Day 27: Selecting Polymers in Some Engineering Applications

Polymer choices for Gears, Bearings?

http://www.eriks.co.uk/image-bank/images/storage/1260_plastic_bearings.jpg

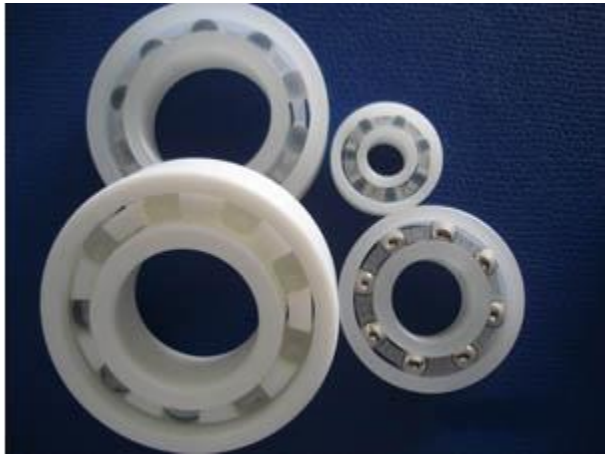
http://www2.dupont.com/Automotive/en_US/assets/images/newsEvents/gears311ehi.jpg

http://www.jimdunlop.com/files/1153351062_DELRIN_500_STRD_410_463X342.jpg

Plastic Bearings

Hartford Technologies uses **polyoxymethylene / Acetal / Delrin (POM),** a semi-crystalline engineered polymer combining high strength with superior impact and fatigue resistance, for many of its plastic bearings programs. Depending on the application, we also manufacture using:

- PE (polyethylene)
- PP (polypropylene)
- PA (polyamide / nylon)
- PTFE polytetrafluoroethylene / Teflon



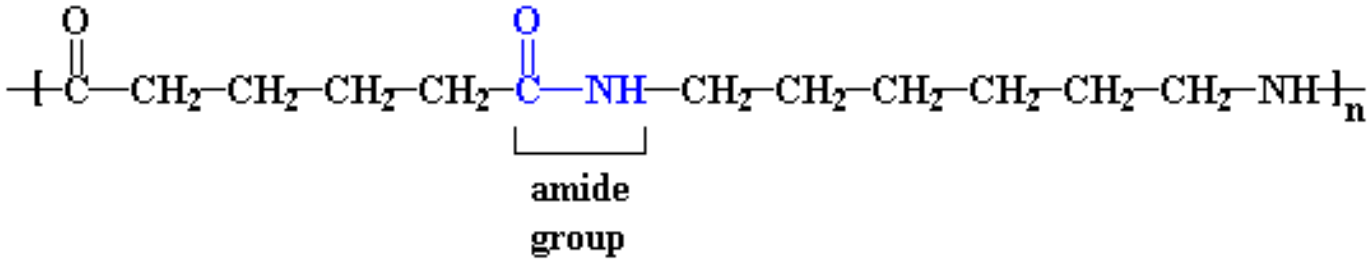
Plastic Flanged Sleeve Bearings

Nylon—A reasonably slippery, rigid, and abrasion-resistant material
that handles light jobs without the need for lubrication.
MDS-Filled Nylon—The same qualities as nylon combined with
wear-resistant molybdenum disulfide (MDS).
UHMW—Ultra-high molecular weight (UHMW) polyethylene is USDA
approved and FDA compliant. It withstands wet, corrosive environments.
Acetal—An economical alternative to PTFE, this material is not only strong, but
also resistant to chemicals and moisture.
PTFE—Has the lowest coefficient of friction of all our materials, so it's ultra-slippery. It
also offers excellent chemical resistance and performs well at extreme temperatures.

http://www.mcmaster.com/#acetal-bearings/=5k7q76

Nylon

- Here is the mer. Condensation polymerization is used. This is (6,6) Nylon. (Trademark and patent by DuPont in the late 1930's.



The amide group greatly stiffens the backbone. Note the absence of bulky side groups. Will it crystalize? Yes. Fiber!!!!

Some Properties of Nylon (6,6)

- Please note the differences between the fiber and the plastic (monolithic) material.

