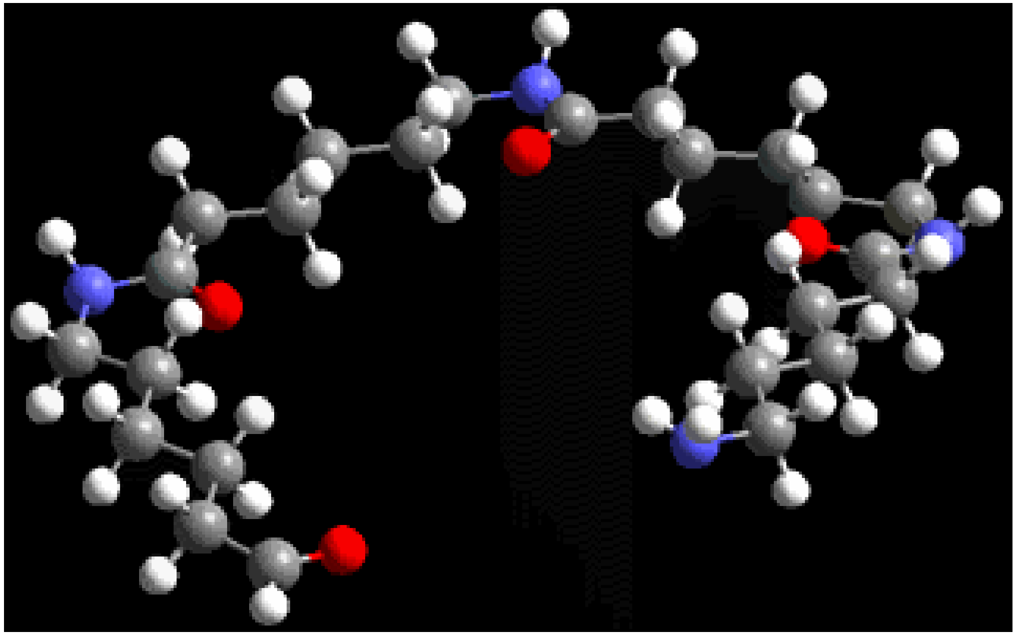
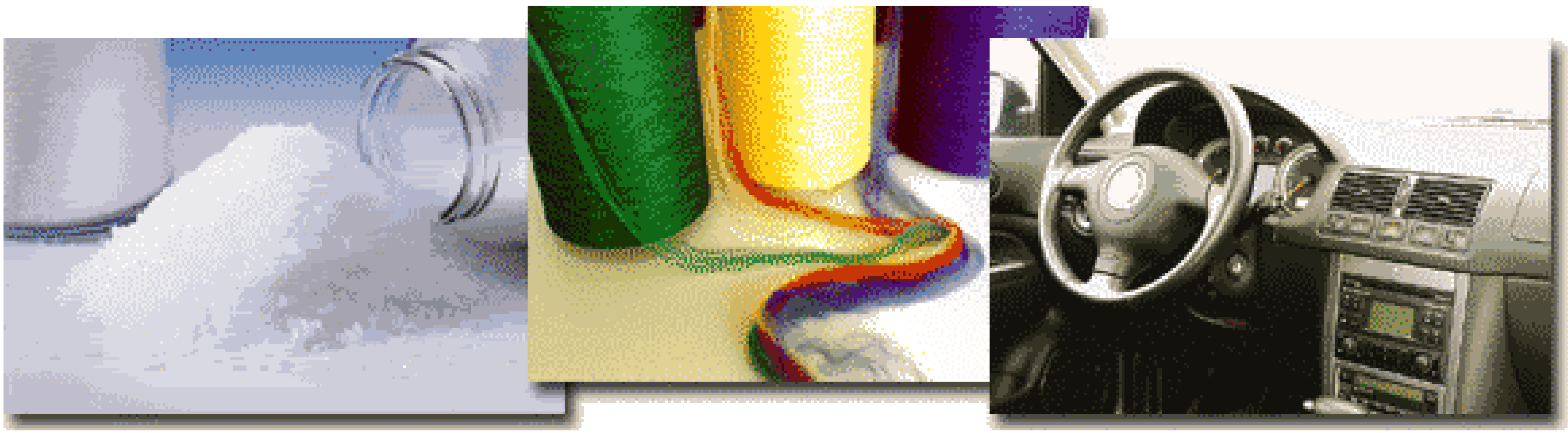
Mathematics and Science in Schools in Sub-Saharan Africa

Material Science

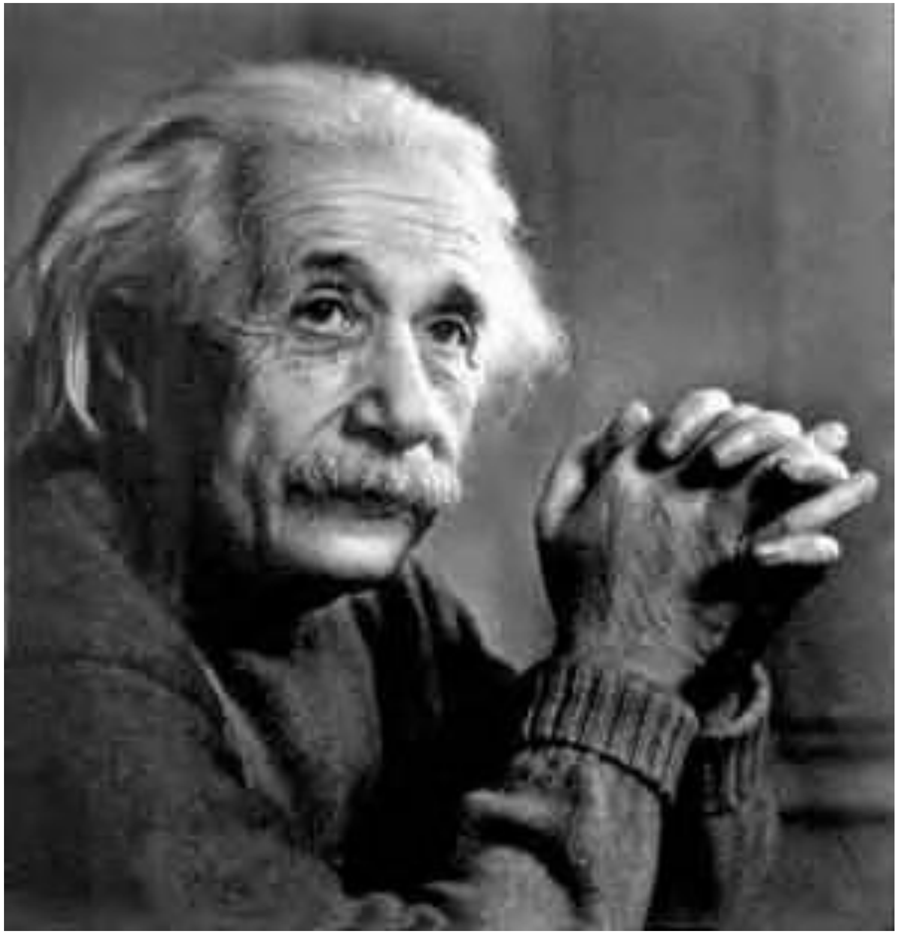


POLYMERS

Examples



Lab: Which Polymer is Which?



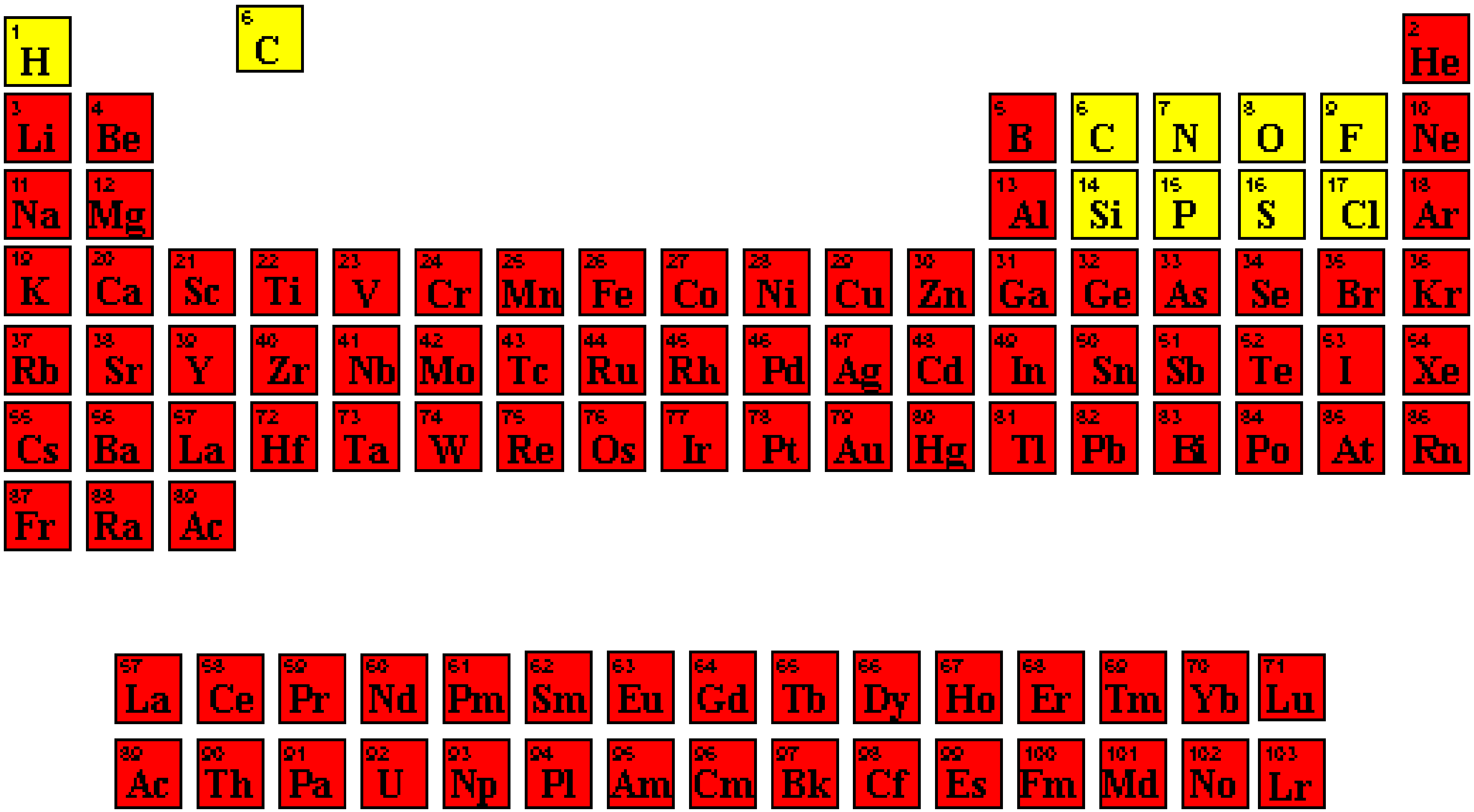
Lab: Which Polymer is Which?

