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

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

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STRENGTH

STIFFNESS

IMPACT

THE FORMULA

Resin + Additives = Change in Properties

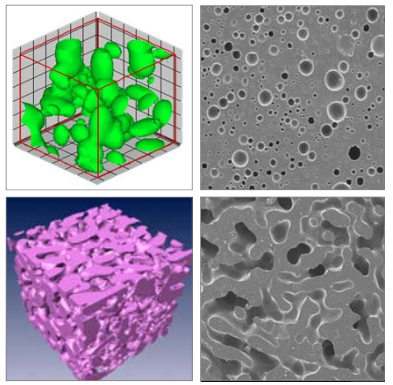
THE FOUNDATION

THE ADDITIVES TOOLBOX

MODIFIERS

Polymer blends

Impact modifiers



POLYMER BLENDS

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

ABS/PC → PC brings
- Toughness
- Strength

PP/Nylon → Nylon brings
- Strength
- Stiffness

PBT/PC → PC brings
- Toughness
- Dimensional stability

POLYMER BLENDS

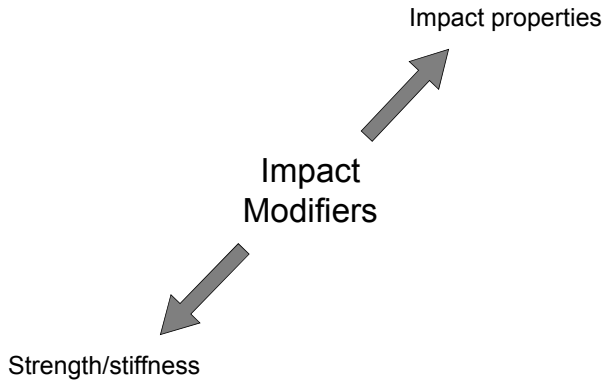
	PC	PC/ABS (RTP 2500 A)	ABS
Specific Gravity	1.19	1.15	1.05
Tensile Strength (MPa)	59	59	45
Notched Izod Impact (J/m)	850	740	250

POLYMER BLENDS

Housing for Hearing Tester

Problem:	Toughness and chemical resistance
Solution:	Polycarbonate/ABS Alloy
Benefits:	Strength and toughness of PC with the added chemical resistance of ABS

MODIFIERS



IMPACT MODIFIERS

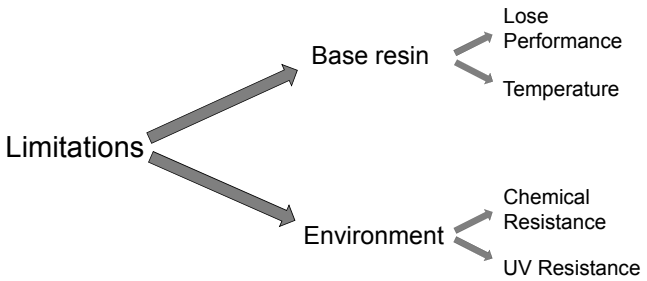
	PA 6/6	Impact Modified PA 6/6
Specific Gravity	1.14	1.08
Notched Izod Impact (J/m)	55	900
Tensile Strength (MPa)	80	45
Flexural Modulus (GPa) (Stiffness)	2.8	1.8

IMPACT MODIFIERS

ATV Wheel Bead Lock Ring

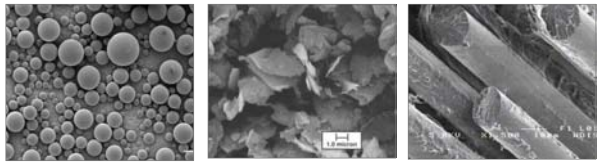
Problem:	Low ductility
Solution:	Impact Modified Nylon 6/6 with fiber reinforcement
Benefits:	• Retain some stiffness of reinforced Nylon • Improved ductility for high strain rate loads

IMPACT MODIFIERS



THE ADDITIVES TOOLBOX

FILLERS



Beads (Glass)

Minerals (Talc)

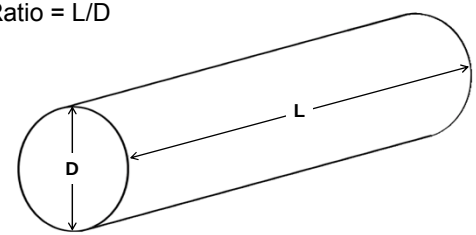
Fibers (Glass)

Photo: Potters, Inc.