Material	Density (g/cc)	UTS (ksi)	Ductility %EL	Elastic Modulus
Plastic	1.16	15	63	430
Fiber	1.22	76	30	

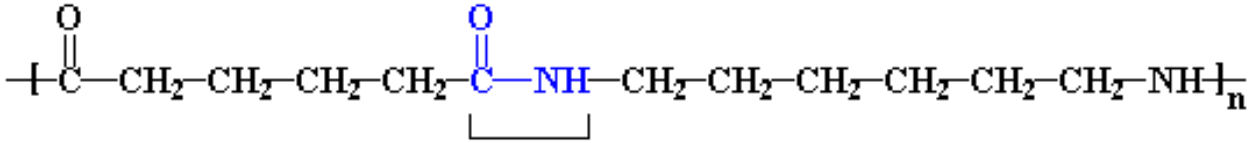
Nylon can be used in small machine parts, such as gears and bearings. And of course, fiber. It is weakened by water absorption.

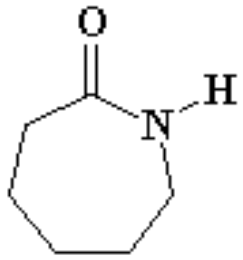
Nylon is more temperature resistant than most polymers.

Polyamides: Nylon 6

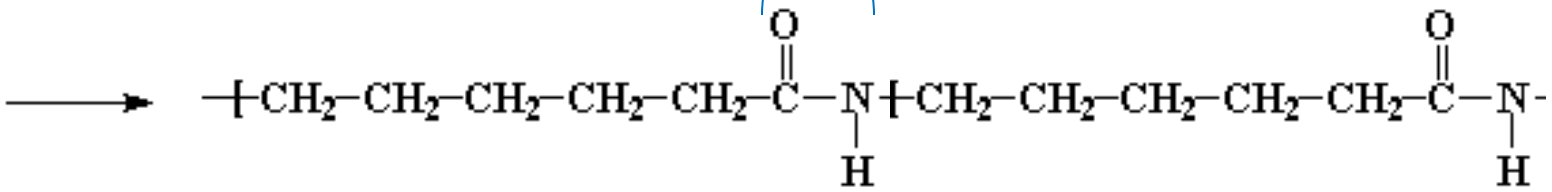
- Nylon 6,6 was trademarked and patented by DuPont in the late 1930's
  - Competitors developed a similar material through a different method using a single monomer
  - Nylon 6 is the result
  - Has similar properties to Nylon 6,6
  - Note the similarity in structure

Nylon 6,6





ε-caprolactam



nylon 6

Competitor for Nylon

- Polyoxymethylene (POM) or Acetal. "Delrin"

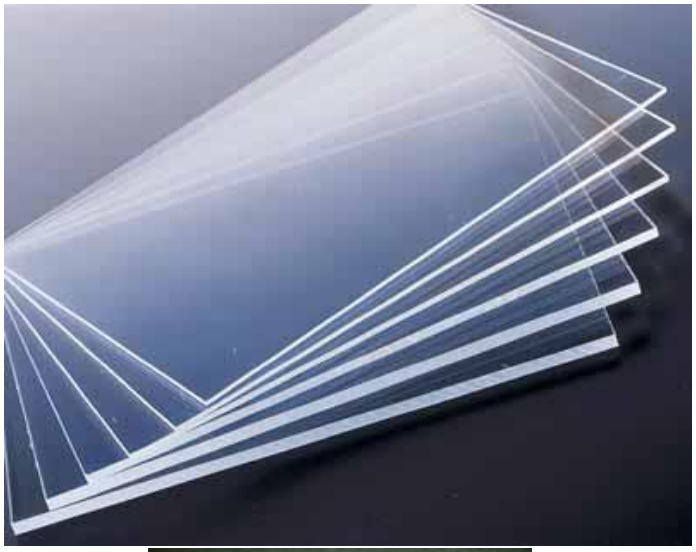
$$-[CH_2-O]-$$

Material	Density (g/cc)	UTS (ksi)	Ductility %EL	Elastic Modulus
Nylon	1.17	11.5	40	470
Delrin	1.41	11	30	450

Good thing about Delrin – does not absorb water and weaken as nylon does.