Data Chart

Polymer (Before)	
Polymer (After)	

Poly & Mer

Elements Found in Polymers



Material Comparison

Material	Metals	Ceramics	Polymers
Elements	Metals		
Composition	Elements & Compounds		
Structure	Crystalline		
Bonding	Metallic		

Material Comparison

Material	Metals	Ceramics	Polymers
Elements	Metals	Metals & Nonmetals	
Composition	Elements & Compounds	Compounds or Mixture of Compounds	
Structure	Crystalline	Crystalline or Amorphous	
Bonding	Metallic	Ionic & Network Covalent	

Material Comparison

Material	Metals	Ceramics	Polymers
Elements	Metals	Metals & Nonmetals	Nonmetals
Composition	Elements & Compounds	Compounds or Mixture of Compounds	Mostly Compounds
Structure	Crystalline	Crystalline or Amorphous	Mostly Amorphous
Bonding	Metallic	Ionic & Network Covalent	Covalent with Weak Intermolecular

Natural Polymers

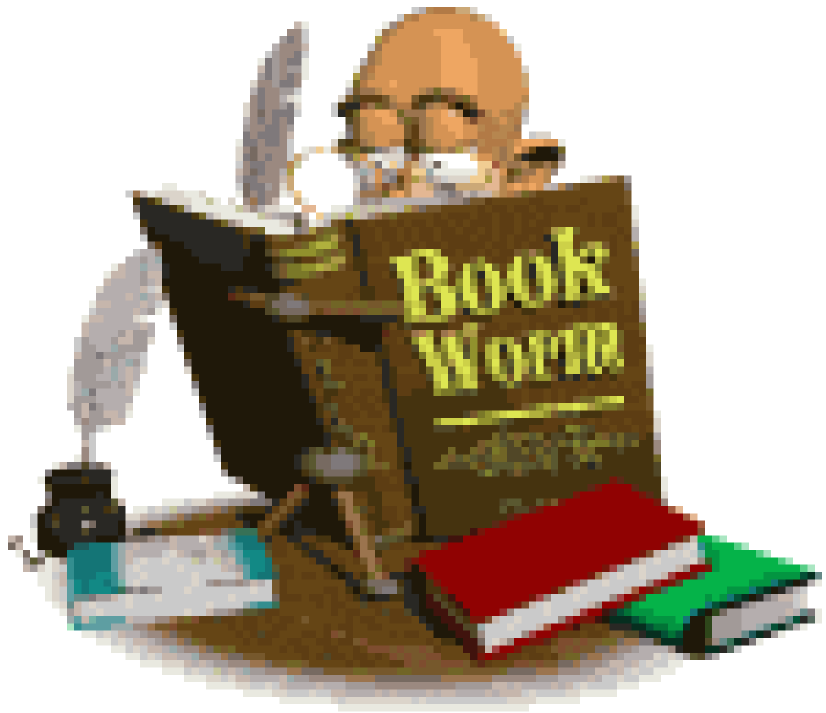
Natural Polymers

Artificial Polymers

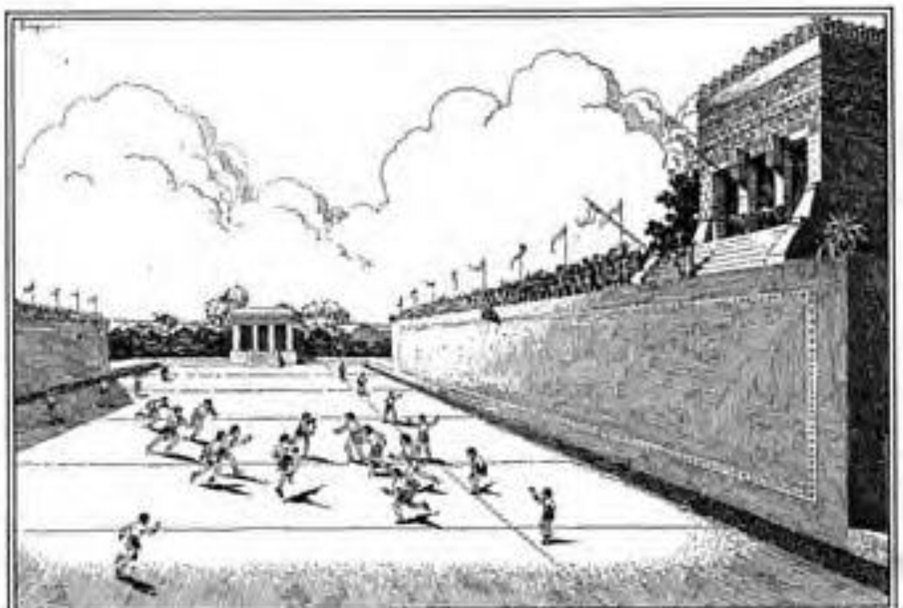
Rayon

200X

Polymer History



1570



50 RERVM MEDICARVM NO. HISP.

De MIZQVIXOCHICOPALLI. Copallifera IX. *Cap. IX.*

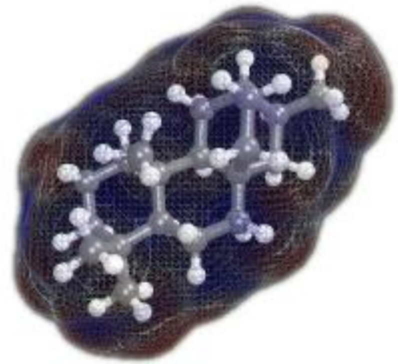
MIZQVIXOCHICOPALLIS quam alij *Xochicopal Quauhitl* vocant, arbor eſt magna, folijs Mali Medicæ, & ſtipite candicantibus punctis diſtincto. floribus vero coccineis & modicis. Gummi fundit è fuluo in purpureum vergens, *Anime* vocatum a quibuſdam, ab alijs vero *Copallis*. maximi habetur ad cætera quibus alia huius generis inſeruiunt præſtanda, ſed præcipue ad odoramenta, & capitis roborationem. naſcitur Copitlani, & Colymæ feruentibus locis

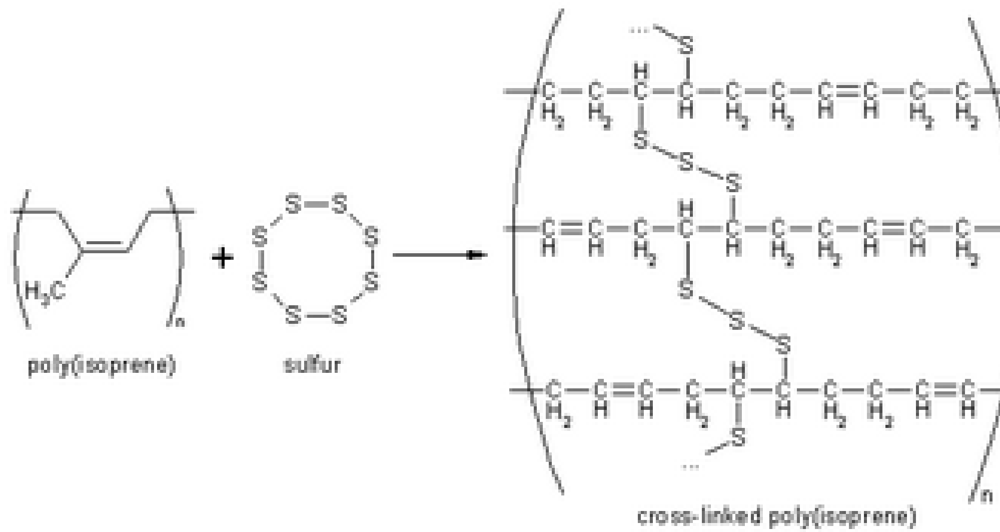
De HOLQVAHVITL, ſeu Arbore CHILLI. Cap. X.

ARBOR eſt *Holquahuitl* cuius duo ſunt genera. Alterum ſtipitem profert magnum, leuem, fuluum, & lenta refertũ medulla, floresq. candicantes, folia maxima, & orbiculos ſtellatos, rubeſcentes ex pallido, adhæreſcentes ſtipiti, & refertos fructu, Ponticis Nucibus pari, candenti luteaq. obducto membrana, & amari ſaporis. Alterum vero folia Mali Medicæ, ſed tamen maiora, vtriuſque arboris cortex amarus eſt. Naſcitur genus vltimum apud Michuacanenſes, vbi *Tarantaquam* vocare conſueuerunt. Primum verò *Mecatlani*, & *Thualapa*. Cortex calidus eſt ordine tertio, & pauliſper lubricus. cuius decoctio ius infuſum medetur dyſenterijs. Fundunt ſectæ gummi, ab Indis *Holli* vocatum, primo lacteum, mox luteum, ac tandem nigrum, poſtquam ſcilicet colligentiũ corporibus illitum ſit. Adeoque vndecunque reſiliens, vt pilæ palmariæ, aut eius, quæ a vento nomen habet, apud vulgus in ſphæricam aptatum figuram præſtet vices, & ad multa præterea vtile eſt. Nam

1839

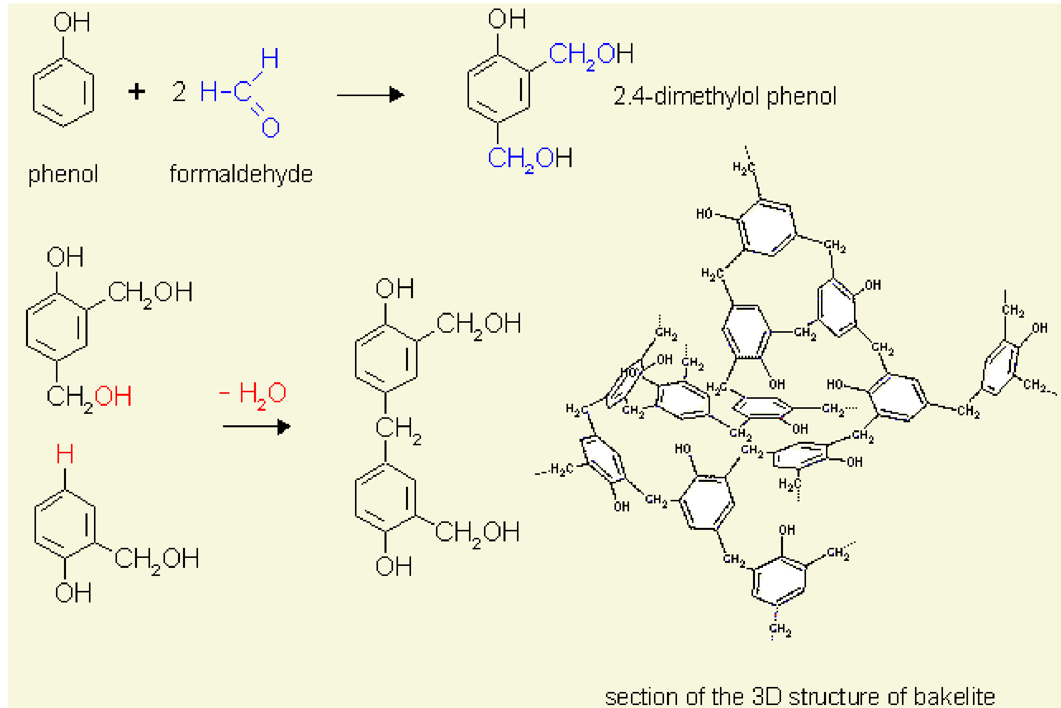
Charles Goodyear





1907

Dr. Leo Baekeland



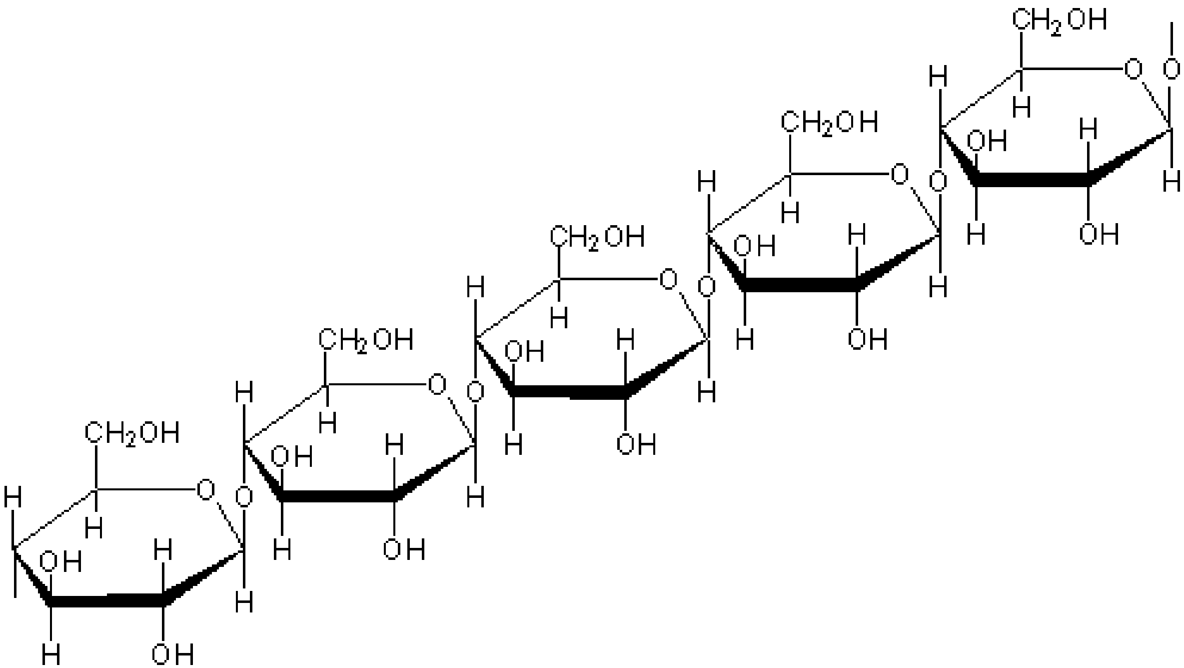
Bakelite- the first synthetic plastic.