ASPECT RATIO

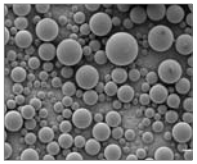
Property change determined by:

Aspect Ratio = L/D



↑ Aspect Ratio → ↑ Reinforcing

LOW ASPECT RATIO



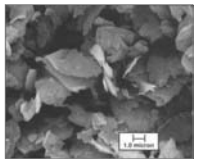
Beads (Glass)

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 (GPa)	2.4	2.6	3.4

LOW ASPECT RATIO

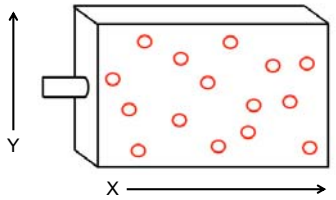


Minerals (Talc)

Aspect Ratio = 2 - 50

	PC	PC + 20% Talc	PC + 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 (GPa)	1.5	2.5	3.8

LOW ASPECT RATIO

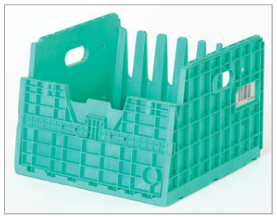


Shrink Rate X = Shrink Rate Y ⟹ Flat Part

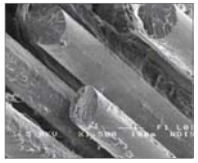
LOW ASPECT RATIO

Reusable Handling Container

Problem:	Warpage prevented smooth operation
Solution:	Mineral filled Polypropylene
Benefits:	• Reduced warpage • Improved functionality



HIGH ASPECT RATIO

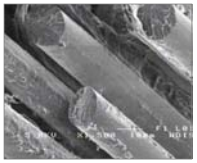


Fibers (Glass)

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 (GPa)	2.4	3.4	7.6

HIGH ASPECT RATIO



Fibers (Glass)

Aspect Ratio = 50 - 250

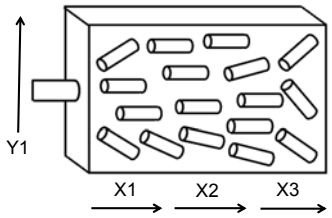
	PP	PP + 40% Talc	PP + 40% Fiber
Specific Gravity	0.91	1.25	1.22
Tensile Strength (MPa)	32	30	84
Notched Izod Impact (J/m)	47	34	108
Flexural Modulus (GPa)	1.5	3.8	7.5

HIGH ASPECT RATIO

Surgery Drill Guide

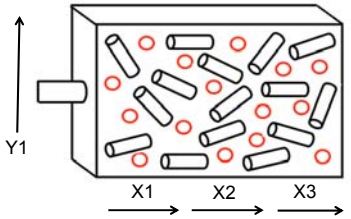
Problem:	Stiffness and dimensional stability
Solution:	Glass fiber reinforced Polycarbonate
Benefits:	• Rigidity • Tight tolerances

