STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

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

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What are we solving?

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Strength

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Stiffness

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Impact

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

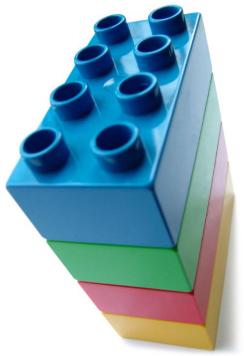
Structural Composites Formula

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Resin + Additives = Change in Properties

Structural Additives: Foundation

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Agenda

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Modifiers
- Fillers
- Lightweighting
- High Temperature Materials

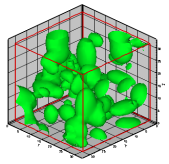
In this Presentation

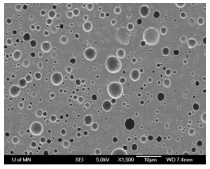
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

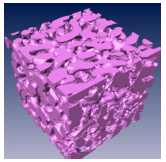
Modifiers

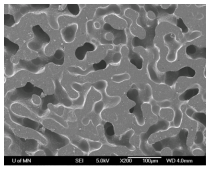
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Polymer Blends
Impact Modifiers









Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

ABS / PC → **PC brings**
- Toughness
- Strength

PP / Nylon → **Nylon brings**
- Strength
- Stiffness

PBT / PC → **PC brings**
- Toughness
- Dimensional stability

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

Polymer Blends

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

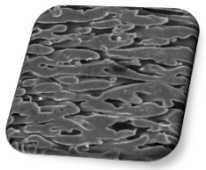
Applications in Automotive

Modifiers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Impact properties

Impact Modifiers



Strength
Stiffness

Impact Modifiers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PA 6/6	IM PA 6/6
Specific Gravity	1.14	1.08
Notched Izod Impact (J/m)	55	900
Tensile Strength (MPa)	80	45
Flexural Modulus (MPa)	2.8	1.8

Impact Modified

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Housing for Wireless Workstation

Problem: Toughness and abrasion resistance

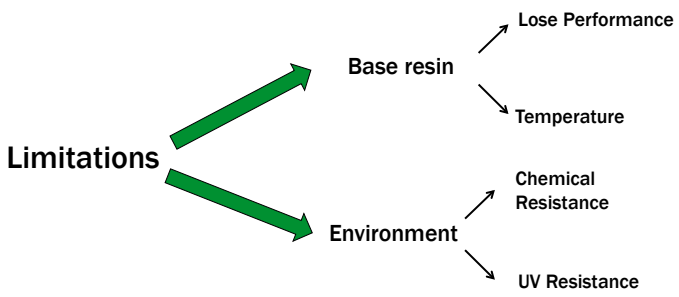
Solution: Impact Modified PA 6/6

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

Automotive Ex.: Airbag Housings

Impact Modifiers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

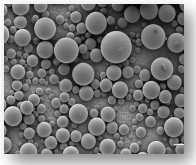


In this Presentation

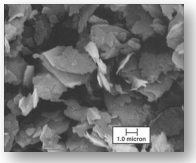
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Fillers

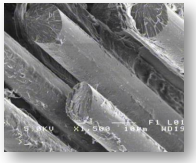
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



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



Minerals (Talc)

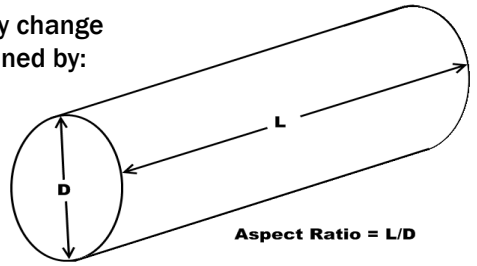


Fibers (Glass)

Fillers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Property change determined by:

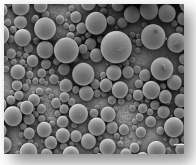


Aspect Ratio

Reinforcing

Low Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



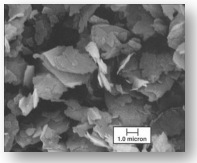
Beads (Glass)
(photo: Potters, Inc.)