Bakelite

Radios, telephones and electrical insulators were made of Bakelite in the past due to its insulating and heat-resistant properties.

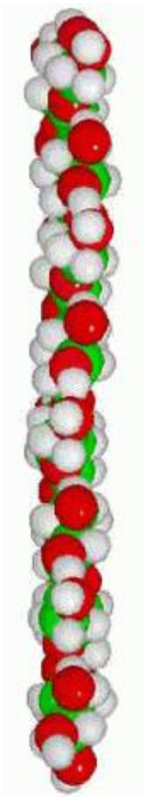
1917

M.Polanyi

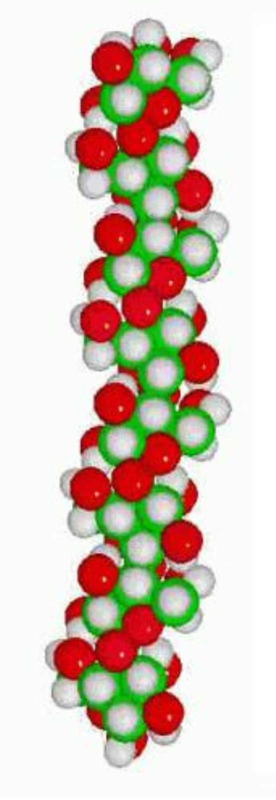


Used X-ray crystallography to discover the chemical structure of cellulose-a long chain molecule.

1920

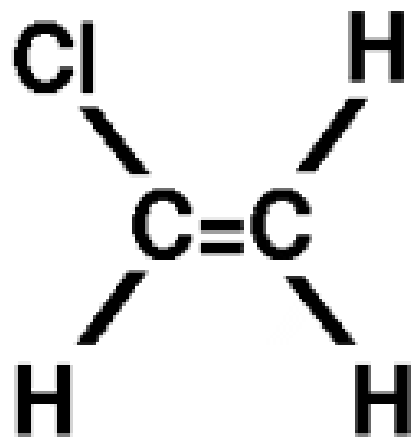


Hermann Staudinger



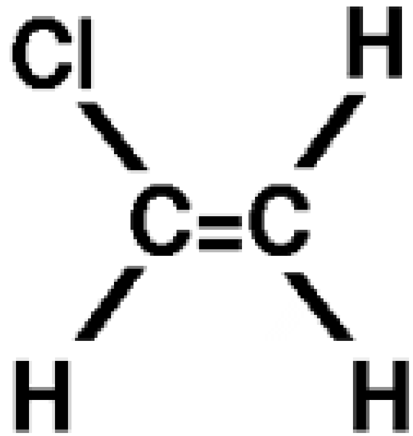
Staudinger's classic paper "Uber Polymerization" presented the world the development of the modern polymer theory.

1927

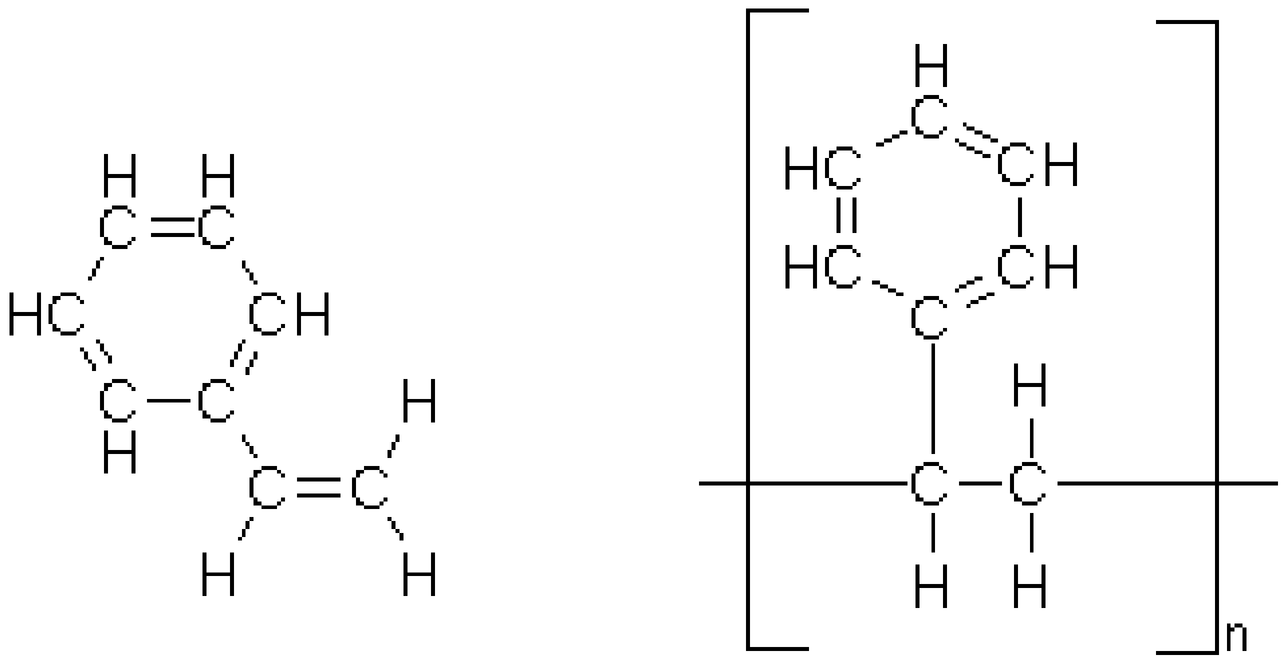


Large scale production of polyvinyl-chloride (PVC) resins begins.

PVC



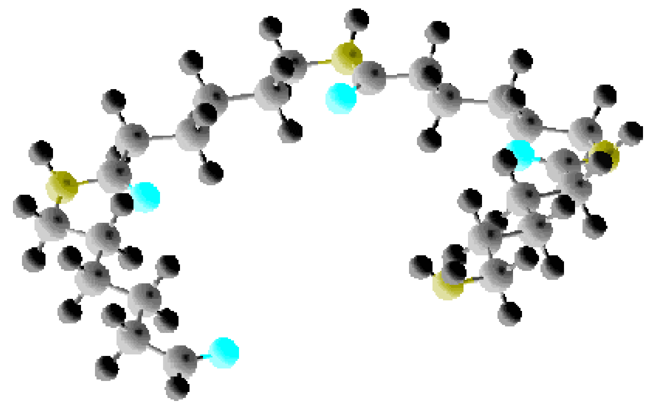
1930

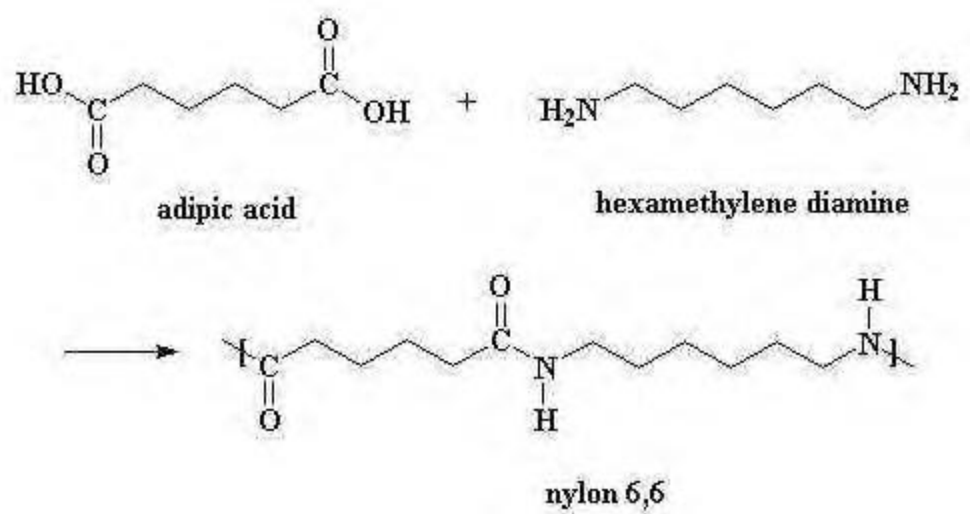


Polystryrene is invented.

Styrofoam

1938

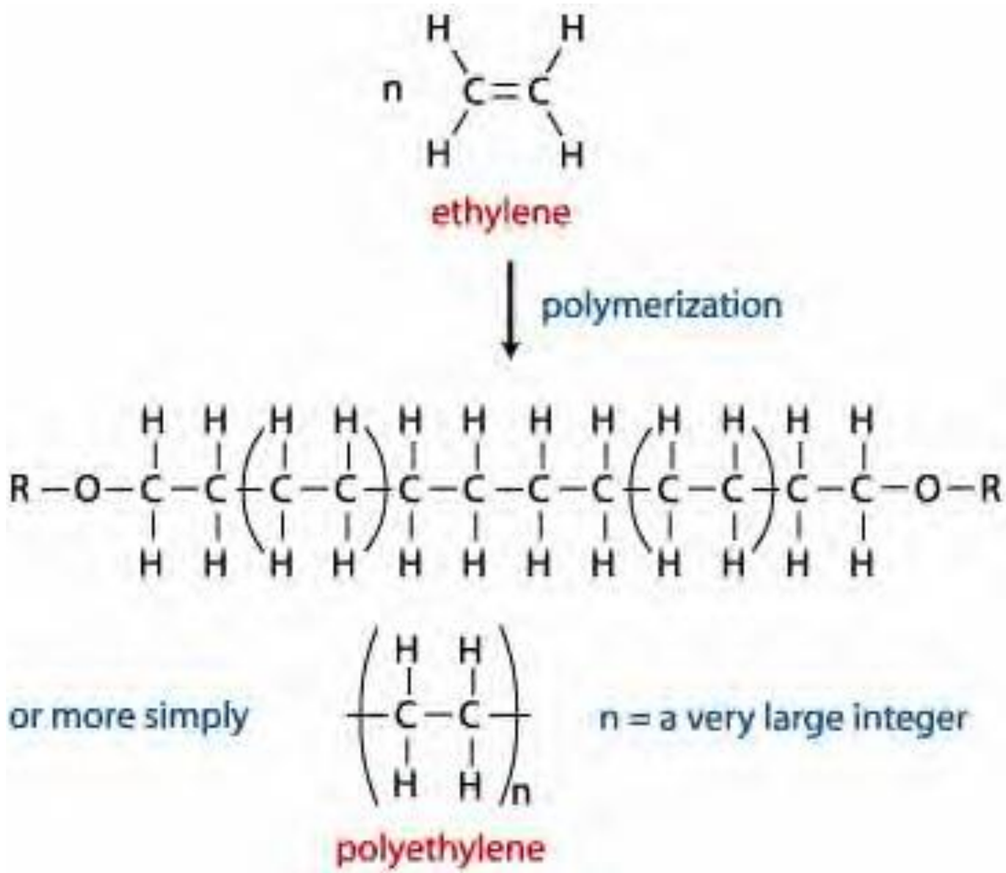




Wallace Carothers of Dupont company produces nylon.

