



Calling in the Reinforcements: Dialing in Mechanical Performance



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STRENGTH



STIFFNESS



IMPACT



THE FORMULA

$$\text{Resin} + \text{Additives} = \text{Change in Properties}$$

THE FOUNDATION

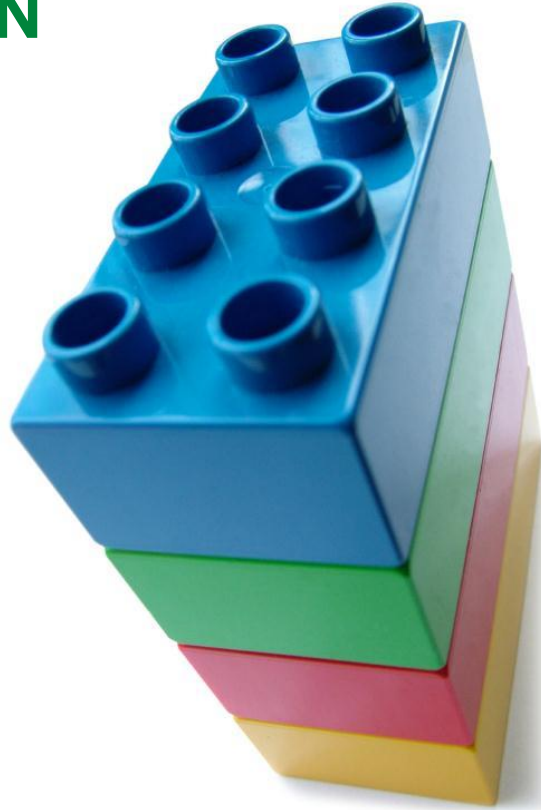
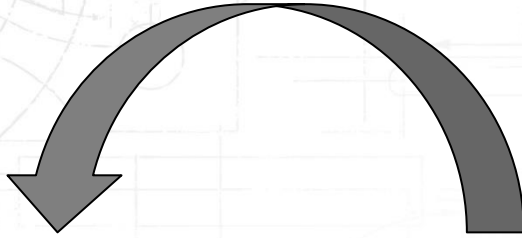
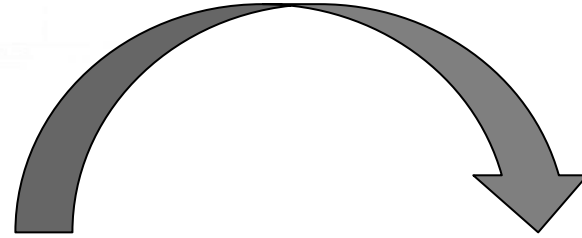


Photo credit: https://photos1.blogger.com/blogger/6135/1838/1600/338064_8618.jpg

THE ADDITIVES TOOLBOX



Modifiers

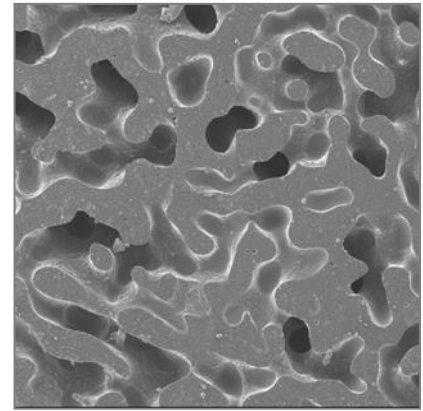
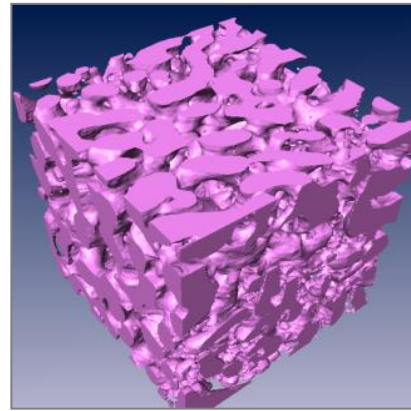
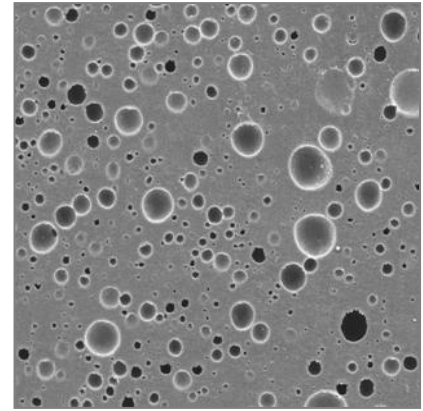
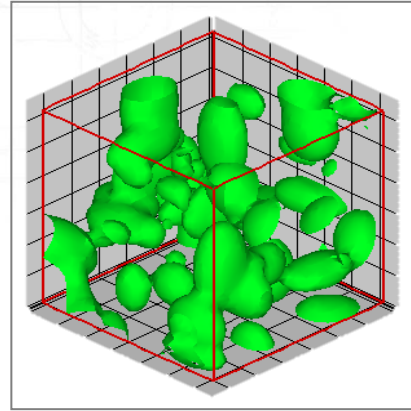