Aspect Ratio = 1

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

Low Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



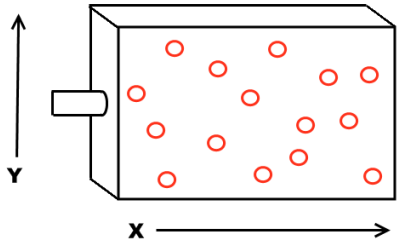
Minerals (Talc)

Aspect Ratio = 2-50

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

Warp Control

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrink Rate x = Shrink Rate y → Flat Part

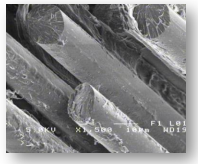
Low Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Key Fob
Problem: Dimensional stability
Solution: PA66 + Glass Beads
Benefit: Uniform shrinkage

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



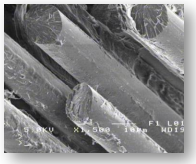
Fibers (Glass)

Aspect Ratio = 50-250

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

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



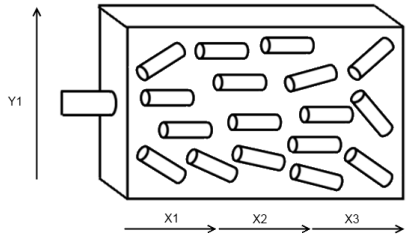
Fibers (Glass)

Aspect Ratio = 50-250

	PP	PP + 40% Talc	PP + 40% Fiber
Specific Gravity	0.91	1.25	1.22
Tensile Strength (MPa)	32	30	84
Notched Izod Impact (J/m)	47	34	108
Flexural Modulus (MPa)	1.5	3.8	7.5

Non-Uniform Shrink = Warp

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Shrinkage X1 & X2 ≠ X3 ⟶ Warp

Strength & Warp Control

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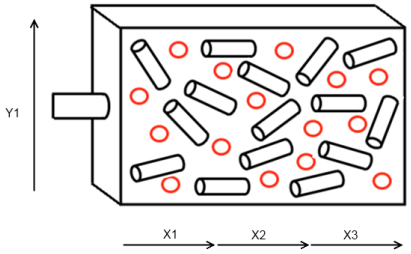

Shrinkage X1 = X2 = X3 ⟶ Flat Part

High Aspect Ratio

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Air Registers

Problem: Stiffness and dimensional stability

Solution: Glass Fiber/Mineral Filled PP

Benefit: High strength, Great Surface Finish

Improvements in SGF PP

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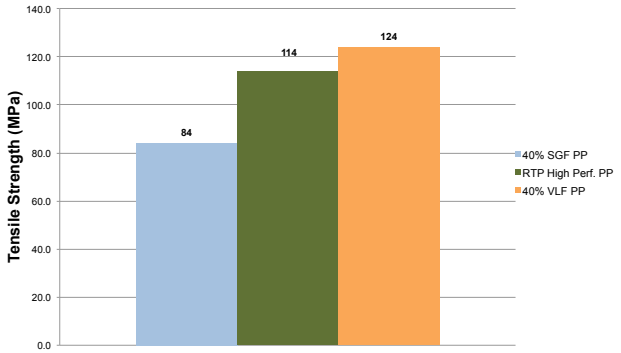
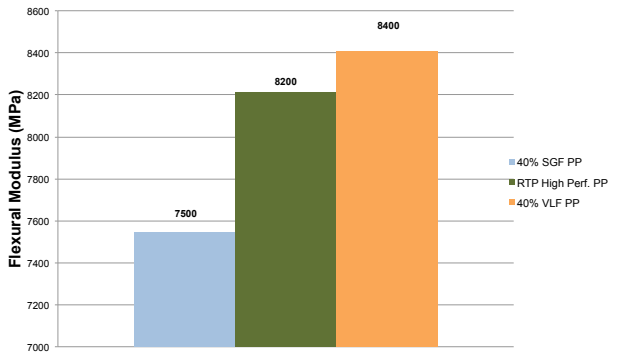