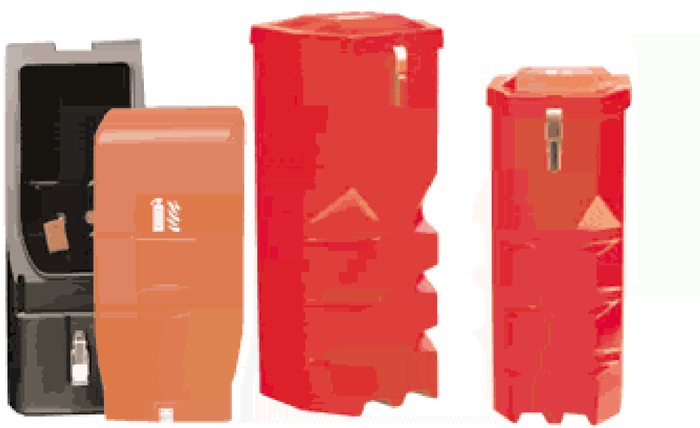
Nylon

1941

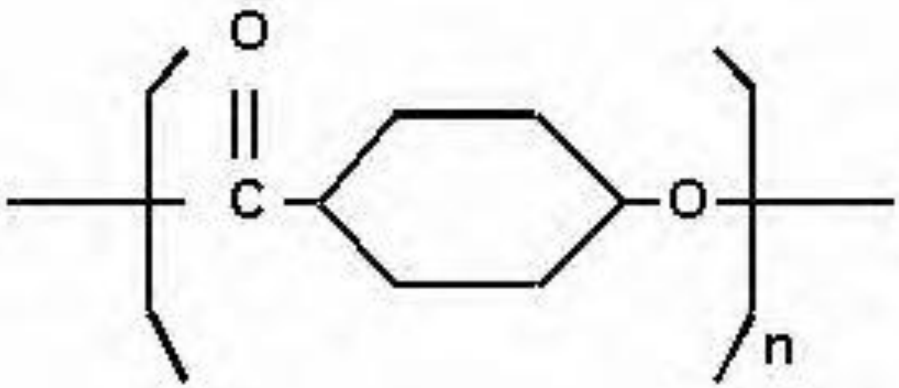


Polyethylene is produced.

Polyethylene

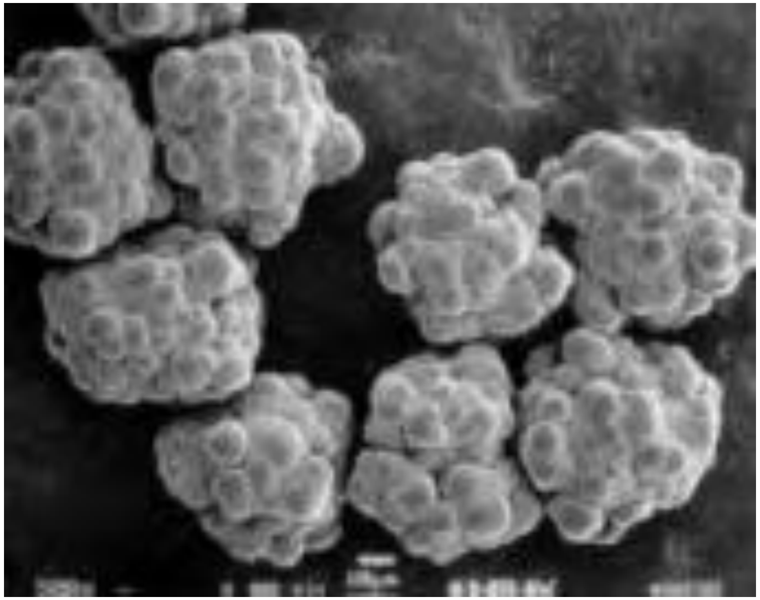


1970



***James Economy develops Ekonol*.**

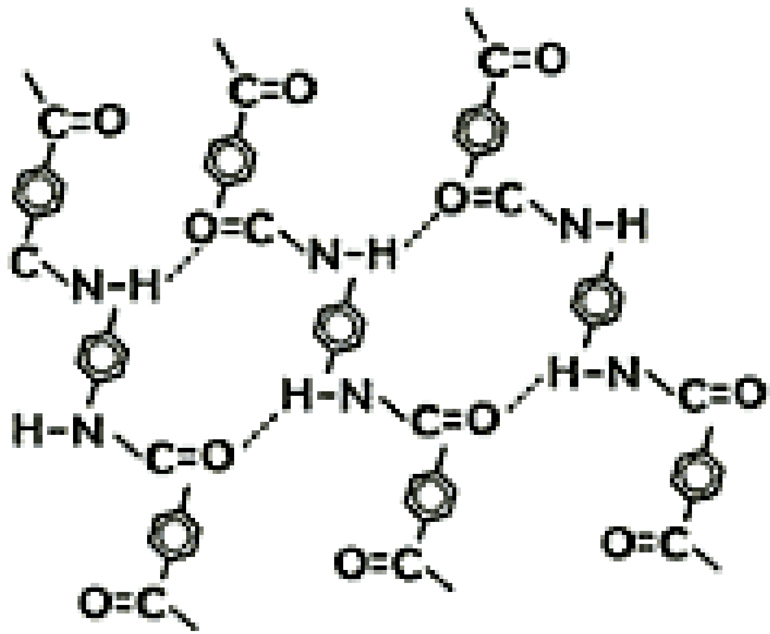
Ekonal



A moldable polymer that has no observable melting point!

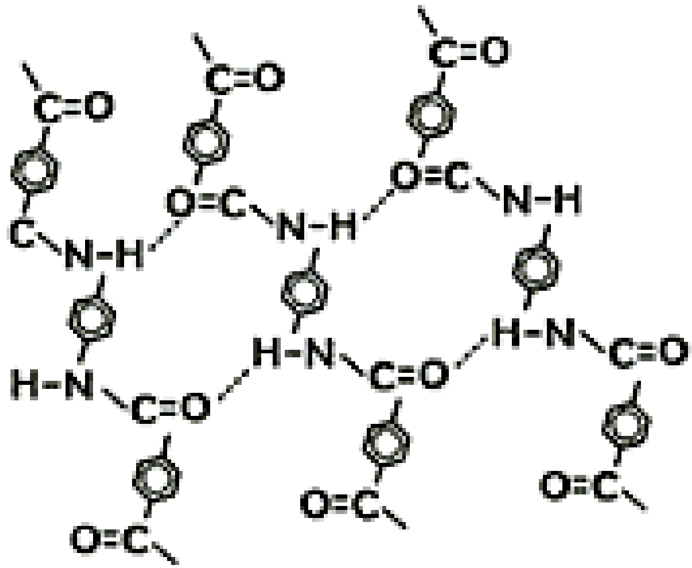
Leads to the development of liquid crystal polymers 1 year later.

1971



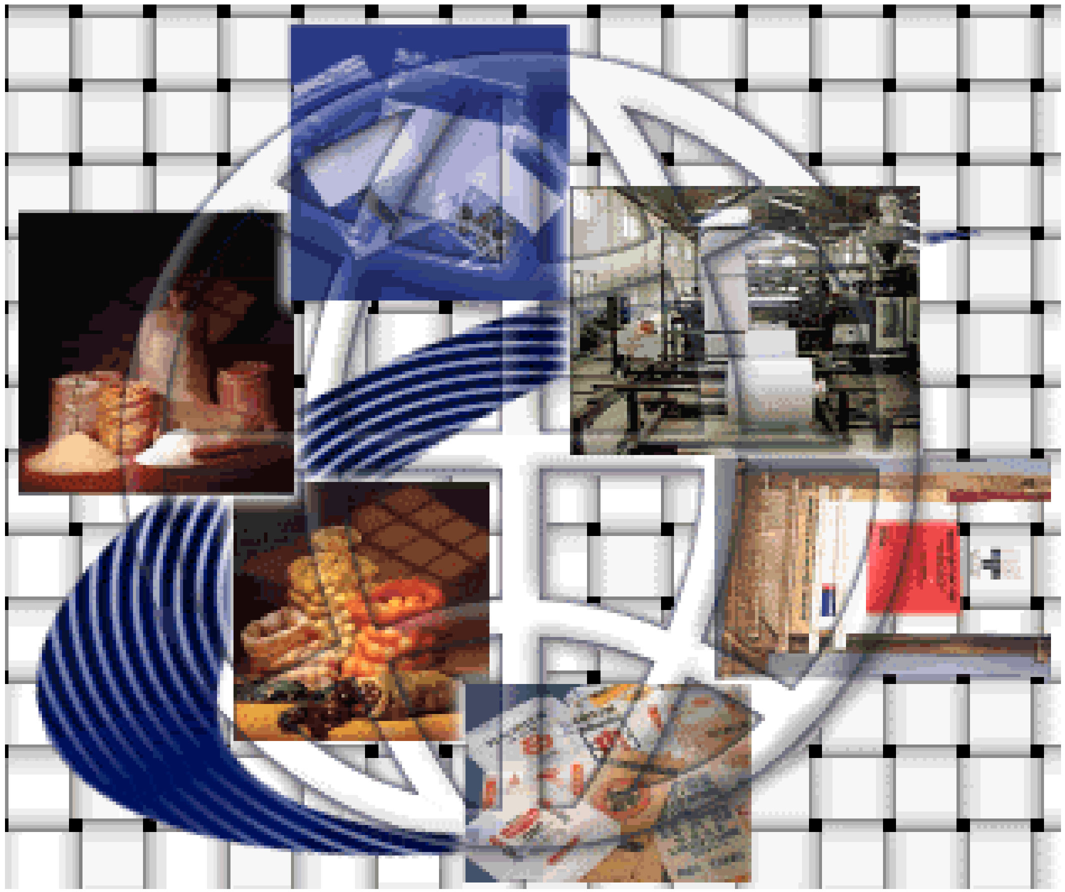
Aramid

Aramid



Kevlar

1976



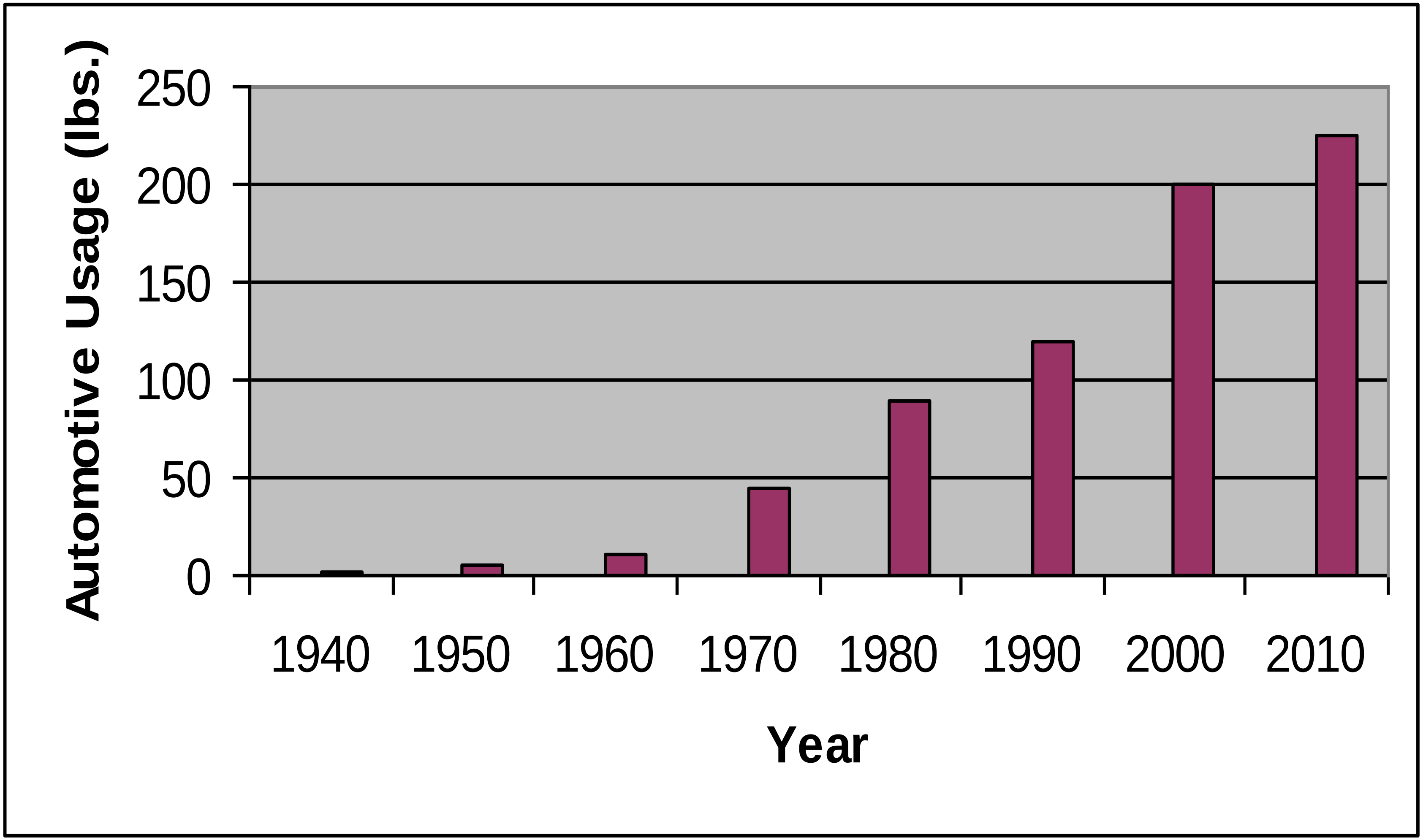
Polymer/plastic industry passes steel as the nation's most widely used material.