Fillers

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
- Higher heat performance

PBT/PC



PC brings

- Toughness
- Dimensional stability

POLYMER BLENDS

	PC	PC/ABS	ABS
Specific Gravity	1.19	1.15	1.06
Tensile Strength (MPa)	60	60	45
Notched Izod Impact (J/m)	800	700	270

POLYMER BLENDS

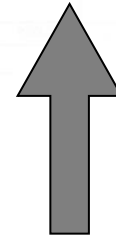
Housing for Hearing Tester

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

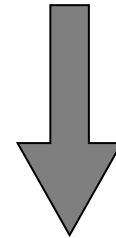


MODIFIERS

Impact Modifiers



Impact properties



Strength/stiffness

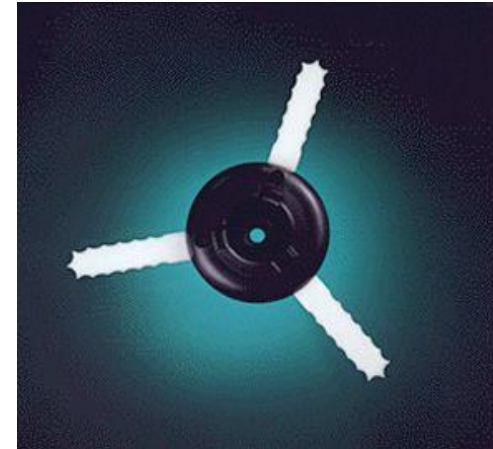
IMPACT MODIFIERS

	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	52
Flexural Modulus (GPa) (Stiffness)	2.8	2.1

