THE PROPERTIES OF PLASTICS

How to Pick the Right Plastic for Your Use

Plastics have changed our world almost as much as semi-conductors have. And, like semi-conductors, they are impacting virtually every part of our lives, in most cases for the better. Plastics lend themselves to robot technology because they are easy to work with, light, strong, clear, colored, flexible, rigid, formable, and reasonably priced. Though there are hundreds of plastics in existence, they fall into two basic categories: Thermoplastics, and Thermosets. This article will deal with thermoplastics and a future article will describe thermosets.

The difference between thermosets and thermoplastics has to do with their basic properties. Thermosets typically are purchased in liquid resin form and include products such as epoxy, polyester, and urethane. Like concrete, the user gets one chance to mold or shape the liquid form before it permanently hardens to the desired state. These products are often combined with fiber reinforcements to produce composites.

Thermoplastics are more like wax in that they can be melted and reshaped over and over. Thermoplastics are typically sold to the consumer in the form of sheets, rods, and tubes, which can be cut and formed for specific uses. Knowing which plastic meets the properties needed for a specific project is often the first challenge a builder faces.

There is no such thing and a handy reference list that identifies which plastic is best for which robot part, though that would sure make things easy. For example, no one plastic is best for the outside body of a robot. As a builder I must ask, ‘Do I want the case to be clear so people can see my interior workmanship? Or, do I want it to be impact resistant to handle attacks from other robots? Or, does it need to filter UV light, or perhaps stand up to chemicals?” All these questions lead to different plastics.

This article will describe various properties of plastics and identify the performance of each plastic in relation to each property. This will allow you to pick out the plastic that best meets your specific need. Since there are literally hundreds of plastics, with more being created every day, this article will be limited to the most common and readily available plastics. Engineering and specialty plastics can be prohibitively expensive and may not offer a significant advantage over a more economical alternative. The plastics included here will be:

ABS
Acrylic
Impact modified acrylic
Polycarbonate
Styrene
Polyethylene

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ABS

ABS is a blend of three different plastics into a sort of plastic alloy. It is most readily available in opaque black and white, with one side smooth and one side textured. ABS is available in thickness down to .040". . ABS is hard, rigid, and very tough. It can be glued and bent as well as vacuum formed. It is more economical than acrylic, but lacks the transparent color options. ABS is used for a variety of parts such as football helmets, camper tops, housings for small appliances, communications equipment, etc. It can be chrome plated for a completely convincing metal look. It has a lower melting point than acrylic, so it lends itself to heat forming and vacuum molding.

ACRYLIC

Acrylic is used for everything from department store displays to aircraft windows. Sometimes known as Plexiglas (a trade name), acrylic is lighter, clearer, and more impact resistant than glass.

Transparency is one of the big advantages of plastics. Though there are several transparent plastics, the greatest clarity comes from acrylic. With a light transmission of 92%, acrylic is clearer than glass. (A typical car windshield transmits about 70%) This clarity when combined with polished edges can produce a spectacular appearance. Frosted acrylic sheet (also known as P-95) seems to glow when it is lit from behind.

Since acrylic comes in a variety of shapes, there are endless possibilities to create special effects. Acrylic fiber optic cable is readily available and can be used to direct or 'pipe' light. Narrow diameter rod can be used to 'pipe' light and if the sides of the rod have a sanded finish, the whole rod will glow with an 'other-worldly' appearance. Acrylic spheres (used to make the eyes in Bicentennial Man) and cabochons also create special effects. Florescent acrylic produces effects that defy description in print. It is a 'must have' for visual impact. Try engraving on it for an even more dazzling effect.

Another advantage of acrylic is its ability to resist the effects of UV. It is virtually unaffected by UV and is ideal for exterior applications. Speaking of UV, regular acrylic filters UV light up to about 360 nm. A special acrylic called OP-3 filters up to 98% of UV below 400 nm. This is ideal for protecting valuable objects from damaging UV light.

Besides being clearer than glass, acrylic has significant impact resistance. It can withstand impact many times greater than glass, and when it does break, the pieces are large and much less sharp than glass.

The one down side of plastic is that it scratches. However, it is now possible to purchase acrylic that has been treated with an abrasion resistant coating. This coating can stand up to steel wool, and is thus ideal for high contact applications.

