Plastics Information

Magnetics is a UL-recognized molder in the QMMY2 fabricated parts program. Many bobbins shown in this catalog are covered. Contact the factory for details on specific parts

	Specific Gravity	Water absorbtion, 24h 73°F (%)	Tensile strength (10^3 psi)	Tensile Modulus (10^5 psi)	Flexural Strength (10^3 psi)	Flexural Modulus (10^5 psi)	Izod Impact, Notched (ft.-lb/in)	Temperature Class*	Coefficient of Expansion (10^{-5} in/in °C)	Deflection Temperature 264 psi (°C)	Dielectric Strength (v/mil)	Dielectric Constant (@1 kHz)	Dissipation Factor (@1 kHz)	Vol. Resistivity @73°F, 50% RH (ohm-cm)	Arc Resistance (Sec)	Flammability	Oxygen Index (%O_2)	UL Card No.	Max. solder temperature (°C)
ASTM Test	D792	D570	D638	D638	D790	D790	D256		D696	D648	D149	D150	D150	D257	D495	UL94			
Rynite FR-515	1.53	.07	15.5		23	8.5	1.2	H	1.7	210	670	3.1	.004	10^{15}	67	V-O	30	E69578	250
Rynite FR-530	1.67	.05	22		32	1.5	1.6	H	1.4	224	650	3.8	.011	10^{15}	117	V-O	33	E69578, E69939, E81777	270
Delrin	1.42	.25	19.5		29	1.4	1.6	A	2.3	163	550	3.8				HB	16	E66288R	
Delrin 900	1.42	.25	10	4.5		4.2	1.3		10.4	130	500	3.7	.005	10^{15}	220	HB		E66288	175
Zytel 101	1.14	1.2	12		23	.41	1.0	B	4.0	232	480	3.9	.02	10^{13}		HB	28	E41938	250
Zytel FR-50	1.56	.6	22.8			11.9	1.9	B	2.2	241	437	3.6	.009	10^{14}	103	V-O		E41938	250
Zytel 70G33L	1.38		18			9.0	2.0			249	530	3.7			135	HB		E41938	255
RTP 205FR	1.66	.6	21	16	33	15.0	2.0		3.4	232	475	3.8	.015	10^{14}		V-O		E84658	248
LNP RF1008	1.46	.6	31		42	16.0	2.60			260						HB		E45195	260
Technyl A20-V25	1.38	.75	19.6		29.7				2.5	250				10^{14}		V-O	32	E44716	
Crastin S660FR	1.45		7.5		11.7	3.9	.8	B		179	560	3.1	.002	10^{16}		V-O	30	E69578(M)	240
E-4008	1.70	.02	21.7		20.1	17.7	2.0					4.5		10^{13}	130	V-O	48	E54705(M)	330
Rogers RX630	1.75	.07	12		23-28	22	1.2	B	1.9	232	500	4.5	.019	10^{13}	180	V-O	40	E20305	400
Rogers RX660B	1.75	.07	12		23-25	22	1.2	B	1.9	232	500	4.5	.019	10^{13}	180	V-O	40	E123472	400
Vyncolite X-611	1.75	.07	12		23-28	22	1.2	B	1.9	232	500	4.5	.019	10^{13}	180	V-O	40	E63312(M)	400
Fiberite 4017F	1.79		9.5		17.5	23	.6	B	1.9	229	400	4.6 @ 1MHz	.026 @1MHz	$2x10^{13}$	180	V-O	42.1	E46372	
PM9630	1.82				27				1.5	249	305			10^{11}	80	V-O		E41429	
T373J	1.41	.40	8		11		42			170	300			10^{12}		V-1		E59481(S)	

*A-105°C, B-130°C, H-180°C

THERMOPLASTIC MATERIALS

NAME	TYPE
Rynite FR-515 Rynite FR-530	Thermoplastic Polyester (PET)
Delrin, Delrin 900	Acetal Resin
LNP RF1008	6/6 Nylon, 40% glass-filled
Zytel 70G33L	6/6 Nylon, 33% glass-filled

NAME	TYPE
RTP 205FR, Zytel 101	6/6 Nylon, 30% glass-filled
Technyl A20-V25, Zytel FR-50,	6/6 Nylon, 25% glass-filled
Crastin S660FR	PBT
E-4008	Thermoplastic LCP

THERMOSET PHENOLIC MATERIALS

Rogers RX630
Rogers RX660B
Vyncolite X-611
Fiberite 4017F
PM9630
T373J

This document reports typical data as compiled from various suppliers' literature. Magnetics assumes no responsibility for the use of the information presented herein and hereby disclaims all liability in regard to such use.