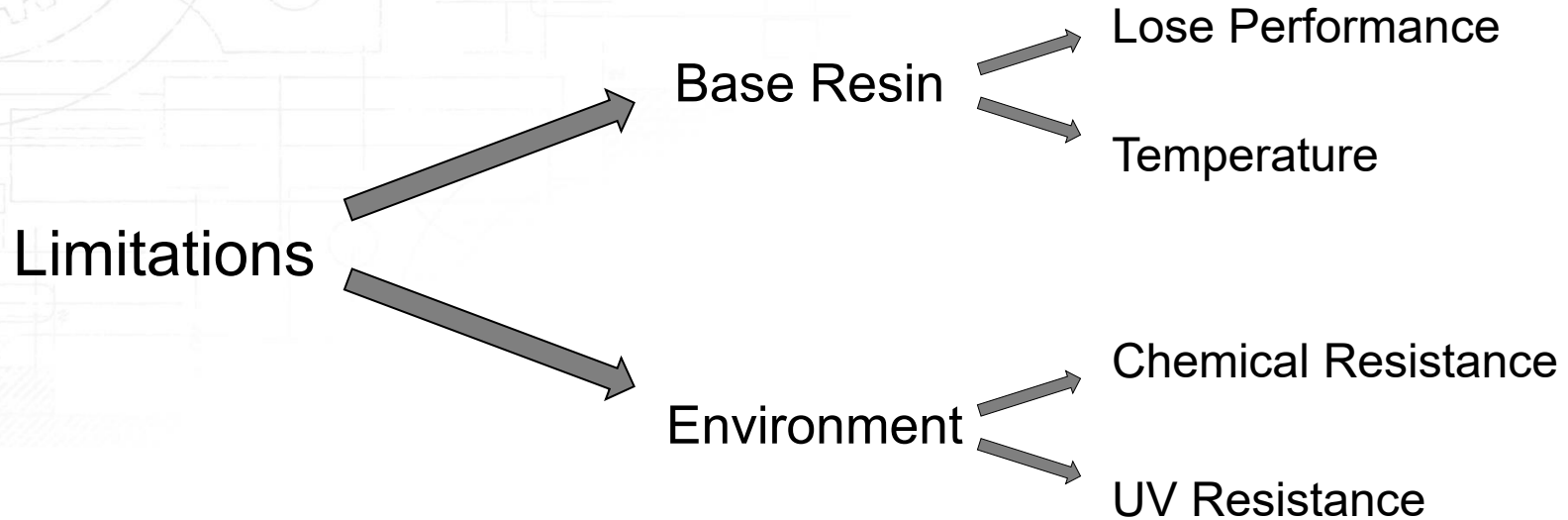
IMPACT MODIFIERS

Grass Trimmer Heads

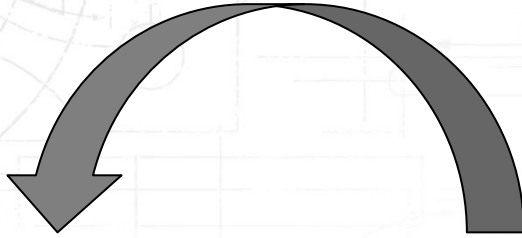
Problem:	Long term durability
Solution:	Impact Modified Nylon 6/6
Benefits:	• Increased ductility • Retained abrasion resistance



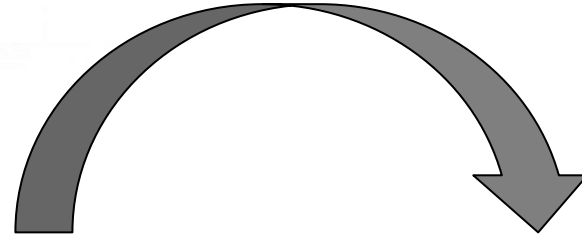
IMPACT MODIFIERS



THE ADDITIVES TOOLBOX

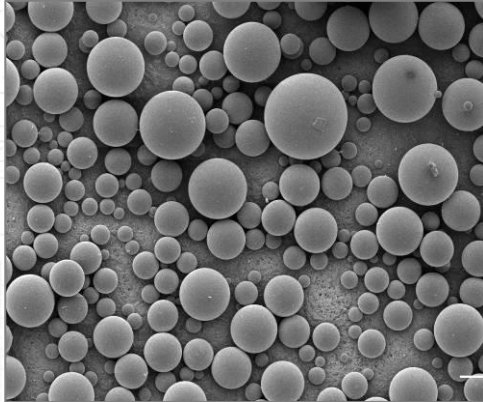


Modifiers



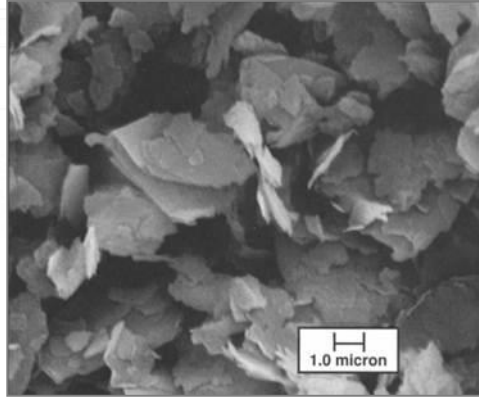
Fillers

FILLERS

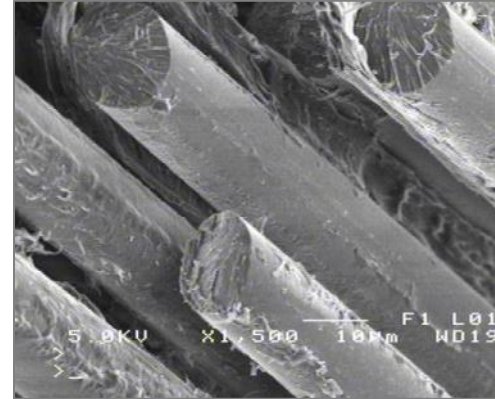


Beads
(Glass)

Photo: Potters, Inc.



