



NUTS & BOLTS

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Polycarbonate—a high performance amorphous engineering thermoplastic

In this issue, NHML will discuss polycarbonate, a high-performance amorphous engineering thermoplastic. It is a very tough and strong plastic that is finding widespread use in industry.

We'll tell you:

- ✓ Exactly what a polycarbonate is
- ✓ What is the cause of unexpected cracking
- ✓ How to check for residual stress
- ✓ Examples of chemical attack
- ✓ What causes hydrolysis
- ✓ How NHML can help you with failure analysis

Our Philosophy

New Hampshire Materials Laboratory has one goal—to help you solve your technical problems at a reasonable cost. Tests help, but are not always enough.

Our team of dedicated and experienced professionals has both the skills and the backup facilities to serve in the following:

- Failure Analysis
- Material Certification & Compliance
- New Product Testing
- Mechanical Properties
- Tensile and Compression Testing
- Heat Treat problems and Verification
- Reverse Engineering
- Weld & Life Testing
- SEM & EDS

N.H. Materials Laboratory Inc.

Looking BEYOND the expected...

Polycarbonate

Background

Polycarbonate, is tough, strong, high-performance amorphous engineering thermoplastic which is finding widespread use in industry. It has application where high impact resistance and its ability to maintain its shape and size even under great stresses over a wide range of temperatures is desired. It is an ideal engineering plastic since it can be injection molded or extruded.

This relatively inexpensive thermoplastic molds easily, takes a good finish and does not attack the molds. Due to its excellent properties, it is often used in the appliance industry for vacuum cleaner bases, cord

hooks, impellers and blender and food processor housings. Motorcycle windshields, police shields and headlight covers are other typical high stress applications that use polycarbonate.

Created by a polymerization process, it contains long chains of linear polyesters of carbonic acid and dihydric phenols like bisphenol.

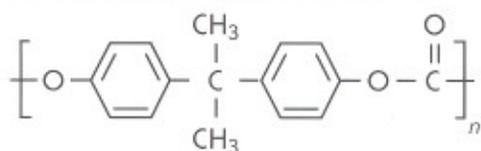
These long chains get entangled with each other and considerable force is needed to disentangle them. However, when heated, the chains move apart enough to permit them to slide over one another. This allows polycarbonate, a thermoplastic, to be molded or otherwise shaped into useable items. If you are either designing, manufacturing or using polycarbonate parts then these are the things you need to know.



If additional information relative to the metallurgical details is needed, please call or contact us by e-mail, Lab@NHML.com.

What is a polycarbonate exactly?

At the mill, the basic polycarbonate molecule is formed by a reaction between an alcohol and carbonic acid. At the same time, a water molecule is given off. This is the key to one of polycarbonates limitations—more about that later. The molecules look like:



The stuff on the left came from the chosen alcohol while the stuff on the right came from the carbonic acid. The neighboring molecules hold onto each other by covalent bonds. The plastic is in the glassy state at room temperature, with its glass transition temperature around 150° C.

PC is often used in copolymers. Copolymerized with various phthalates it acquires better heat resistance. It may be blended with PET, PBT, ABS and Styrene-Maleic Anhydride, often for better fracture resistance and flexibility.

Cracking

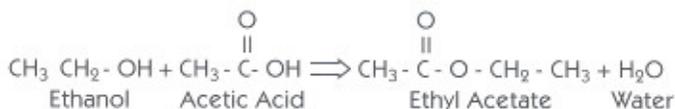
Unexpected cracking by polycarbonate is often due to stress corrosion. Remember that both tensile stress and an attacking chemical are needed. The stress can either be applied stress, residual stress or both. An example of applied stress: a female pipe thread tapped into the polycarbonate part. The male thread screws into it and the taper expands the female part, putting it into tension. Residual stress comes from quenched in stress, after dropping out of the mold, when the different areas of the part cool at different rates. Applied stress has to be designed out of the part by varying the cross sectional thickness of the part. Residual stress gets annealed out. The time and temperature is dependent on the particular plastic. A quick check to tell if residual stress is present in a transparent polycar-

bonate part is to place a polarized filter or even a pair of polarized sunglasses in front of a light bulb and let the now polarized light shine through the part.