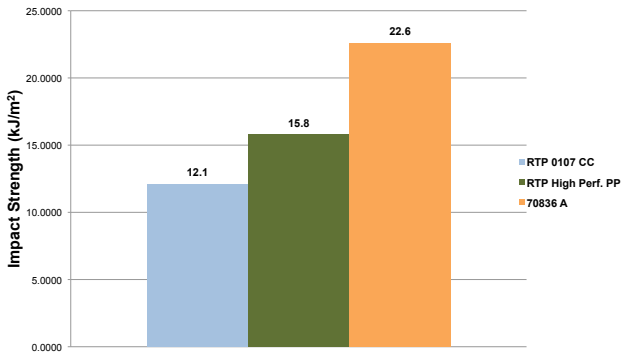
Improvements in SGF PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Improvements in SGF PP

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Extreme Aspect Ratio

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Long Glass Fiber

Aspect Ratio = 300+

	PP + 40% Short Glass	PP + 40% Long Glass
Specific Gravity	1.22	1.22
Tensile Strength (MPa)	84	124
Notched Izod Impact (J/m)	108	228
Flexural Modulus (MPa)	7.5	8.4

Pellet Comparison

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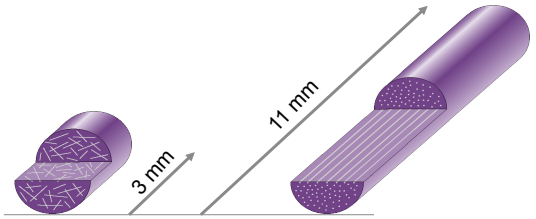

Short Fiber **VLF**

Fiber Length
~ 1-2 mm
11 mm

Secret to Success: The Skeleton

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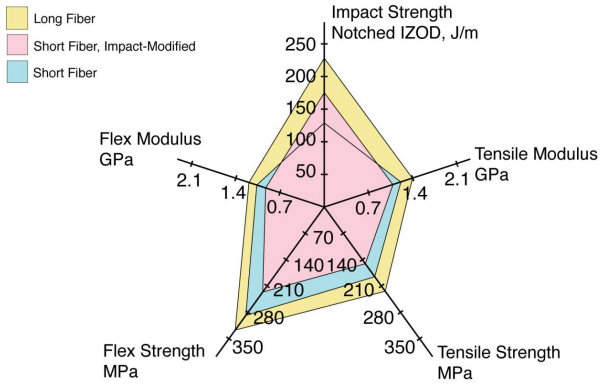
PA 66 + 60% VLF
Seat Belt Tensioner Housing

Polyamide 6/6 – 40% Glass Fiber

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



VLF Applications in Automotive

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Hollow Glass Microspheres

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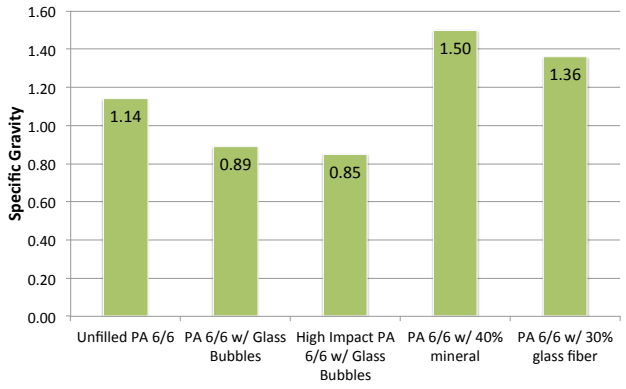
- Lightweighting where properties are less demanding