Plastics!

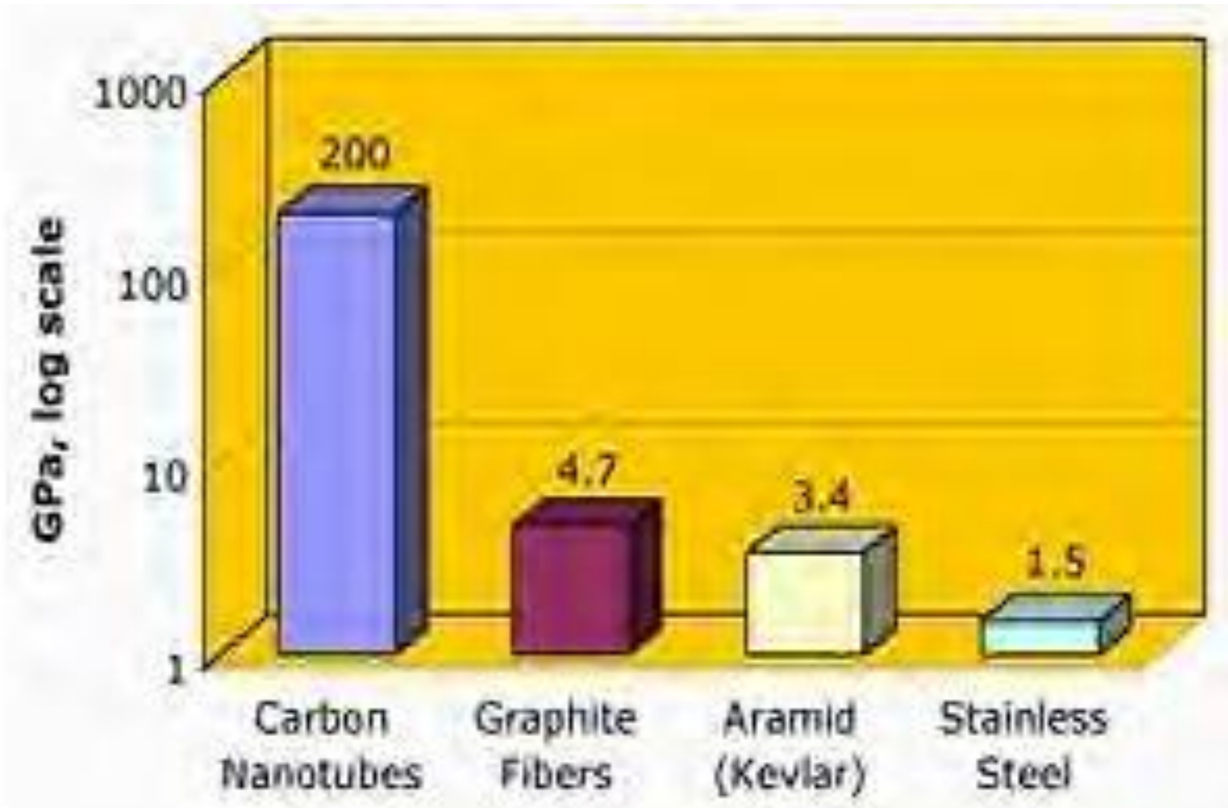
Now we use more plastic than steel, aluminum and copper combined!

Carbon-Fiber

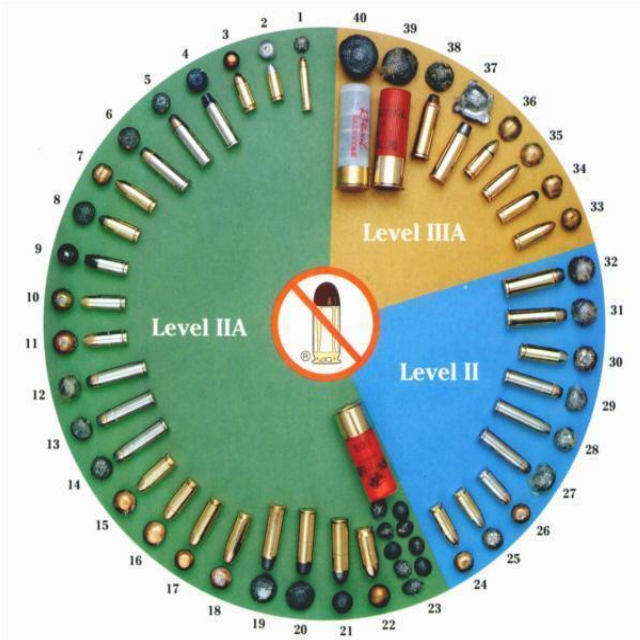
Plastics Usage in Cars



Strongest Material?

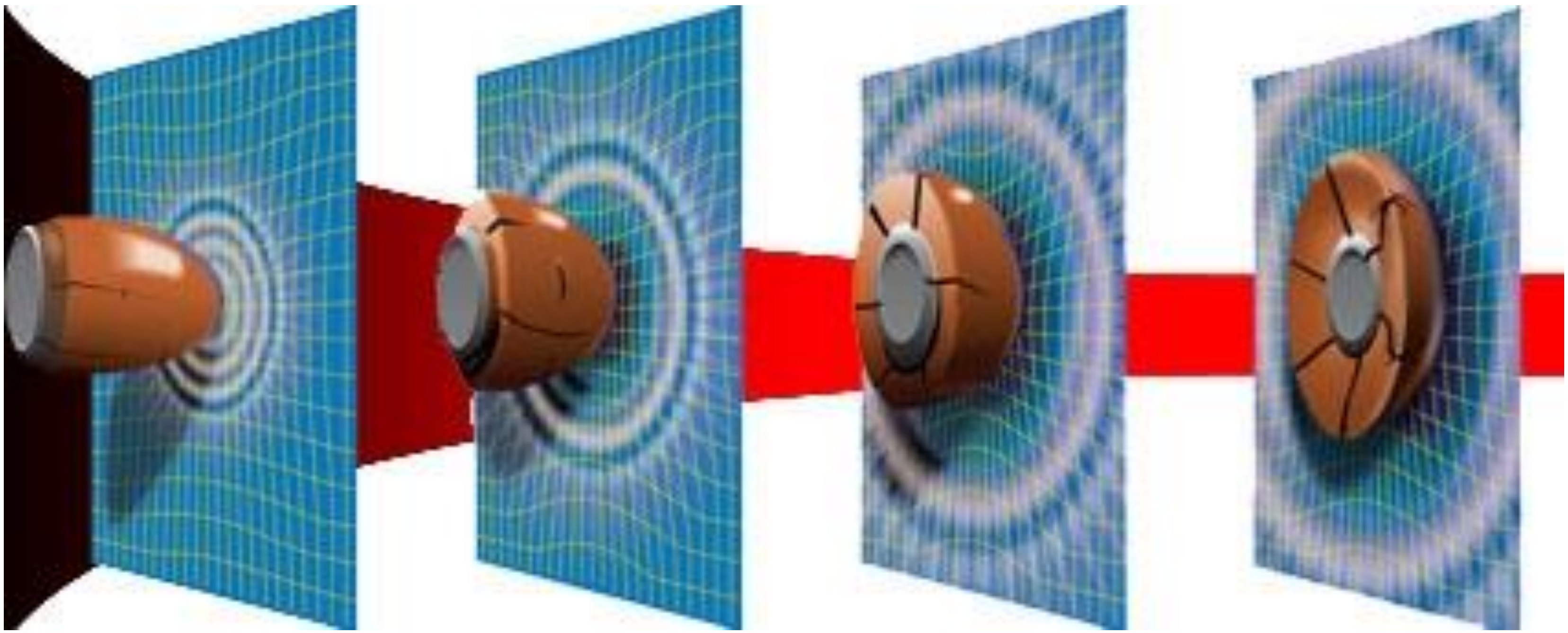


Carbon Nanotube Application



Anti-Ballistic Materials

Bullet-proof jackets stop bullets from penetrating by spreading the bullet's force.



Targets can still be left suffering blunt force trauma, perhaps severe bruising or, worse, damage to critical organs.

Scientists use the elasticity of carbon nanotubes to not only stop bullets from penetrating but to actually rebound their force.

2008

A polymer that transforms into a fireproof ceramic.

HIPS Coating

H*ybrid*

I*norganic*

P*olymer*

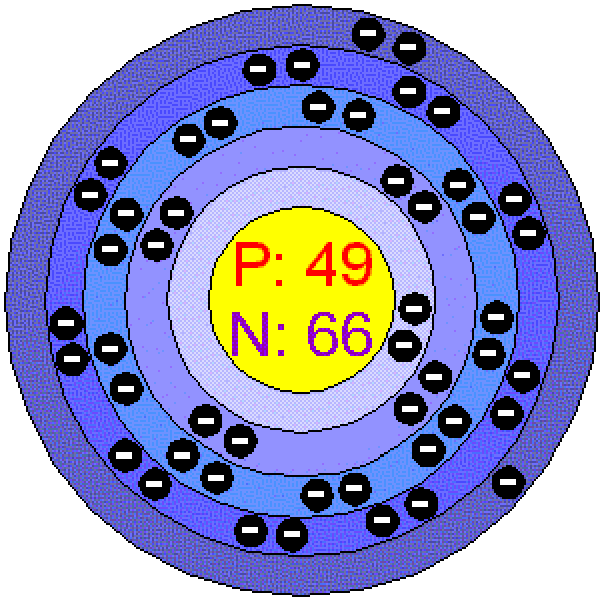
S*ystem*

Withstand temperatures over 1000ºC!