HIGH ASPECT RATIO - WARP



Shrinkage X1 & X2 ≠ X3 ⟹ Warp

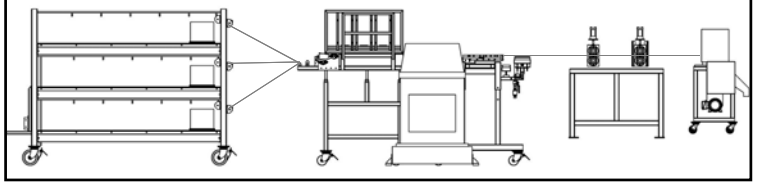
HIGH ASPECT RATIO - FLAT



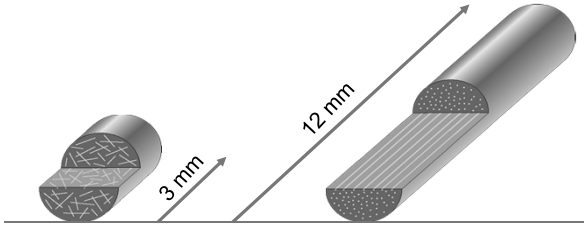
Shrinkage X1 = X2 = X3 ⟹ Flat Part

EXTREME ASPECT RATIO - VLF

Fiber Extruder/Die Puller Pelletizer



EXTREME ASPECT RATIO - VLF



Short Fiber

Fiber length: ~ 1-2 mm

Long Fiber

Fiber length: 12 mm

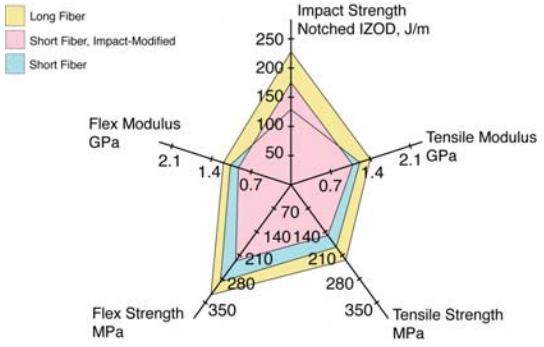
EXTREME ASPECT RATIO -VLF

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 (GPa)	7.5	8.4

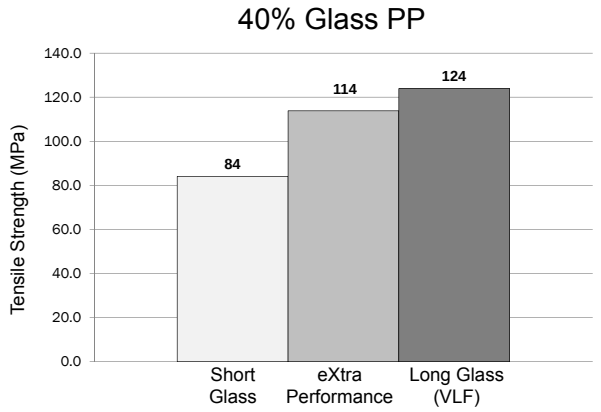
EXTREME ASPECT RATIO - VLF



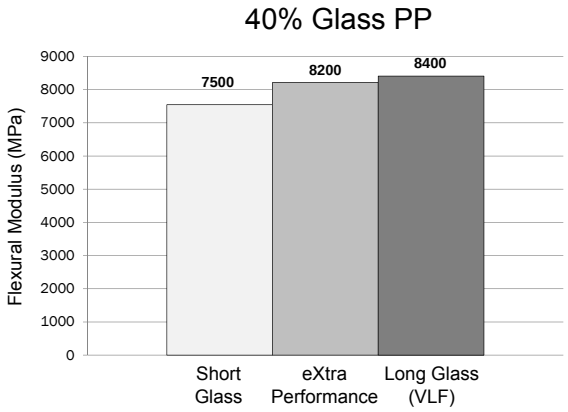
EXTREME ASPECT RATIO - VLF

PA 66 + 60% VLF
Seat Belt Tensioner Housing

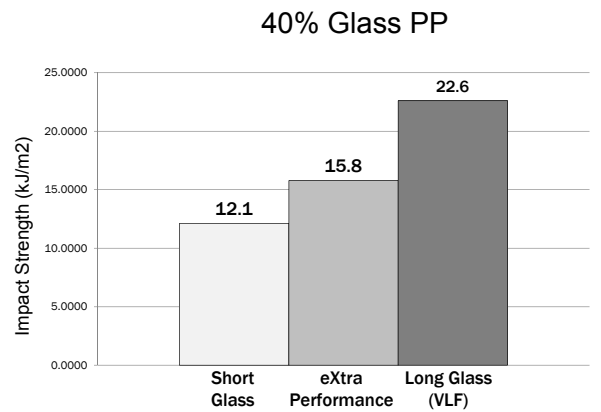
IMPROVEMENTS IN SGF PP



IMPROVEMENTS IN SGF PP



IMPROVEMENTS IN SGF PP



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 (MPa)	93	186	265
Notched Izod Impact (J/m)	53	133	91
Flexural Modulus (GPa)	3.8	13.8	30.3

FIBER COMPARISON- PP

	PP 40% GF	PP 40% VLF	PP 30% CF
Flexural Modulus (MPa)	6900	8250	9000
Tensile Strength (MPa)	85	120	90
Notched Izod Impact (kJ/m^2)	12.1	22.8	6
Specific Gravity	1.21	1.21	1.00

FIBER COMPARISON – PA 6/6

	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

	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

CARBON FIBER APPLICATION

Brake Rotor Measuring Probe

Problem:	Casting replacement
Solution:	Carbon fiber reinforced PPA
Benefits:	• High strength • High stiffness