Hollow Glass Spheres

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Hollow Glass Spheres

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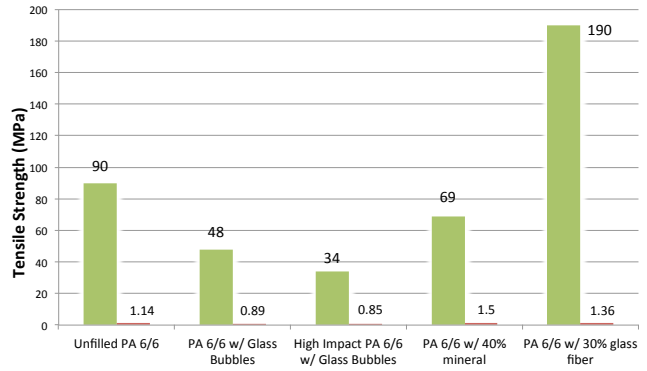

Hollow Glass Spheres

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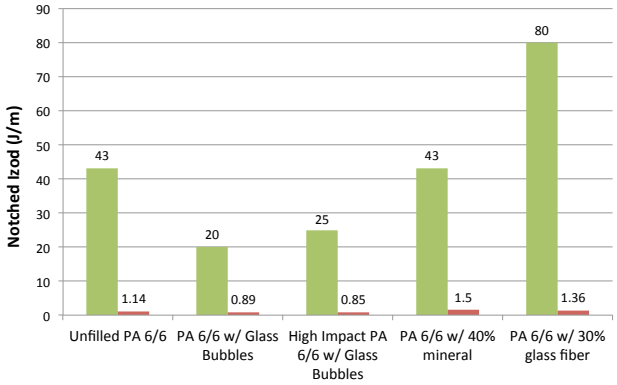

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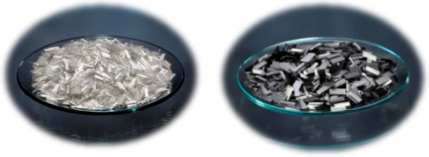
Carbon Fiber

Carbon Fiber

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Fiber	E-Glass Fiber	Std. Modulus Carbon Fiber
Typical Diameter (μm)	10-17	5-10
Density (g/cm^3)	2.55	1.81
Est. Tensile Strength (MPa)	3400	4100
Est. Flexural Modulus (MPa)	73	240



Carbon Fiber - Polypropylene

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

	PP 40% GF	PP 40% VLF	PP 30% CF
Tensile Strength (MPa)	85	120	105
Flexural Modulus (MPa)	6900	8250	11800
Notched Izod Impact (kJ/m^2)	12.1	22.8	10.2
Specific Gravity	1.21	1.21	1.06

Fiber Comparison – PA 6/6

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	PA 6/6 60% VLF (Long Fiber)	PA 6/6 35% Carbon Fiber
Flexural Modulus (MPa)	19.3	19.0
Tensile Strength (MPa)	275	244
Tensile Elongation (%)	2.0	2.0
Specific Gravity	1.71	1.29

Fiber Comparison – PPS

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	PPS 40% Glass	PPS 20% Carbon
Flexural Modulus (MPa)	15.1	15.8
Tensile Strength (MPa)	169	172
Tensile Elongation (%)	1.5	1.0
Specific Gravity	1.68	1.40

High Temperature Polymers

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

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

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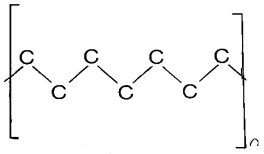
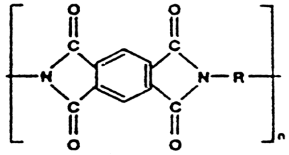
Polyethylene
Tg -5 °F



