863-6580	+86 512-6283-8383

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