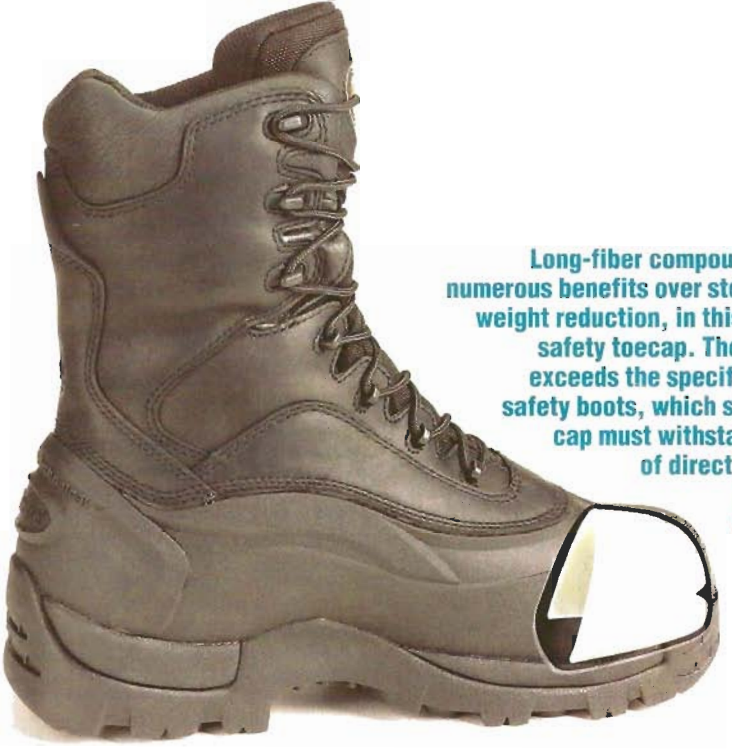
Modern soldering techniques commonly use temperatures in excess of the softening points of all thermoplastic bobbin materials. These typically run from 400°C to 600°C. Extreme care is required to prevent loosening of the terminals during soldering.

Crastin-DuPont, Wilmington, DE
Delrin-DuPont, Wilmington, DE
Rynite-DuPont, Wilmington, DE
Zytel-DuPont, Wilmington, DE
Rogers RX630-Rogers Corporation, Manchester, CT
Rogers RX660B-Rogers Corporation, Manchester, CT
PM9630-Sumitomo Chemical Co. Ltd., Tokyo, Japan
E4008-Sumitomo Chemical Co. Ltd., Tokyo, Japan
Fiberite-ICI Inc., Winona, MN
LNP-LNP Engineering Plastics, Exton, PA
RTP-RTP Company, Winona, MN
Technyl-Nyltech, Lyon, France
T373J-Chang Chun Plastics Co. Ltd., Taipei, Taiwan
Vyncolite RX611-31-Vynckier S.A., Belgium

STIFF COMPETITION

All thermoplastic composites aren't created equal. A systematic material-selection process will help ensure composites perform as expected and don't break the bank in the process.

Steve Maki
Vice President Technology
RTP Co.
Winona, Minn.



Long-fiber compounds provide numerous benefits over steel, such as weight reduction, in this work-boot safety toecap. The compound exceeds the specifications for safety boots, which states that a cap must withstand 7,500 lb of direct impact and 2,500 lb of static load.

"How do I choose the right thermoplastic composite?" is a question that may put knots in the stomachs of even the most seasoned designers. That's because there are thousands of thermoplastic composites available. So it's important to take a systematic and logical approach when choosing a composite. There are five fundamentals that are key: Resin morphology, cost comparison, temperature resistance, property enhancement using aspect ratio, and ultimate-performing long fiber.

RESIN MORPHOLOGY

Over 60 thermoplastic base resins can go into a composite. It's helpful to understand a little about thermoplastic chemistry and, in particular, understanding morphology.