Minerals
(Talc)

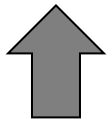
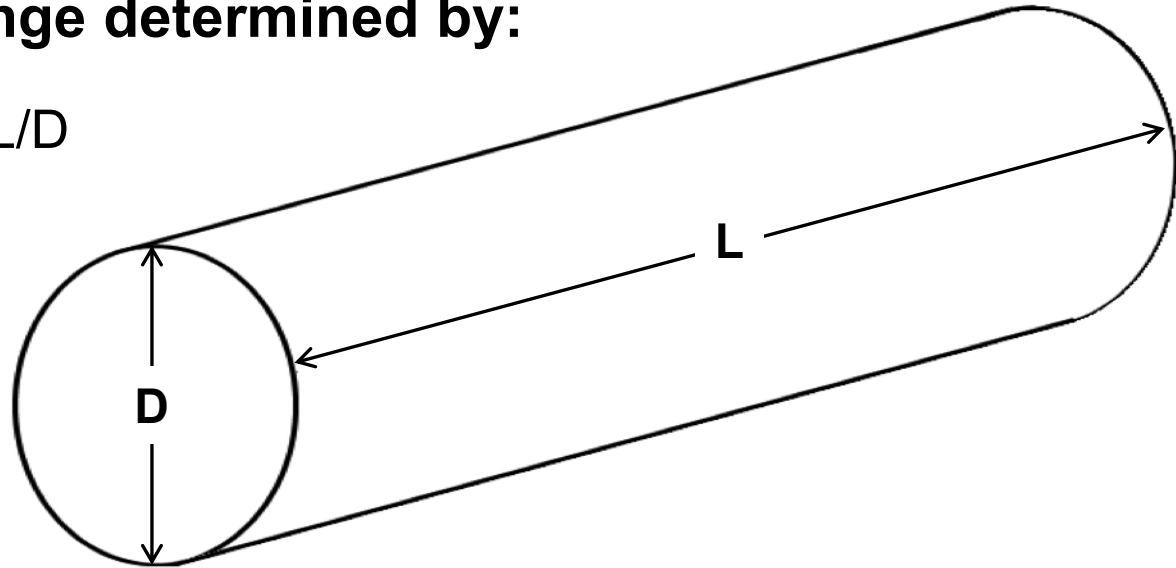


Fibers
(Glass)

ASPECT RATIO

Property change determined by:

$$\text{Aspect Ratio} = L/D$$

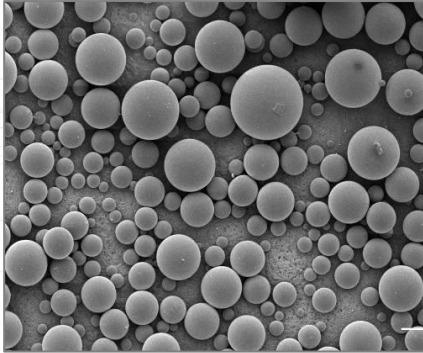


Aspect Ratio



Reinforcing

LOW ASPECT RATIO



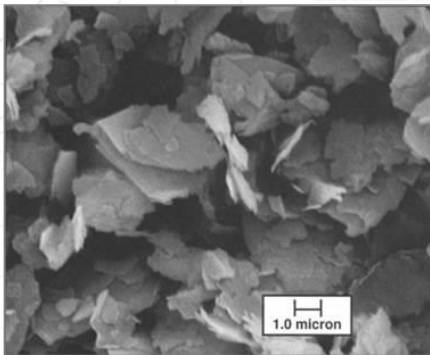
Beads
(Glass)

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)	60	55	48
Notched Izod Impact (J/m)	800	100	80
Flexural Modulus (GPa)	2.3	2.6	3.4