HIGH TEMPERATURE POLYMERS

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

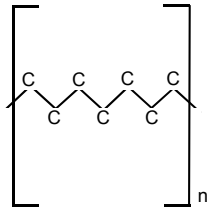
Thermal & Cost Increases

Commodity • Engineered • High Performance

CHEMICAL STRUCTURE

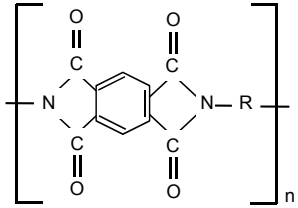
Polyethylene

Tg -5 °F

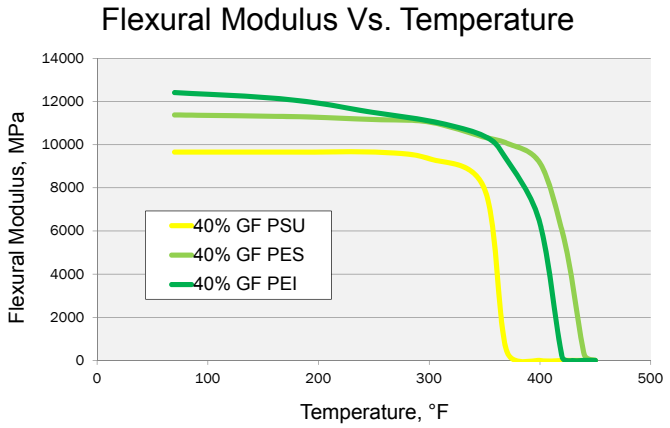


Polyimide

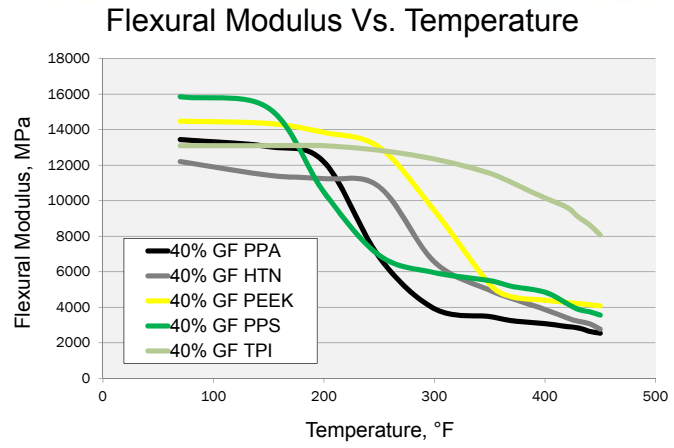
Tg 482 °F



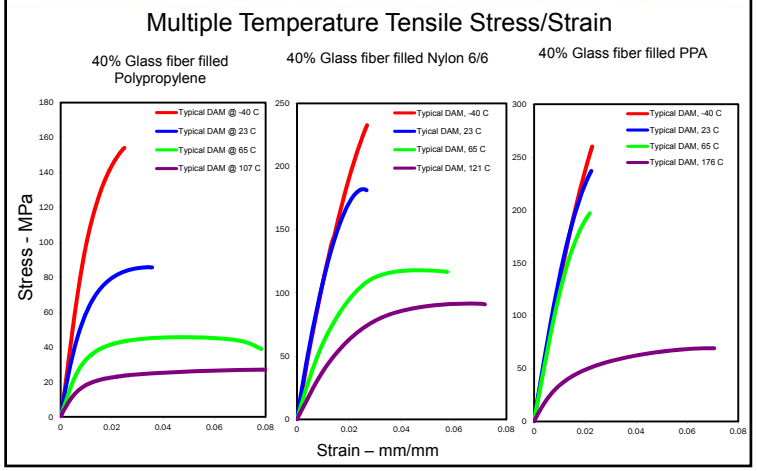
AMORPHOUS MATERIALS



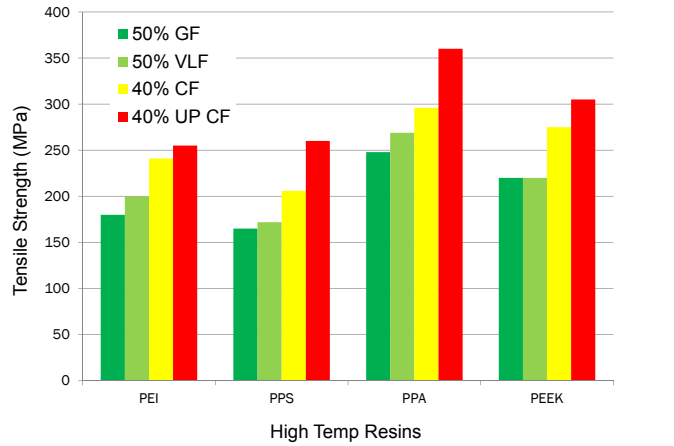
SEMI-CRYSTALLINE MATERIALS



ELEVATED TEMP PROPERTIES



ULTRA PERFORMANCE PRODUCTS



HIGH TEMPERATURE APPLICATION

Surgical Head Restraint

Problem:	Stable under MRI/CT energy
Solution:	Carbon fiber reinforced PEEK
Benefits:	• High stiffness • Creep resistance • Resistance to autoclave

SUMMARY

Modifiers
- Polymer Blends - overcome morphology deficiencies
- Impact Modifiers - increase impact but reduction in strength/stiffness

Fillers
- Performance driven by aspect ratio

High Temperature
- Range of polymers offer array of performance

Overall: Combinations of technologies result in balancing of properties and requirements