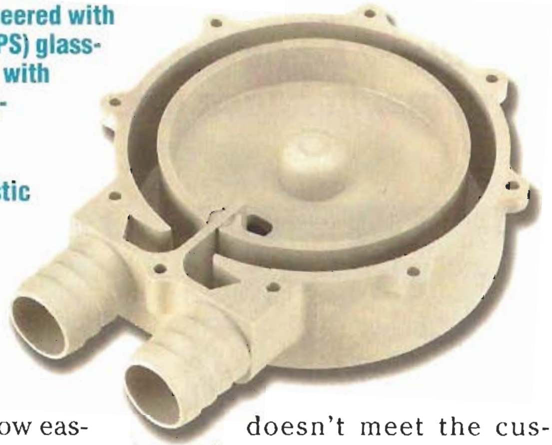
Although morphology sounds like a complicated term, it can simply be viewed as the orientation that the molecules of the polymer (plastic) take when they go from the melt state to a solid during processing. A thermoplastic resin will fall into one of only two categories of morphology: amorphous or semicrystalline.

Amorphous polymers have a random molecular orientation and include acrylic, polystyrene (PS), styrene acrylonitrile (SAN), acrylonitrile butadiene styrene (ABS), polycarbonate, polysulfone (PSU), polyethersulfone (PES), polyarysulfone (PAS), and polyetherimide (PEI).

Polymers with semicrystalline morphologies have ordered or crystalline molecules dispersed within regions composed of random amorphous molecules. They include polypropylene (PP), polyethylene (PE), nylon (PA), PBT polyester, PET polyester, acetal or polyoxymethylene (POM), polyphenylene sulfide (PPS), polyetheretherketone (PEEK), and liquid-crystal polymers (LCPs).

Understanding which morphology best suits the application is important because there are advantages for each morphology type. Amorphous polymers are dimensionally stable and don't shrink, warp, or creep much. They also have good impact strength (toughness) and transparency. On the other hand, semi-

Edited by Jean M. Hoffman



A disposable pump is engineered with a polyphenylene-sulfide (PPS) glass-fiber-reinforced compound with PTFE lubrication using FDA-compliant polymers and ingredients. PPS is a semicrystalline thermoplastic that is a candidate for applications that require a balance of properties to meet crucial strength, temperature, and economical demands.

crystalline polymers flow easily inside the mold, resist chemicals and wear, and work with a wider range of reinforcements.

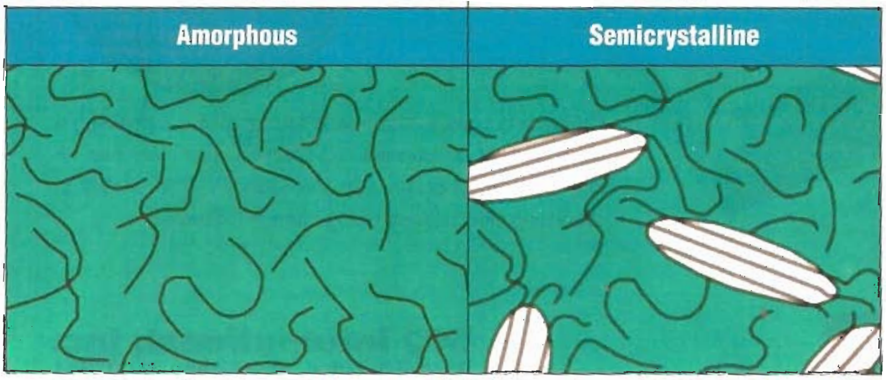
Key to identifying the best resin morphology lies in determining what requirements are most important — dimensional stability, tight tolerances, moldability into thin-wall sections, resistance to chemicals and wear, transparency, and so forth. The assessment will roughly cut resin choices in half.

COST COMPARISON & TEMPERATURE RESISTANCE

Cost is, of course, extremely important. It is possible to develop a composite to meet even the toughest physical requirements. But the effort is wasted if the design doesn't meet the customer's cost expectations.

Thermoplastic resins can be arranged into three categories based on cost. Commodity resins typically have large volume market costs of less than \$1.50/lb. Medium-cost engineering resins typically fall between \$1.50 and \$3/lb. And the high-cost high-temperature resins run above \$3/lb.

There is a direct correlation between the cost of a resin and how well it will resist high temperatures. This is why it is important to not overspecify thermal requirements. Temperature resistance can be measured in a variety of ways (melt temperature, heat-deflection temperature, glass-transition temperature, and continuous-use temperature). The resins that offer the highest capabilities in each of these categories will cost the most. For example, a couple of the top thermal performers include PEEK and thermoplastic polyimide (TPI) and both cost over \$30/lb.



Thermoplastic resins fall into one of only two categories of morphology. An amorphous morphology has a random molecular orientation. Semicrystalline polymers have ordered or crystalline regions of molecules dispersed within the random amorphous molecules.