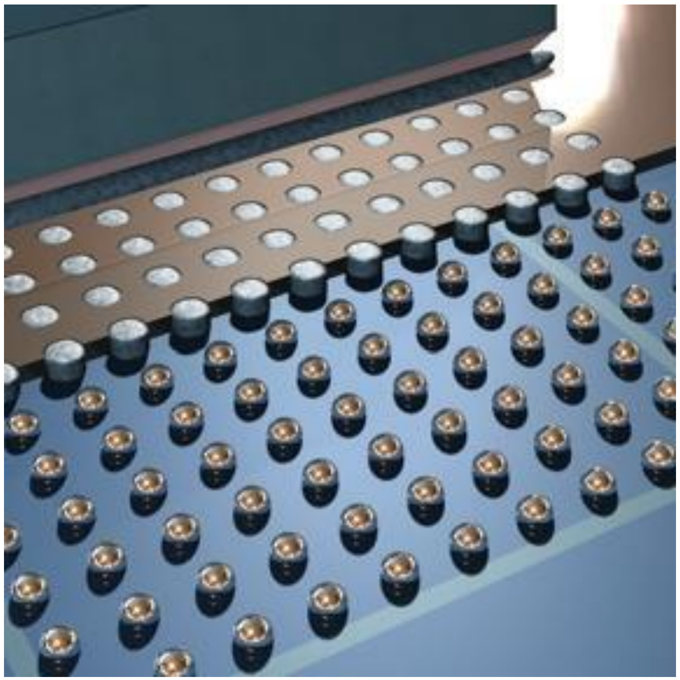
Lithium-ion Battery Fires

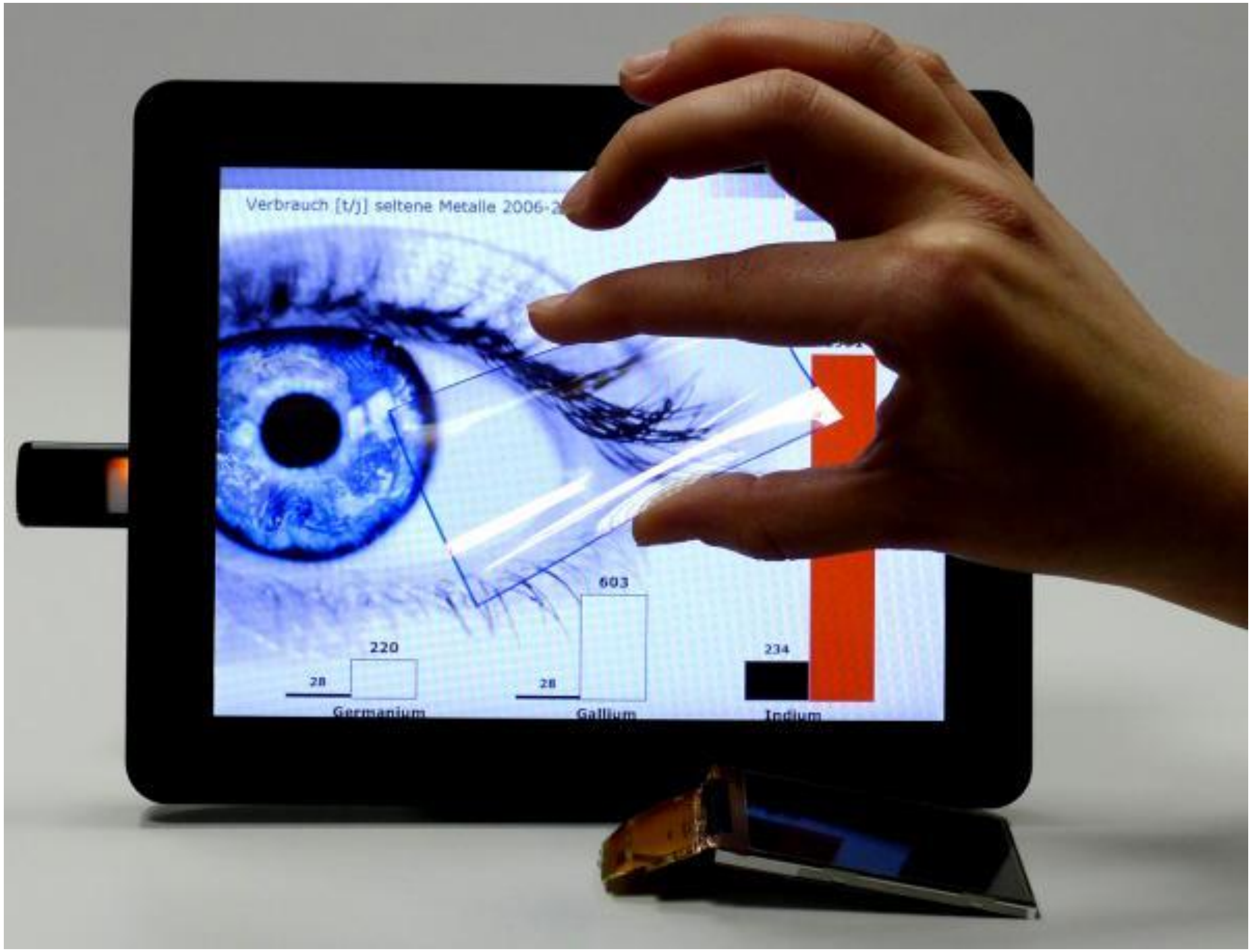
2011

Touchscreens


P: 49
N: 66

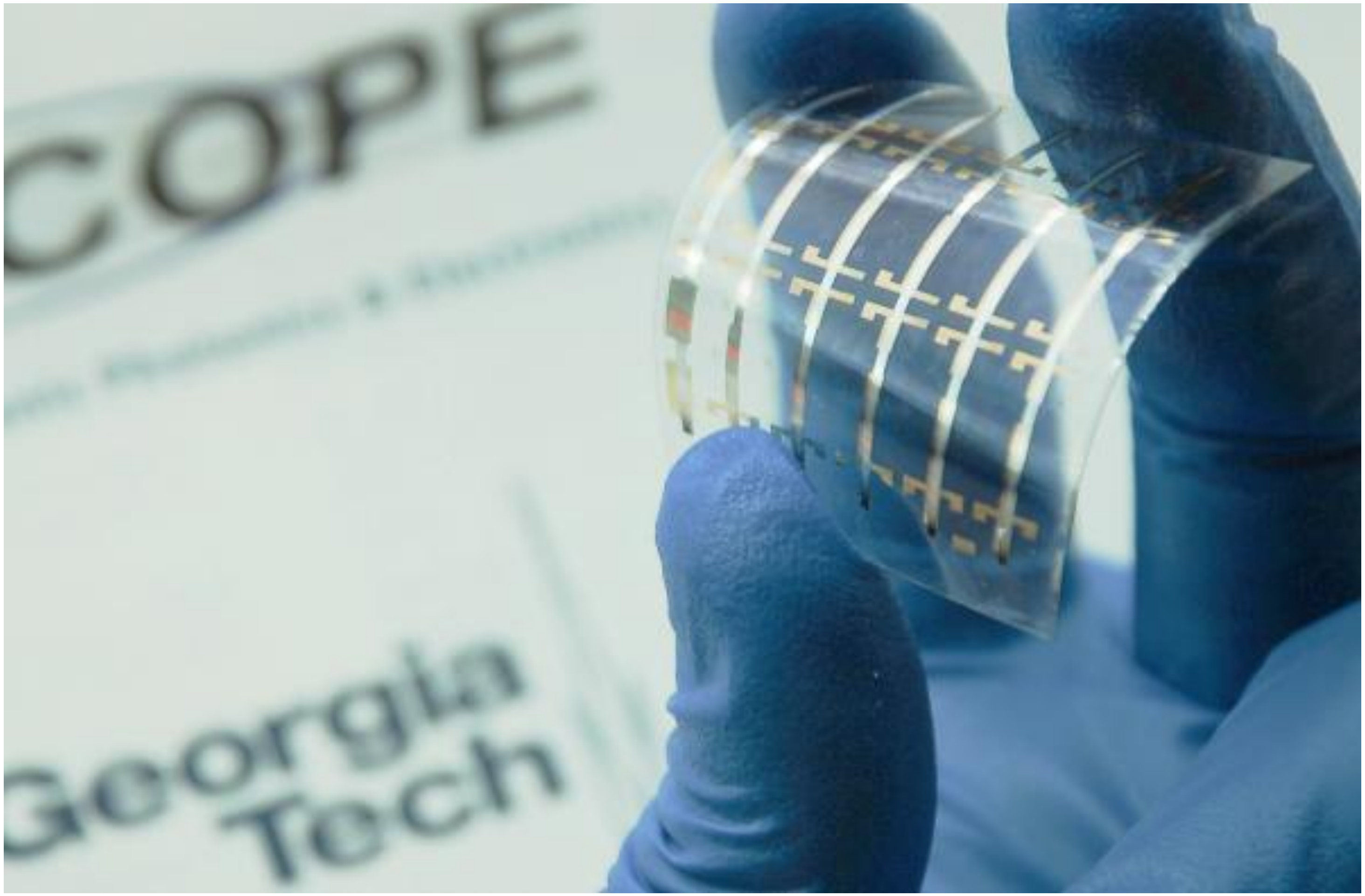

INDIUM
99.99 %





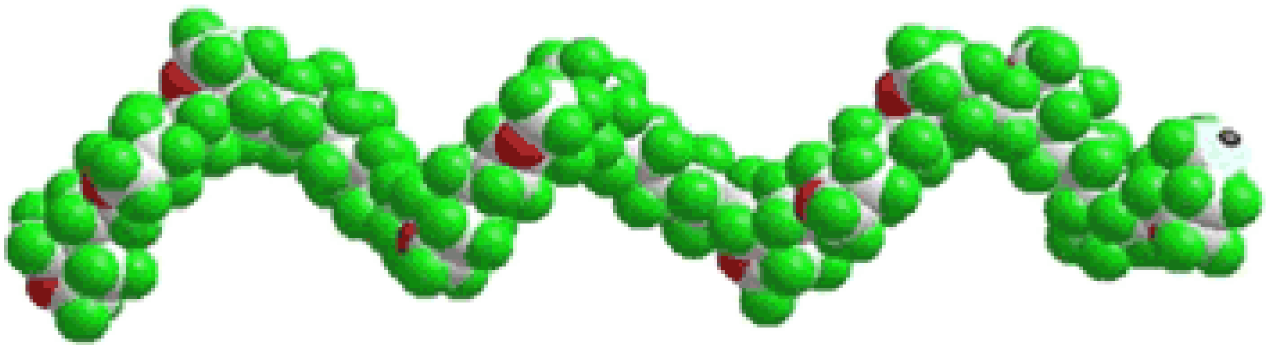
Touchscreens that contain carbon nanotubes can be made of low-priced renewable raw materials.

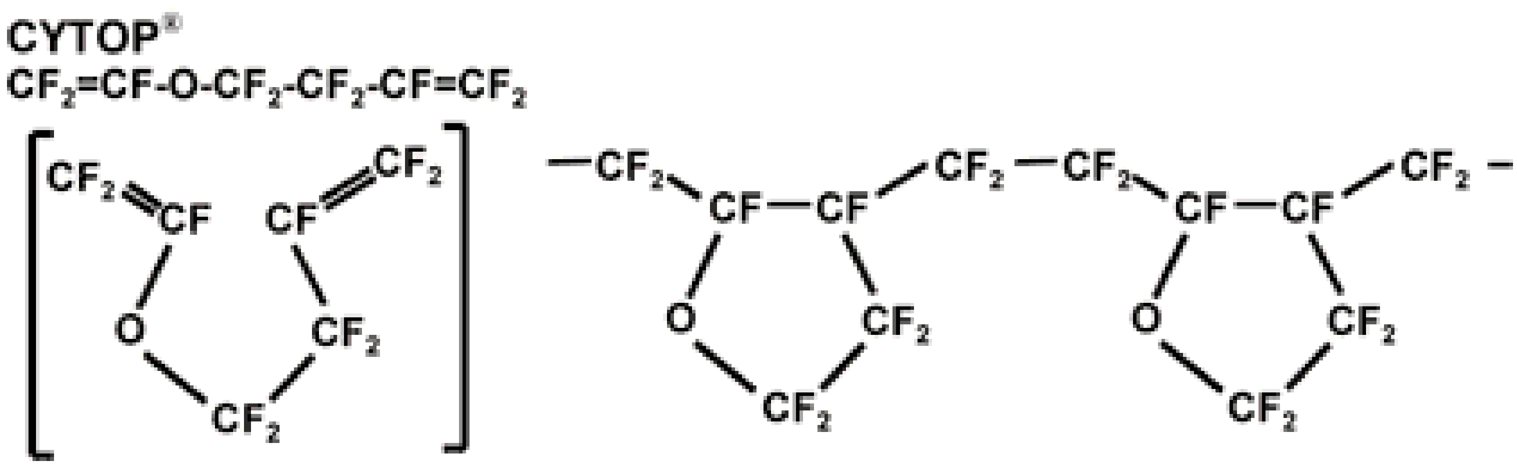
2011



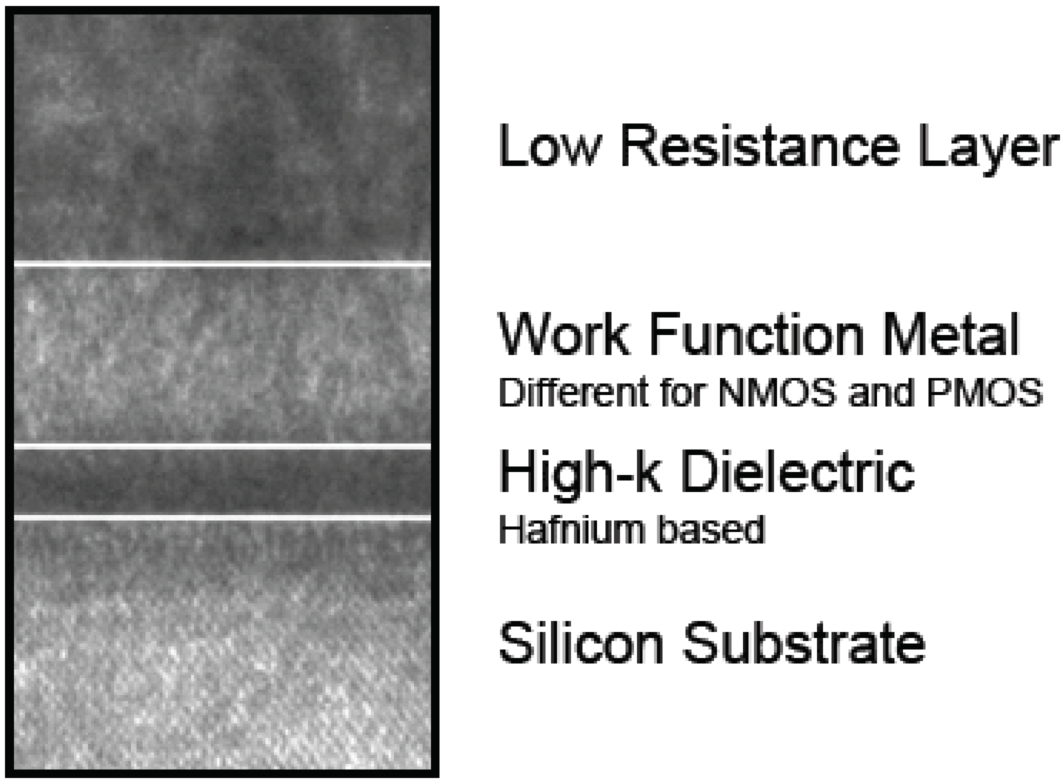
Flexible plastic electronics!