LOW ASPECT RATIO

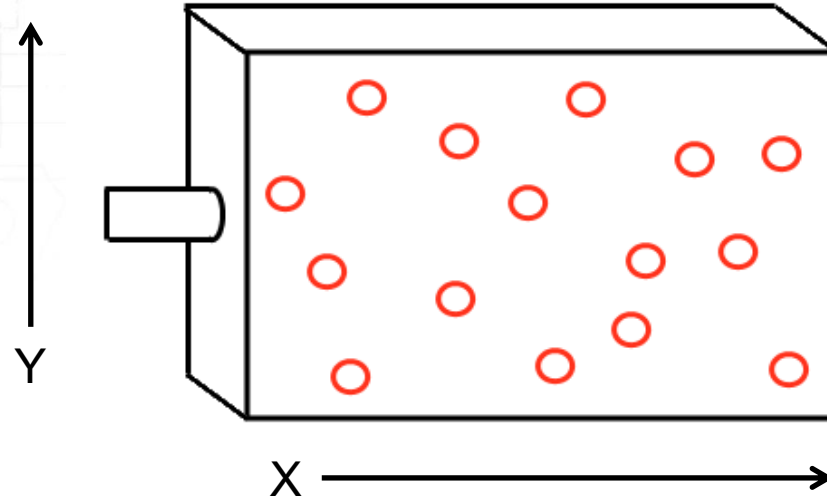


**Minerals
(Talc)**

Aspect Ratio = 2 - 50

	PP	PP + 20% Talc	PP + 40% Talc
Specific Gravity	0.91	1.05	1.25
Tensile Strength (MPa)	32	32	30
Notched Izod Impact (J/m)	53	53	43
Flexural Modulus (GPa)	1.4	2.6	3.9

LOW ASPECT RATIO



Shrink Rate X = Shrink Rate Y $\longrightarrow$ Flat Part

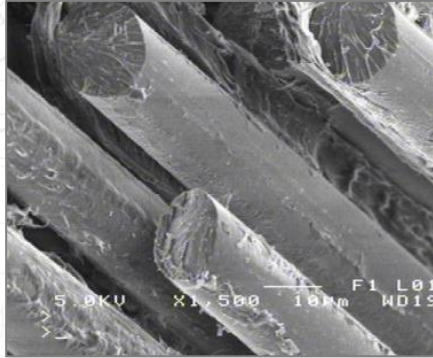
LOW ASPECT RATIO

Reusable Handling Container

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



HIGH ASPECT RATIO

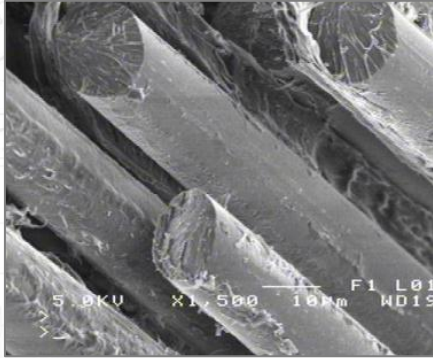


Fibers
(Glass)

Aspect Ratio = 50 - 250

	PC	PC + 30% Glass Beads	PC + 30% Glass Fiber
Specific Gravity	1.19	1.42	1.42
Tensile Strength (MPa)	60	48	124
Notched Izod Impact (J/m)	800	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	1.21
Tensile Strength (MPa)	32	30	82
Notched Izod Impact (J/m)	53	43	120
Flexural Modulus (GPa)	1.4	3.9	6.5