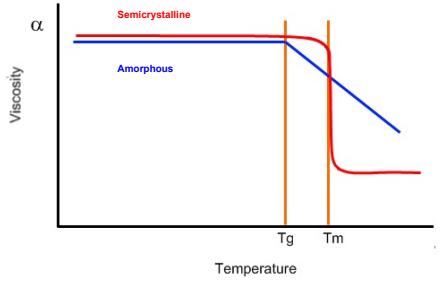
Polyimide
Tg 482 °F



Tg

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

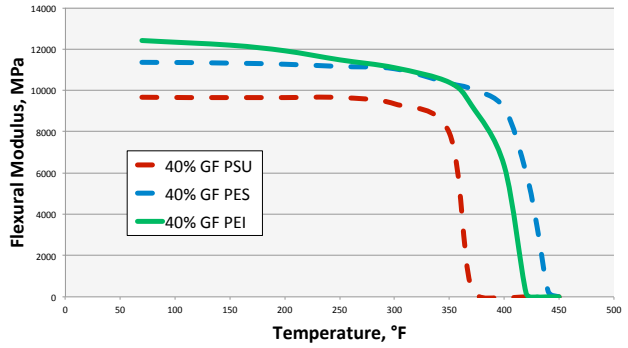
- **Tg = the softening point.**
  - **There is a drop in strength and modulus above the Tg**
  - **Crystalline materials will tend to creep above the Tg**
  - **Amorphous materials will start to flow above the Tg**



Amorphous Materials

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

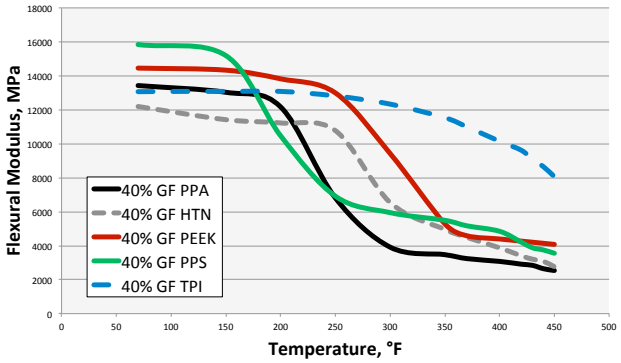
Flexural Modulus Vs. Temperature



Semi-Crystalline Materials

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Flexural Modulus Vs. Temperature



Elevated Temp Properties

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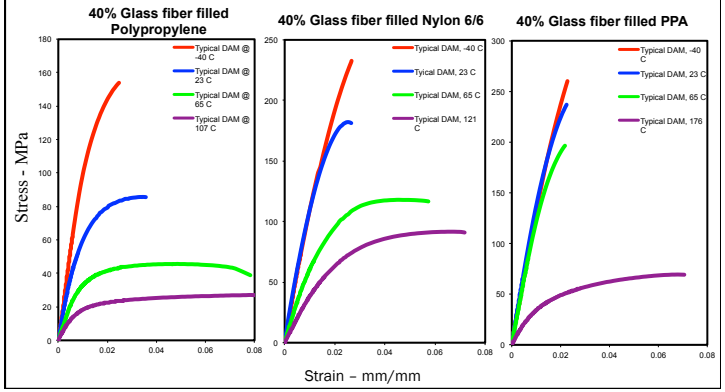
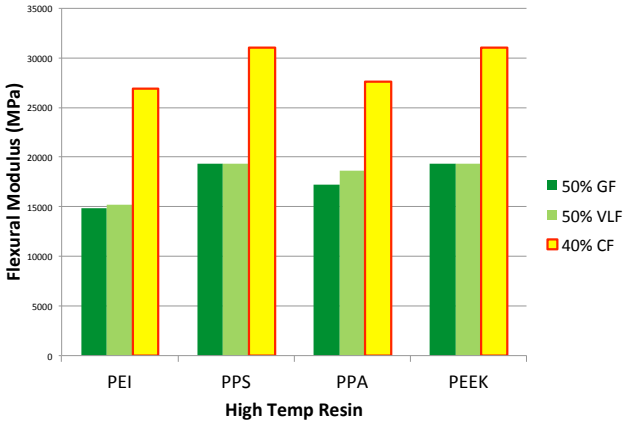
Multiple Temperature Tensile Stress/Strain