Costs are usually discussed in terms of dollar/pound. But a thrifty part designer will calculate how much it costs to produce a certain volume of parts: $\$/\text{in.}^3$

$\$/\text{in.}^3 = \$/\text{lb} \times \text{specific gravity} \times 0.0361$.

If you ever find yourself outbid by a competitor using a higher specific gravity material, calculate the $\$/\text{in.}^3$ and you may be surprised to find that you actually have the better price.

Evaluating the composite based on morphology, cost, and thermal requirements will narrow the choices to just two or three resins.

PROPERTY ENHANCEMENT USING ASPECT RATIO

The resin is only half the story in building a composite. Next, one should ask what must be added to the resin to give the composite the right performance. To answer this question, it's important to understand another physical term: aspect ratio. The aspect ratio will help predict the type of physical property enhancement the additive will impart when compounded into the base resin.

The aspect ratio can be defined as the length divided by the diameter of the additive. For a spherical bead, the length equals the diameter and thus the aspect ratio is 1. For a fiber, it is also easy to calculate the aspect ratio because the length and diameter are usually well defined. For some additives, such as minerals with an irregular shape, the aspect ratio is a little harder to figure. It is often calculated by di-

A precolored glass-fiber-reinforced nylon 6 compound is customized with a dazzling metallic effect to give this rotary tool a professional and durable appearance. In addition to meeting the critical color match, the compound provides the necessary impact resistance and UL94 HB recognition.

viding the particle's maximum length with its thinnest cross-section measurement.

Additives with aspect ratios of less than 10 have minimal ability to improve tensile and flexural strengths of the base resin. These additives are generally referred to as fillers and include talc, calcium carbonate, and glass beads. Though they don't improve strength, they do moderately improve modulus (stiffness) and heat-distortion temperatures.

They also can be added to reduce part warpage, improve dimensional stability, and reduce the overall cost of the composite (especially with more expensive base resins). Fillers act as a contaminant and initiate stress cracking. Thus, they lower the impact resistance (toughness) of the plastic.

Additives that have an aspect ratio above 50 can significantly improve the base resin tensile and flexural strengths. These additives are generally referred to as reinforcements and include fibers made from glass, carbon, aramid (Kevlar), and basalt. Besides boosting strength, reinforcements can make the composite stiffer and raise its heat-distortion temperature.

Because they have a tendency to align themselves with the flow direction during molding, reinforcements contribute to anisotropic shrinkage (different in flow direction versus transverse direction), which can make parts warp. Fillers such as glass beads or talc are sometimes added along with glass fiber to make the shrinkage more isotropic and reduce warp. Regarding impact resistance (toughness), reinforcements tend to make brittle resins tough and tough resins brittle. Examples of this include a brittle polyphenylene sulfide resin becoming tougher when reinforced with glass fiber and a tough polycarbonate becoming more brittle when reinforced with glass fiber.

Additives with aspect ratios between 10 and 50 will have a moderate effect on improving tensile and flexural strengths of the base resin. These additives are referred to as transition materials and include wollastonite, mica, and milled-glass fiber. They will improve modulus and heat distortion slightly more than the fillers.

AMORPHOUS AND SEMICRYSTALLINE THERMOPLASTICS

Amorphous	Semicrystalline
Acrylic	PP
PS	PE
SAN	PA
ABS	PBT
PC	PET
PSU	POM
PES	PPS
PAS	PEEK
PEI	LCP

ADVANTAGES OF AMORPHOUS AND SEMICRYSTALLINE THERMOPLASTICS

Property	Amorphous	Semicrystalline
Low shrinkage	✓	
Low warpage	✓	
Tight tolerances	✓	
Toughness	✓	
Creep resistance	✓	
Transparency	✓	
Mold-flow ease		✓
Chemical resistance		✓
Response to reinforcement		✓
Wear resistance		✓

Understanding which morphology is important because there are advantages for each morphology type.

COST COMPARISON

	Amorphous	Semicrystalline
Low-cost, commodity resins	Acrylic, PS, SAN, ABS	PP, PE
Medium-cost engineering resins	PC	PA, PBT, PET, POM
High-cost, high-temperature resins	PSU, PES, PAS, PEI	PPS, PEEK, LCP

Transition materials typically serve in situations where dimensional stability is of prime importance and it's acceptable to have strength, modulus, and heat distortion lower than from glass fiber.

The accompanying chart shows the difference in performance for a nylon 6/6 containing 40% of filler (talc), a transition material (mica), and reinforcement (glass fiber).