Acrylic is also available in a rainbow of colors, ranging from transparent to opaque. It can easily be machined, bent, and glued. More details on that are below.

POLYCARBONATE

Polycarbonate is readily available in clear, smoke, and white and in thickness down to .005". It is an extremely impact resistant material that is designed for applications requiring durability and high service temperatures. While not quite as clear and acrylic (approx. 80-89% transmission), it offers much superior impact properties. To illustrate this, our company has a piece of 1/8" thick polycarbonate mounted in a frame that is taken around to various trade shows and demonstrations. People are invited to use a hammer to break the material. After three years of serious pounding, no one has managed to break it! So, if you are looking for a plastic that can take a beating, this is the choice.

Polycarbonate is also able to handle higher temperatures before softening and it has superior chemical resistance, especially to acids. Polycarbonate can be heat bent at a temperature of about 300 F. While glue joints are possible with polycarbonate, they are not as strong as acrylic joints. Thin gauge polycarbonate is commonly used for the body shells on RC cars. Even in thin gauge, it is incredibly tough. Polycarbonate can be sawed, drilled, routed and tapped.

IMPACT MODIFIED ACRYLIC

Impact modified acrylic, also known as HP at our stores, offers the appearance advantages of acrylic and the impact properties approaching polycarbonate, in a single product. It fabricates more easily than polycarbonate and produces better glue joints. The down side is that it is an interior only product. It is rapidly affected by UV, causing the product to haze quickly. It is also sensitive to heat, which will cause it to turn milky. Even with these limitations, HP offers a great combination of looks and performance.

STYRENE

This sheet material, most commonly available in white, also offers excellent impact resistance. Its chief advantage is its thermoformability. In thin gauge, it is ideal for vacuum forming or heat bending. It glues well, but does not have good chemical resistance, especially to aromatic and chlorinated solvents. The other big advantage of styrene is its price. It is approximately 1/3 less in cost than acrylic, and about half the price of polycarbonate. This is a versatile and economical product worth experimenting with.

POLYETHYLENE

Polyethylene is perhaps the largest volume manufactured thermoplastic. It is used for everything from sandwich bags to cutting boards, to gallon milk bottles. It is characterized by toughness, outstanding chemical resistance, low coefficient of friction, and ease of machining. The most readily available versions of polyethylene are low density and high density. Low density is used for bags, packaging, and plastic sheeting often used for a moisture barrier. High density is more durable and used for containers such as juice bottles. Polyethylene is generally a white translucent color and is readily available in thickness ranging from .060” to 1”, in both smooth and textured finishes.

For robot applications, the big advantage of polyethylene is its easy machinabity and impact resistance. It can be milled into low friction gears and bushings, which do not need to be lubricated and have high resistance to wear yet light weight. It is the only one of the plastics mentioned here that will actually float in water.

There is one other polyethylene that is often mentioned, called UHMW, which stands for ultrahigh molecular weight polyethylene. This engineering plastic is costly and is seldom required for most applications. HDPE (high-density polyethylene mentioned above) will usually meet the UHMW applications.

WORKING WITH THE PLASTICS

Plastic is in many ways easier to work with than wood. Below are a few brief suggestions. Your local TAP Plastics store has much more detailed information available.

BENDING

All of the above plastics can be bent with the use of heat. Caution needs to be used, as these are combustible materials, so heating in your home oven or with a torch is to be avoided. A heating element in a channel or nichrome wire can be used to make a line bender, which will heat the material to about 300 F for bending.

POLISHING

Acrylic and HP can be easily edge polished with the use of a torch. The easiest method is using MAPP gas. Propane and Oxygen in combination can also be used. Propane alone does not provide enough heat for a good finish. In the absence of a torch, a buffing wheel can also be used with a polishing compound.

Polycarbonate cannot be flame polished and must be buffed. The other plastics do not edge polish very well.

CUTTING

Typical home shop tools can be used with modest success. Very thin material (up to .125) can be scored or even cut with a matte knife and then either snapped or bent to fatigue. Thicker materials should usually be cut with a saw.