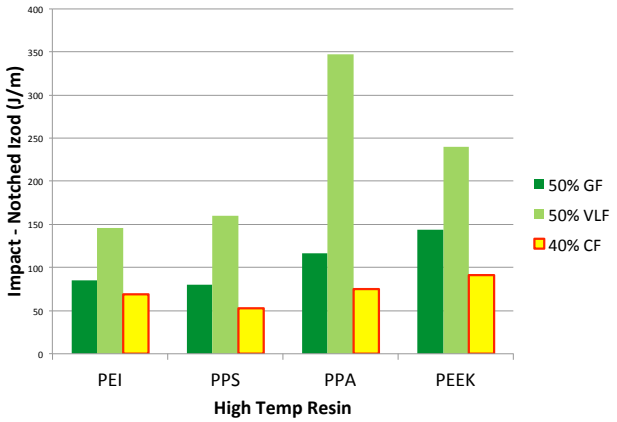
Flexural Modulus

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Impact – Izod Notched

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



High Temperature Applications

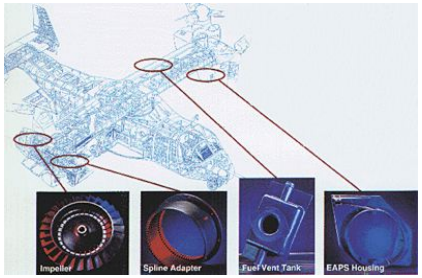
YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Multiple Components on V-22 Osprey

Problem: Environment

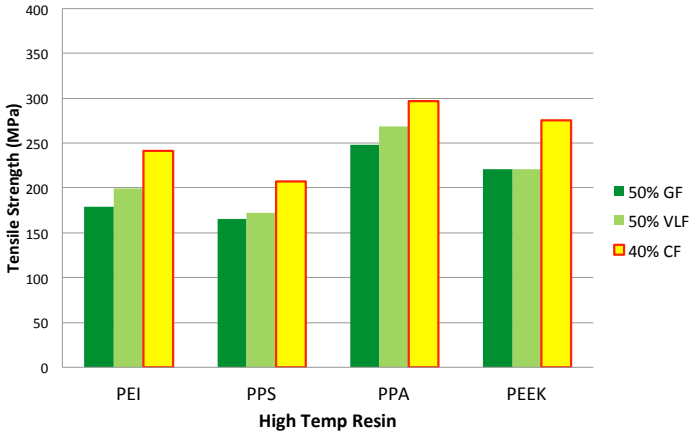
Solution: Carbon fiber reinforced TPI and PEEK

Benefit: Flame retardant, temperature resistance, strength/stiffness



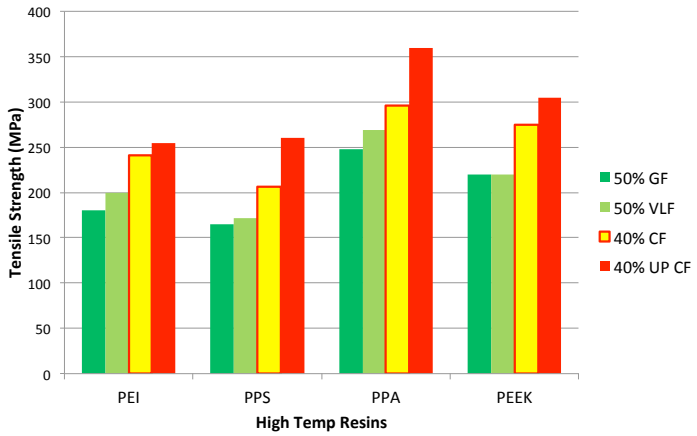
Tensile Strength

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



Tensile Strength

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS



High Performance Application

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

Application: Brake Rotor Measuring Probe

Problem: Casting replacement

Solution: Carbon fiber reinforced PPA

Benefit: High strength and stiffness

Summary

YOUR GLOBAL COMPOUNDER OF CUSTOM ENGINEERED THERMOPLASTICS

- Modifiers
  - Polymer Blends
  - Impact Modifiers
- Fillers
  - Performance driven by aspect ratio
- High Temperature
  - Wide range of polymers with varying performance
  - Understanding environment and stress levels is key to success

STRUCTURAL • ELASTOMERS • WEAR • COLOR
CONDUCTIVE • FLAME RETARDANT • FILM/SHEET

Questions?

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