Why would you expect Acetal to be strong? (chain length, side group, backbone, crystallinity, …)

Polymer Choices for Transparent Applications?



http://www.arnoldsound.com/solutions.htm

http://www.fabplastic.co.uk/acatalog/Plastic_Champagne_Glasses.html

http://www.godofthundermusic.com/electric_guitars.htm

http://www.ospreyco.com/interpretation/acrylic.html

http://www.odeecompany.net/promotional-products/category-polycarbonate-water-bottles.php

http://www.mikesearch.com/tags/b/bifocal-safety-glasses/

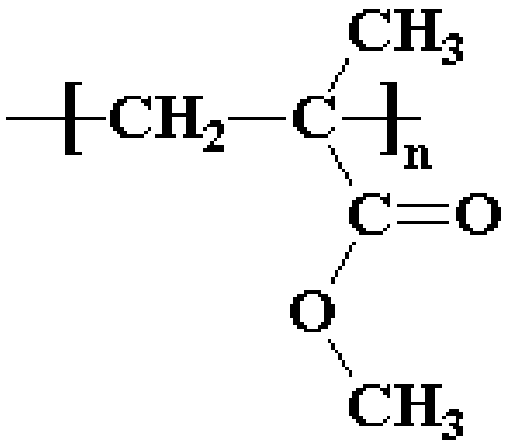
Polystyrene

- We have seen that PS is
  - Usually amorphous (atactic bulky side group)
  - Clear
  - Brittle

- This is the material in CD “Jewel Cases”

PMMA (Polymethyl methacrylate)

- This important thermoplastic has several trade names including: Lucite and Plexiglas.



Do we think that this stuff will form fibers? What about crystallinity?

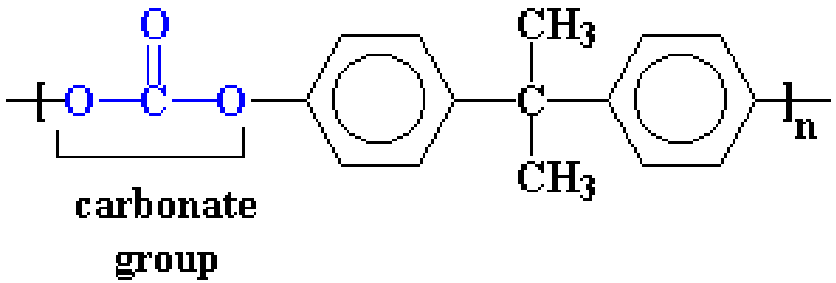
PMMA is Amorphous and is a great glass substitute.

- Because it is non-yellowing, it is a common outdoor window and sign material.

Side windows

Polycarbonate PC

- Here is the mer. This one is called a polyaromatic form of PC. Called LEXAN by GE.



Strengthening Mechanism? Crystallinity?

Polycarbonate

- Much tougher than other clear plastics
- Also more expensive than the others
- Not as good for clear outdoor applications

Properties of PC and PMMA

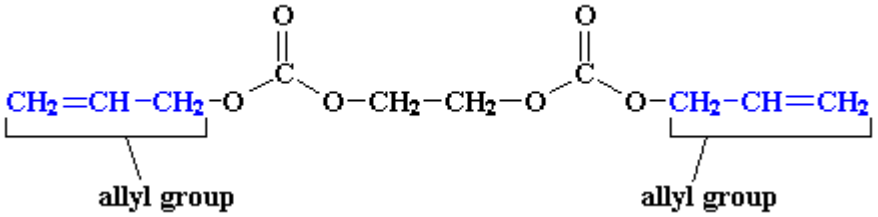
- From Matweb:

Material	Density (g/cc)	UTS (ksi)	Ductility %EL	Izod Impact Ft-lb/in
PMMA	1.19	10.2	--	0.225
Polycarbonate	1.24	8.2	14	2.5

Lexan is used for bullet proof windows!