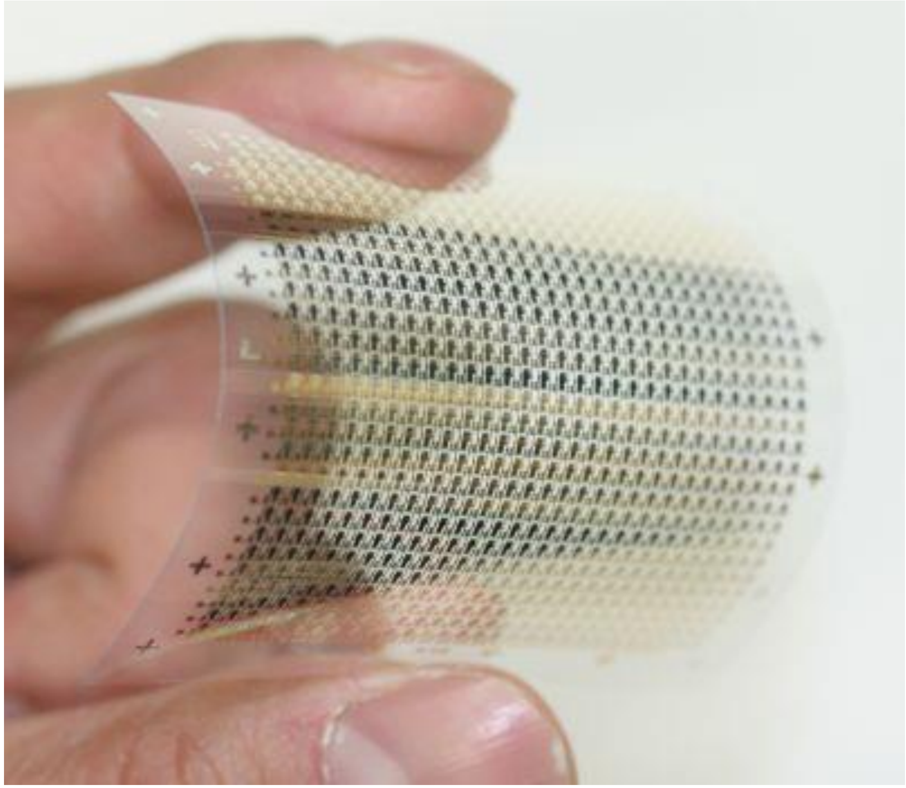
The bilayer dielectric is made of a fluorinated polymer known as CYTOP.





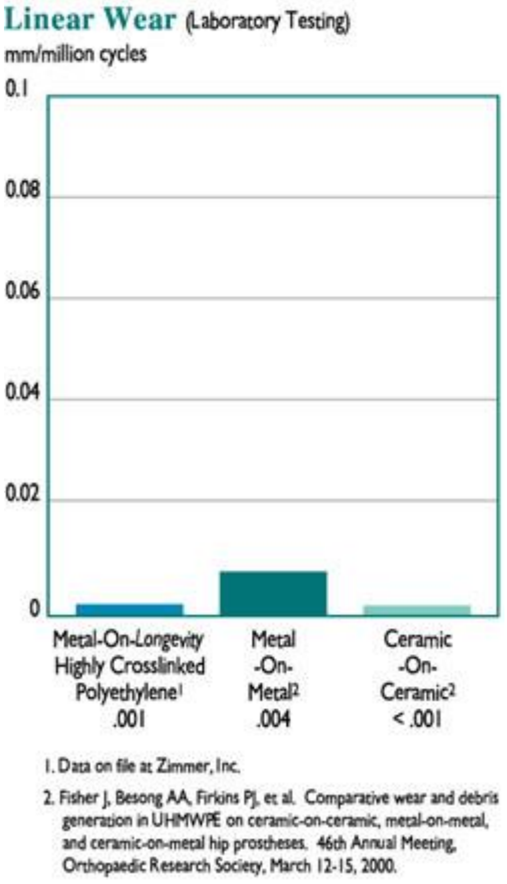
The bilayer dielectric is also made with a High-k metal oxide layer.

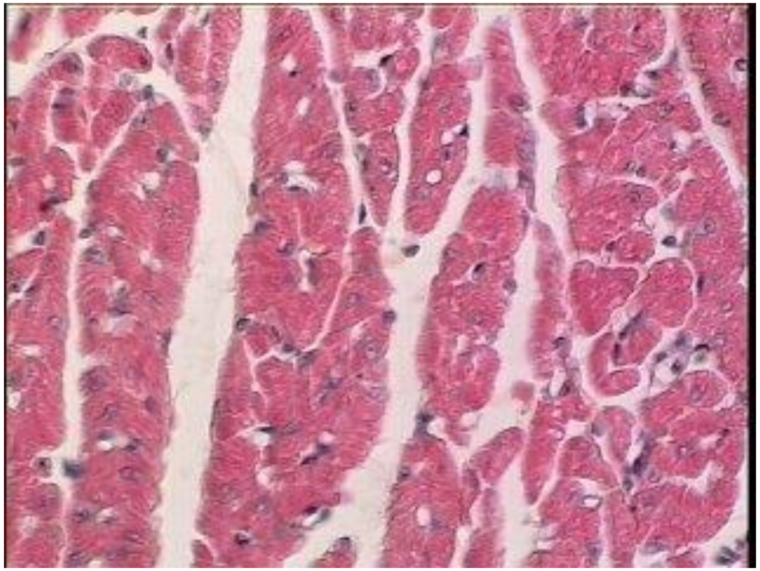


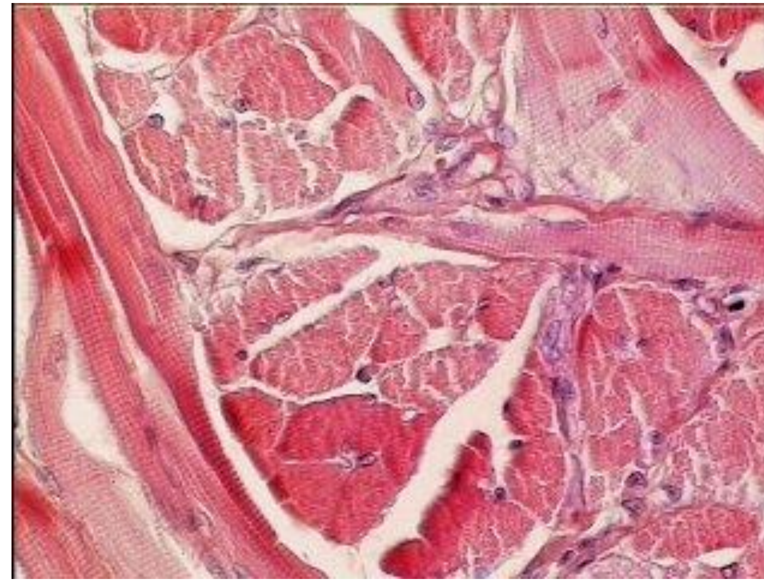


Alone, each substance has its drawbacks but together, each substance retains its benefits and their drawbacks are cancelled out!

Medical Applications





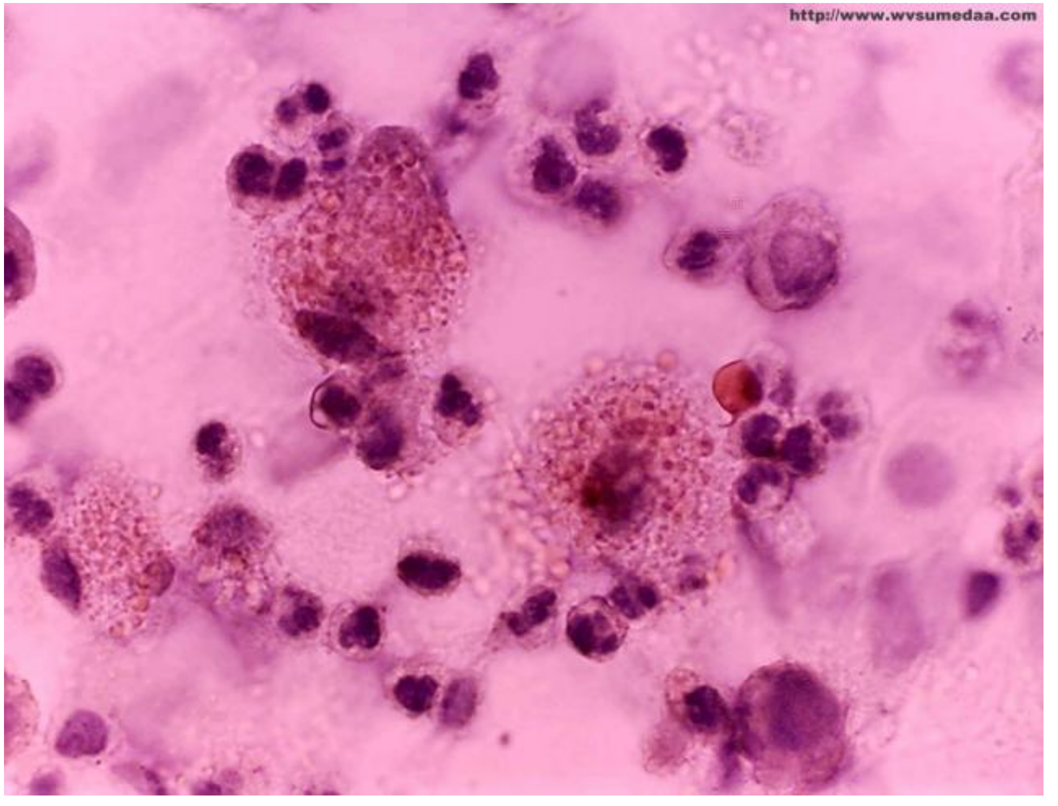



smooth muscles
cut in cross-section
connective tissue
components
fascicle

The NanoTech Institute recently announced the development of artificial muscle tissue that is 100 times stronger than natural human muscles.