A saber saw can be used, but it will leave a rough edge. When using a saber saw, the biggest problem is vibration between the saw and the plastic. Laying the plastic on top of a two-inch thick piece of Styrofoam and holding the plastic down while cutting through both the Styrofoam and plastic can solve this. The Styrofoam provides a good solid base. Another problem with a saber saw is that the blade heats up and melts the plastic. This can be minimized by blowing compressed air on the blade while cutting. The blade itself should have about 10 teeth per inch and should be used to cut only plastic.

A band saw works fairly well, but again compressed air might help to minimize melting. The blade should have 14 teeth per inch. A band saw will not produce a good finished edge, but can be used for rough cutting.

A table saw is the best method for cutting plastic, but the proper blade should be used. A new plywood blade can do an adequate job. But for better edge quality carbide tipped blade with a triple-chip tooth design is best. A 10” blade should have about 80 teeth.

DRILLING

All these plastics drill very easily. The secret is to use the proper bit. A regular twist drill bit will chip the plastic. There are economical drill bits available, which will produce very clean cuts. Trying to use typical home bits will only produce frustration and wasted plastic. Drill speed should range from a slow 400rpm for large holes (1”), up to 3500rpm for 1/8” holes.

FASTENING

Mechanical fasteners work with all the above plastics. The guidelines for this process are extensive and are available in any TAP Plastics store.

All of the plastics except polyethylene can be glued. The glues actually solvent weld the parts so that in most cases the joint is as strong as the sides. Again extensive details are available in any TAP store.

SHOPPING FOR PLASTIC

When shopping for plastic, there are some key questions to ask in order to get correct pricing, avoid unexpected delays, and make sure you are purchasing the correct product.

When requesting the price of a particular plastic over the phone, it is essential that you ask for the price of a specific size piece. When someone quotes you a price ‘per square foot', you may not be getting the full picture. Some companies will charge a four square foot minimum, regardless of how small a piece you need. Other companies have cutting charges, and other costs, which may not be quoted over the phone. So for accurate pricing, ask, "How much is the price for a such and such plastic, 11"X13" (or whatever your size is)." This should reveal any hidden charges that don't show up until you purchase the piece. If you have a shape other than a square or rectangle, this should be mentioned too, as that may incur special labor charges.

Ask about turn-around time. For simple shaped pieces (squares, rectangles, circles, etc.), the order should be done while you wait, unless you need a very large quantity. 'While you wait' should not mean 30 minutes or more. It should mean 5-15 minutes. Some industrial suppliers may have a great price, but you may grow old waiting for a small order. Obviously, if your piece(s) have holes to be drilled, edges to polish, etc., the waiting period should be a bit longer.

Finally, ask the sales person what he or she thinks is the best material for your project. A knowledgeable sales person can help prevent problems and can often suggest more economical ways of doing your project.

As can be seen by this very brief introduction, the possibilities are endless. Plastics are versatile, economical, and practical. This article just scratches the surface, so to speak. Any TAP Plastics store can provide you with extensive and practical information. Though our web site is not up and running yet, watch for it to arrive soon at tapplastics.com!

Below is a chart with some comparative information. The numbers for things like tensile strength are helpful in comparing one plastic with another. For example, if I wanted the stiffest material below, I would pick the highest flexural modulus, which is acrylic.

	Acrylic	ABS	Polycarbonate	Hi-impact Styrene	HP	HDPE
Cost[1]	Med.	Med.	High	Low	High	Low
Clarity	Best	Opaque	Good	Opaque	Good	Opaque
Impact Resistance	Good	Esc.	Exc.	Exc	Very Good	Exc.

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Specific Gravity[2]	1.19	1.05	1.20	1.05	1.11	.96
Flex. Modulus[3]	480,000	300,000	340,000	280,000	440,000	220,000
Hardness[4]	Best	Fair	Very good	Fair	Good	Gair
Heat distortion[5]	195	190	270	190	195	170
Tensile Strength[6]	10,000	6,000	9,400	2,600	7,800	4,400

1- Relative to others in list
2- Measure of relative weight. Water has a specific gravity of 1.0g/cc. The higher the specific gravity, the more dense the material
3- Measure of 'stiffness', measured in psi
4- Resistance to scratching. Note: Acrylic and Polycarbonate are available in a highly scratch resistant finish.
5- Temperature at which material begins to deflect under a load, measured in F.
6- The strength needed to pull a piece apart as if pulling on the ends. Measured in psi.