HIGH ASPECT RATIO

Surgery Drill Guide

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



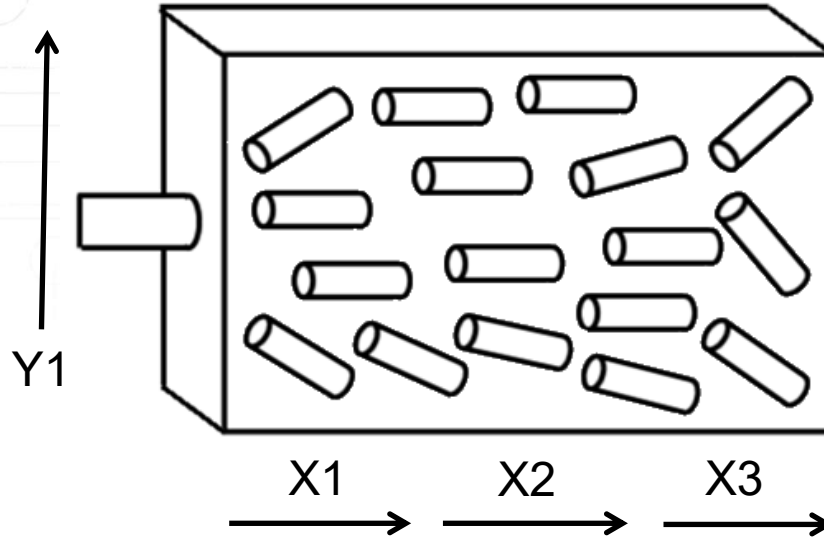
IMPACT MODIFIERS

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

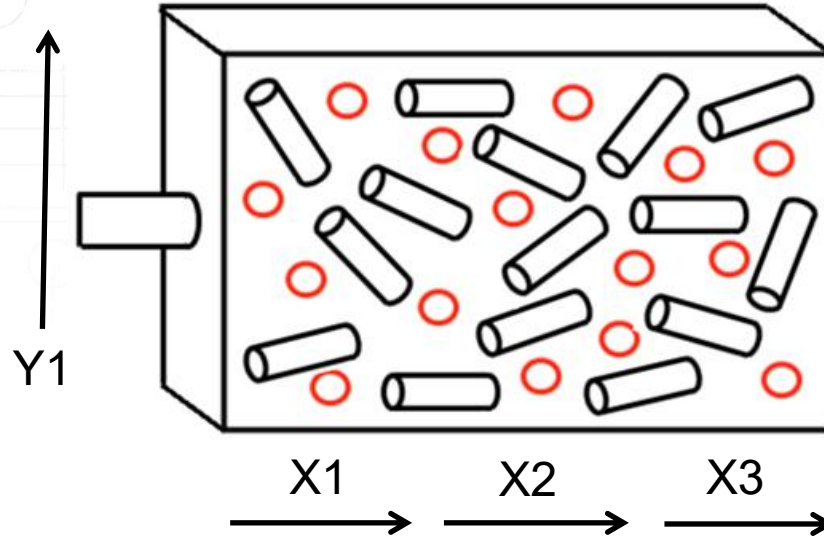


HIGH ASPECT RATIO - WARP



Shrinkage $X1$ & $X2 \neq X3 \longrightarrow$ Warp

HIGH ASPECT RATIO - FLAT



Shrinkage $X1$ & $X2 = X3 \longrightarrow$ Flat Part

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 – PA 6/6

	PA 6/6 60% LGF (Long Fiber)	PA 6/6 30% Carbon Fiber
Flexural Modulus (GPa)	20.0	19.0
Tensile Strength (MPa)	262	248
Tensile Elongation (%)	2.0	2.5
Specific Gravity	1.71	1.27

FIBER COMPARISON – PPS

	PPS 40% Glass	PPS 15% Carbon
Flexural Modulus (GPa)	15.2	15.9
Tensile Strength (MPa)	169	172
Tensile Elongation (%)	1.5	1.1
Specific Gravity	1.68	1.40