Examine the part while wearing a pair of polarized sunglasses. Because of polycarbonate's special optical properties, often the polarizing lens in front of the light is not necessary. If a pattern of residual stress is present you'll see it in the plastic. While the patterns you see are an indication of tensile stress the real total stress is somewhat more complicated. However, if there is a need to know this additional information, do not hesitate to give us a call.

Chemical Attack

The attacking chemicals are most often an ester or a ketone. An ester is the dehydration product of a reaction between carboxylic acid and an alcohol. Ethyl Acetate is an example.



The esters we see most often causing trouble are the synthetic lubricating oils and some cutting oils. For example, synthetic oil is put into the air compressor supply. In a few days or few weeks, all of the polycarbonate pressure regulators tapping into the supply line develop cracks. Always check the MSDS sheets on your lubricants and don't use anything that says "esters" if there is polycarbonate parts anywhere in your system.

Hydrolysis

Remember the water molecule that is given off when the PC molecule is being made? Give back the water and the PC molecule may come apart. This process is referred to as "Hydrolysis" and it is bad news. So we can't use PC in high humidity at elevated temperatures—no steam for polycarbonate!

Studies have shown a rapid drop in average molecular weight for PC's under hot/humid conditions. This means that the PC polymer chains are being cut to pieces by the water molecules. One study found the average molecular weight of a commercial grade PC dropped to approximately 65% of it's initial value after 40 weeks at 100% relative humidity at only 65° C.



This reduction in molecular weight leads to a loss of mechanical properties, and causes brittle rather than ductile fractures.

This susceptibility of PC to hydrolysis also has implications for processing. PC must be dried before processing in a hopper dryer or on trays at 120° C for 3 to 4 hours. The drying operation should reduce the moisture content to approximately 0.02%.

Chemicals that Attack Polycarbonate

The chemicals that attack PC are numerous:

Strong Bases

Ammonium Hydroxide
Sodium Hydroxide
Potassium Hydroxide

Halogenated Solvents

Methylene Chloride
Chloroform
Carbon Tetra Chloride

The Ketones

Acetone
Acetonitrile
Ethyl Acetate
Methyl Ethyl Ketone – (MEK)

Other Stuff

Benzene (An aromatic)
Benzyl Alcohol
Lacquer Thinner
Mineral Spirits
Jet Fuel
Dimethyl Sulfoxide
Diethyl Ether
Carbon Disulfide
Xylene
Urea

Failure Analysis

What do we do when you come to us asking, "Why did this PC part crack?"

We break open a fracture and examine it with an optical microscope. The telltale signs of stress corrosion cracking are the same kind of waviness that you can see on a broken beer bottle fractured surface. The fracture will stop where it passes out of the stressed area.

We will try to collect a droplet of liquid from the surface. Sometimes we can get just enough liquid out of the cracks for our microanalytical techniques. We use **Infrared Spectroscopy** and possibly **Gas Chromatography** to identify the droplet.

We will ask you to bring a thimble full of each of the fluids that the PC may have come in contact with.

Please use clean, glass containers. We don't want to end up analyzing either the plastic container, the cover or any other contaminant. We will check the liquids for esters and for a match with whatever we collected from the part.

We will use **DSC, Differential Scanning Calorimetry**, if we need to know the PC's glass transition temperature. This often comes up if you ask the question, "Is this defective part made from a new batch of resin equal to former parts made from a previous batch?"

Summary

While polycarbonate is a remarkably strong, versatile plastic with a wide number of applications, you must keep in mind it's hydroscopic nature and it's vulnerability to certain common solvents and chemicals.

People at NHML...

Introducing Jeff Masse, Chief Chemist



We are fortunate to have someone with such skills and background as Jeff Masse heading our Chemical Department. Jeff comes to us from working for FAA and Pfizer Pharmaceuticals. He has his Masters degree from UCLA and

has a very strong background in Physical and Organic Chemistry as well as Analytical and Biochemistry.

Recently married, Jeff and his new wife are busy restoring a wonderful old farm house in East Waterboro, Maine

Polycarbonate has excellent strength and toughness. However, it is susceptible to stress cracking, aromatic solvents and is difficult to machine.

Can We Help You?

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