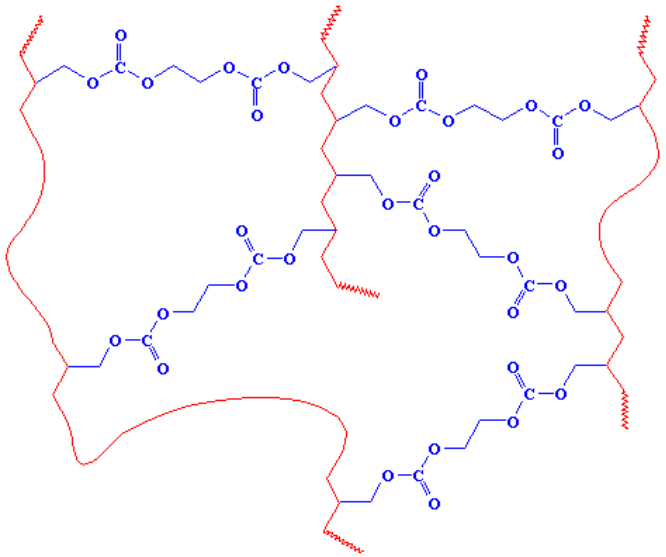
A Different Kind of Polycarbonate

- Here's another monomer which leads to a "polyaliphatic" polycarbonate.



Instead of polymerizing into chains, this one polymerizes into a 3D network solid.

It is called a thermoset. This is the stuff eyeglasses are made from



How About Fibers?

http://www.machovec.com/rope/product.htm

In the "olden days", rope was made of natural fibers, mostly manila, but also hemp and others. They have been superseded by manmade fibers.

There are three main kinds of manmade fiber: **nylon, polyester, and polypropylene.**

Nylon is the strongest of the three, followed by **polyester** and then **polypropylene**.

Nylon, is very strong and elastic.

Polyester is strong with low-stretch (Dacron® is a trademark).

Polypropylene floats.

Recent additions to manmade fibers are **Spectra**® (brand name of Allied Chemicals) and **Kevlar®** (brand name of DuPont). Both are very light with immensely strong filaments.

High Strength Fibers

- Polyaramid – Kevlar®, Twaron ®
- UHMWPE - Spectra®, Dyneema ®

http://directory.officer.com/product/61316/AMERICAN_BODY_ARMOR_Xtreme_Force

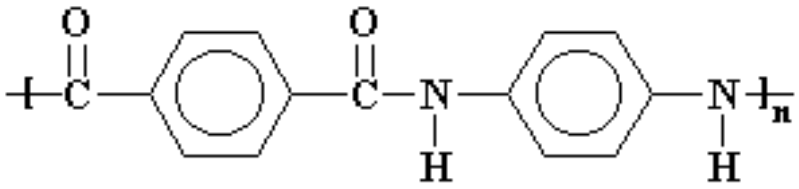
http://northshorejournal.org/helmet-saves-4th-infantry-division-soldier

http://www.fdarchery.com/cgi-bin/cartviewer.cgi?category=010

http://www.warwickmills.com/Knit-Safety-Gloves.aspx

Relatives of Nylon: The Aramids

- Here is a truly wonderful engineering polymer.



In Kevlar the aromatic groups are all linked into the backbone chain through the 1 and 4 positions. This is called *para*- linkage.

Talk about a stiff backbone And there are not any bulky side groups so this stuff will go crystalline! In fact, it is used mostly as a fiber.

PE - UHMWPE

- Ultra High Molecular Weight Polyethylene can be a fiber.
- Alignment and Crystallinity combine for high strength
- Density is still less than water

Kevlar fiber is very strong!

- Compare Kevlar and the related polymer Nylon.

Material	Density (g/cc)	UTS (ksi)	Ductility %EL	Elastic Modulus
Kevlar Fiber (12 micron)	1.47	500	3%	102 ksi
Spectra Fiber	0.97	400	3%	24.9 ksi
Nylon Fiber	1.22	76	30	

Kevlar: Very high mp— 500C

This is showing off the polymer in its strongest possible form, a thin fiber. Uses: Armor, belts, hoses, reinforcing fiber in a composite.

How is Fiber Made?

- There are several processes, here is one: wet spinning. Polymer starts out in solution.