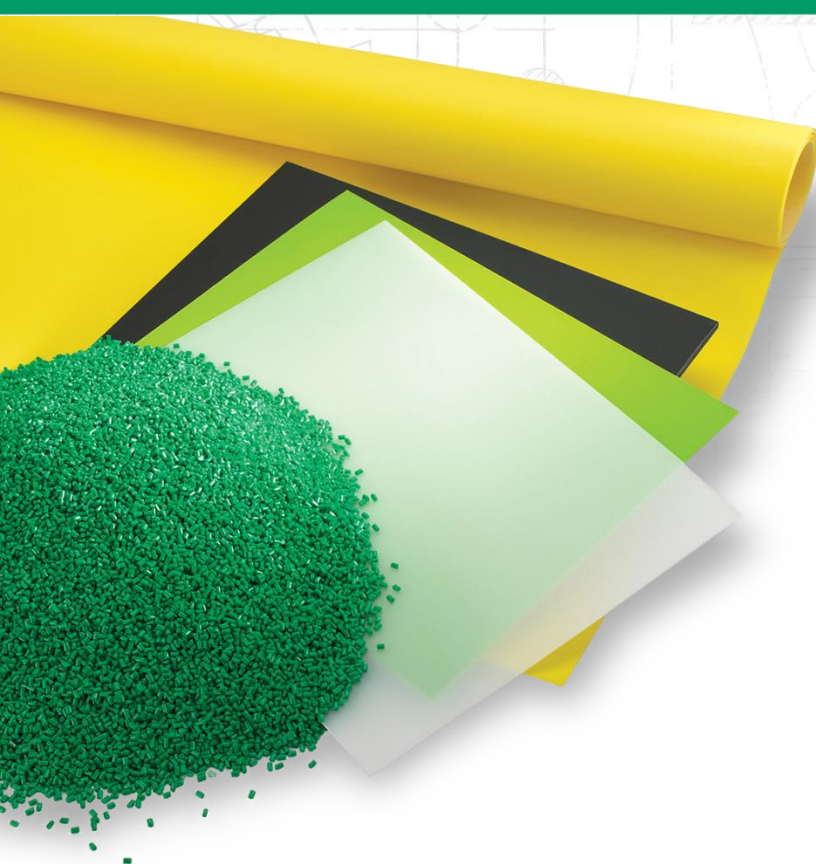
CARBON FIBER APPLICATION

Brake Rotor Measuring Probe

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



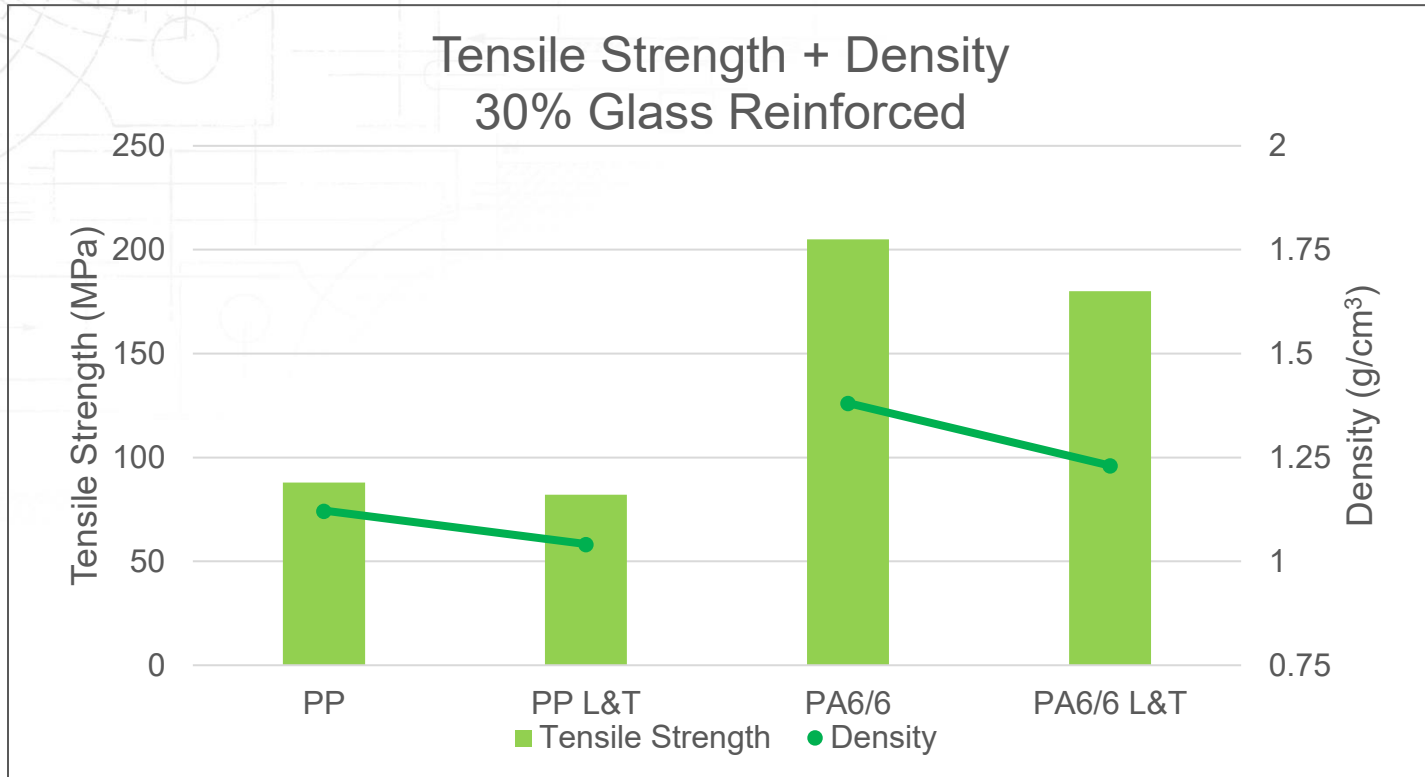
ADDITIONAL STRUCTURAL TECHNOLOGIES



LIGHT AND TOUGH (LT) COMPOUNDS

- LT Compounds are a cost-effective solution to reduce weight of glass reinforced compounds
 - Benefits:
 - Up to 10% reduction in density, independent of wall thickness
 - Maintain mechanical properties
 - Drop-in solution for existing tools
 - Side Benefits:
 - Improved surface finish vs. foaming
 - Reduced warp

DENSITY VS. STRENGTH COMPARISON



DENSITY MODIFIED COMPOUNDS

- Sometimes weight is *the key* characteristic
- Low Specific Gravity
 - Objects that need to float