PERFORMANCE COMPARISON OF NYLON 6/6 COMPOSITES

Property	Unfilled	40% (talc) filler	40% (mica) transition	40% (glass-fiber) reinforcement
Mold shrinkage, in./in.	0.014	0.007	0.006	0.004
Tensile strength, kpsi	11	11	15	32
Flexural strength, kpsi	16	16	22	45
Flexural modulus, kpsi	400	800	1,200	1,700
Notched Izod impact, ft-lb/in.	1	0.9	0.9	2.6
Heat-distortion temperature @ 264 psi, °F	160	350	400	480

LONG VERSUS SHORT

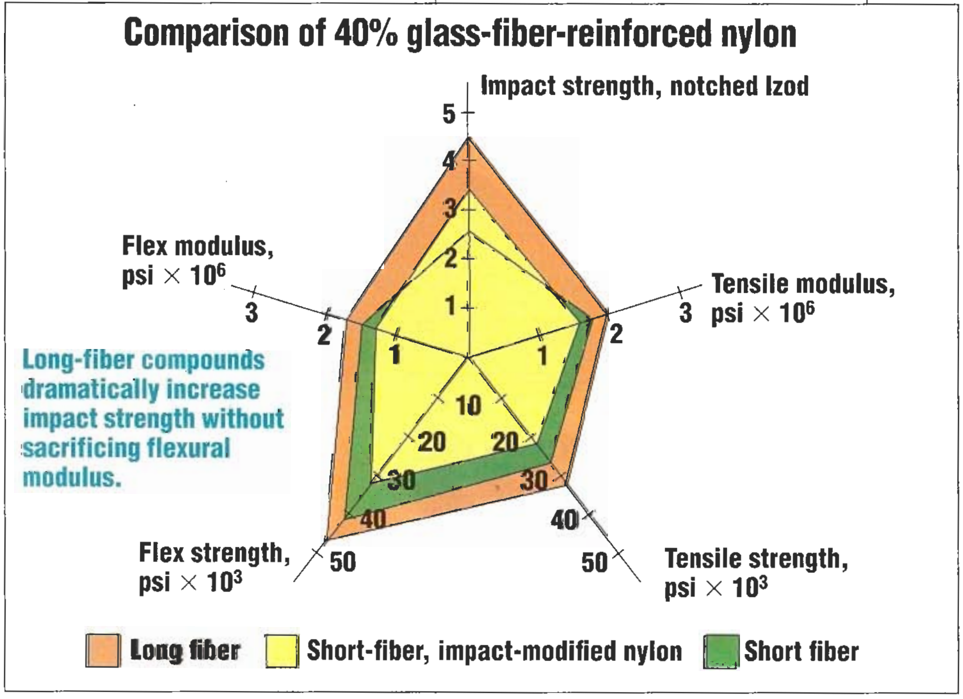
Physical property data indicates that the aspect ratio of the additive has a direct correlation to the strength, modulus, and heat-distortion properties, and possibly the impact resistance of the composite. Maximizing the aspect ratio of the reinforcement fiber will maximize composite performance and is the logic behind long-fiber composites.

A pultrusion process manufactures long-fiber composites. Here the fiber roving is pulled through a machined die in which the base resin is forced to impregnate the individual fibers. The impregnated fiber rovings are pulled from the die and into a pelletizer that cuts the strands into pellets.

The fiber length in the pellets will be the same as the pellet length, which for most materials is a half-inch. Using a 17-μm-diameter fiber results in a fiber aspect ratio of about 750, which is about 10 times larger than that of chopped-fiber compounds typically produced via the extrusion compounding process.

Prior to long-fiber compounds, rubber-based impact modifiers were added to improve impact resistance of a chopped-fiber composite. This improves composite toughness but reduces its strength, modulus, and heat-distortion temperature. The effect of having an extremely high-aspect-ratio fiber in long-fiber composites has been the improvement of all the physical properties, which is depicted in the accompanying spider chart for 40% glass-fiber nylon materials.

By having the ultimate in strength, modulus, impact, and heat distortion, long-fiber composites have become the choice for demanding applications, such as replacing metal in load-bearing applications. The high-aspect ratio in the long-fiber composites also gives these materials excellent creep resistance. **MD**



Comparison of 40% glass-fiber-reinforced nylon

Long-fiber compounds dramatically increase impact strength without sacrificing flexural modulus.

MAKE CONTACT

RTP Co., (800) 433-4787, *rtpcompany.com*