 - Densities below 0.8 g/cm^3
- High Specific Gravity
 - Counterweights
 - Lead replacement
 - Perceived value
 - Densities $2\text{-}11 \text{ g/cm}^3$



SUSTAINABLE COMPOUNDS

- RTP Company reacts to your needs for sustainability
 - Recycled compounds including Post-Industrial (PIR) or Post-Consumer (PCR) Recycled content
 - Bio-sourced raw materials
 - Specialty Nylons
 - Specialty polyesters – PBS, PLA
 - Cellulose reinforcements



SUMMARY

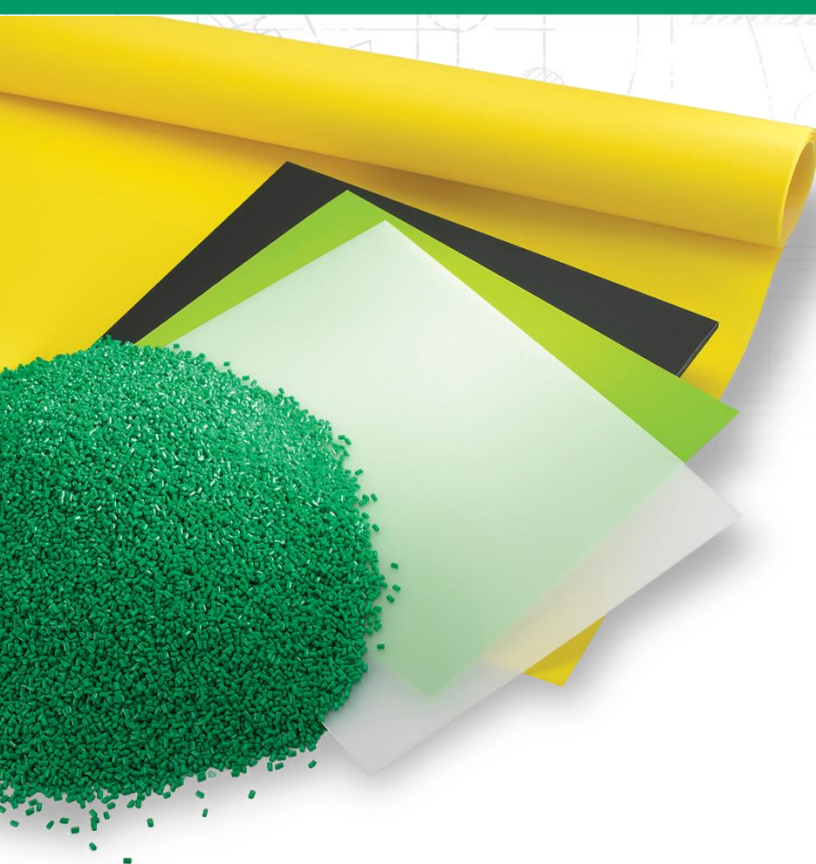
Modifiers

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

Fillers

- Performance driven by aspect ratio

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



THANK YOU!

Questions?

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