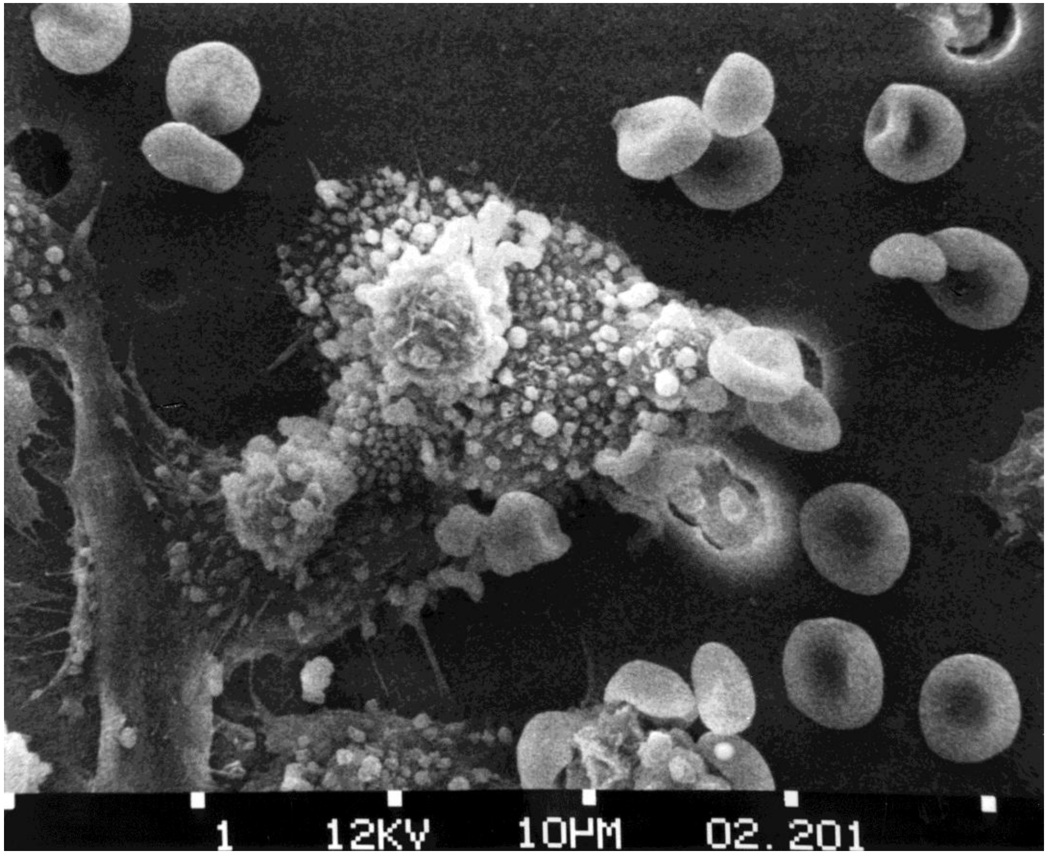
Applications: artificial limbs and perhaps even artificial heart tissue.

Cancer Cells



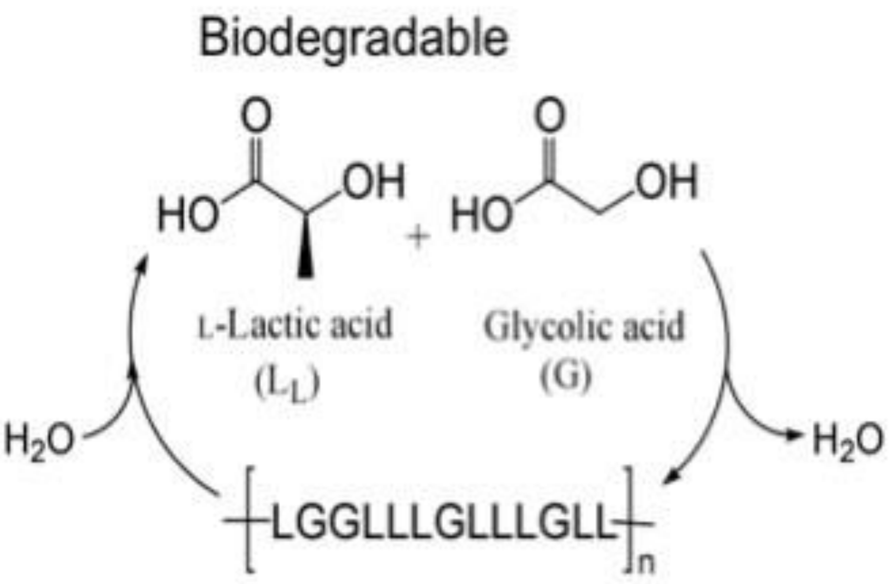
One of cancer's cleverest tricks is its ability to hide from the immune system.

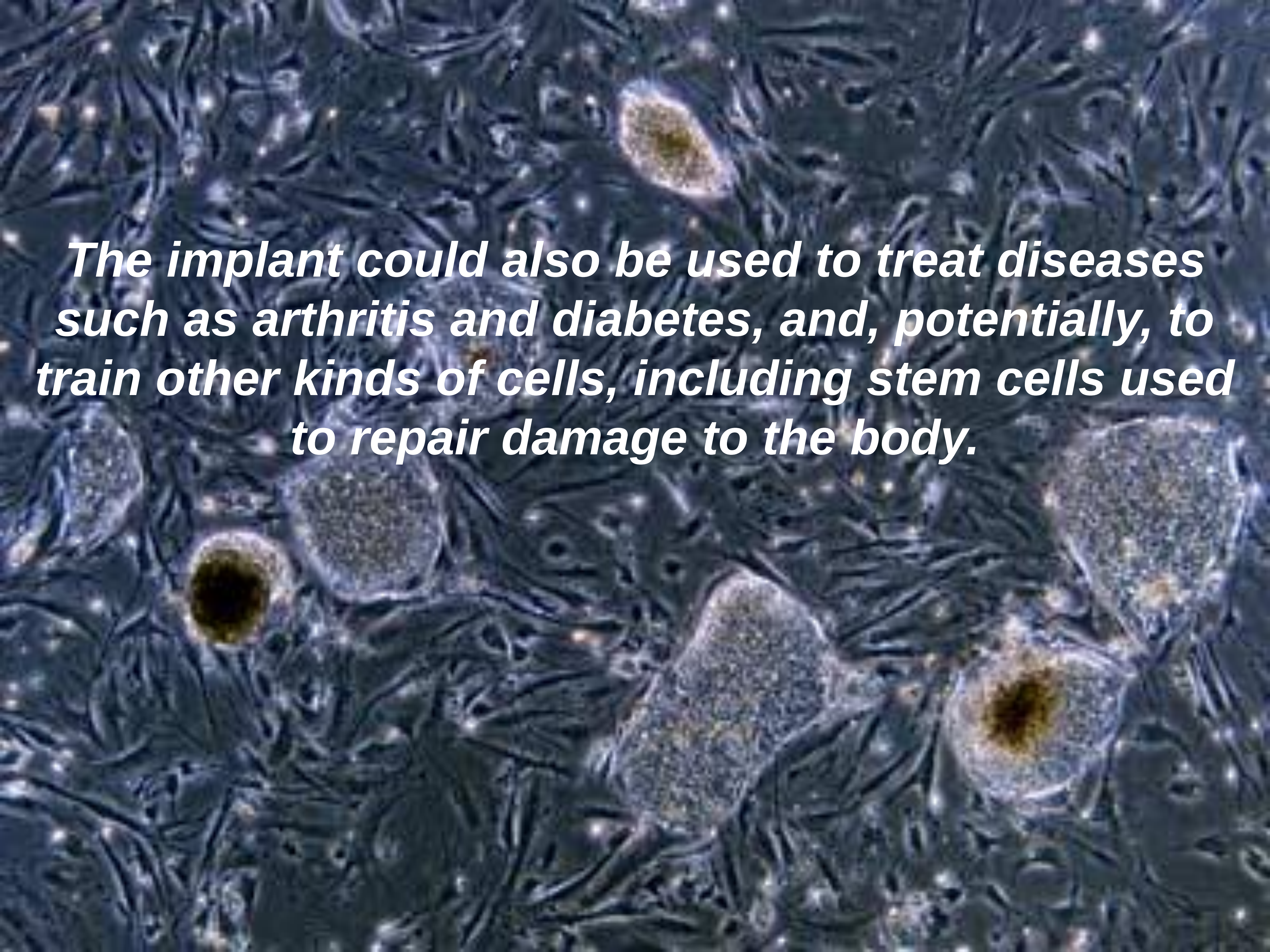
Polymer Nano-Trainer



Researchers have developed a polymer implant attracts and trains immune-system cells to go after cancer.

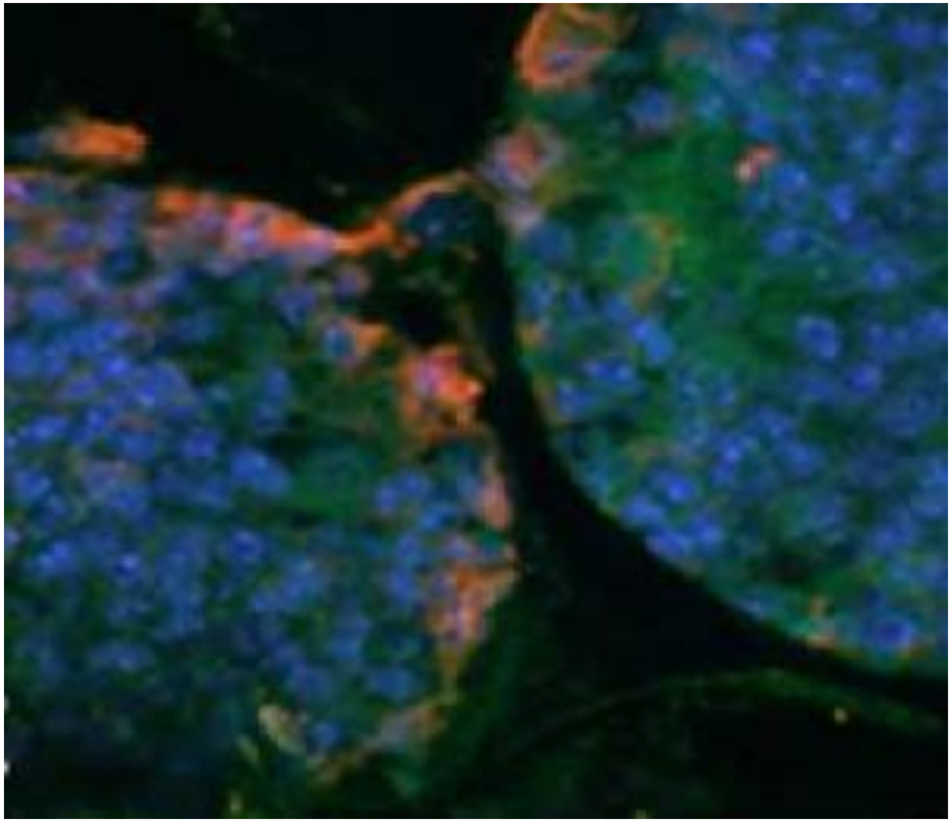
The macroporous poly-lactide-co-glycolide (PLG) polymeric matrix used in the study has a history of safe use in humans.



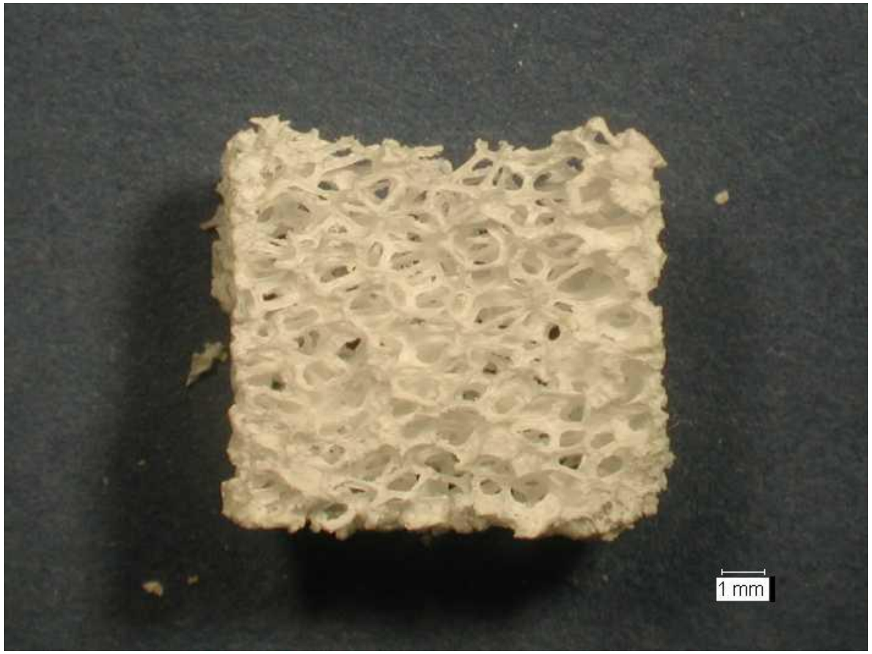


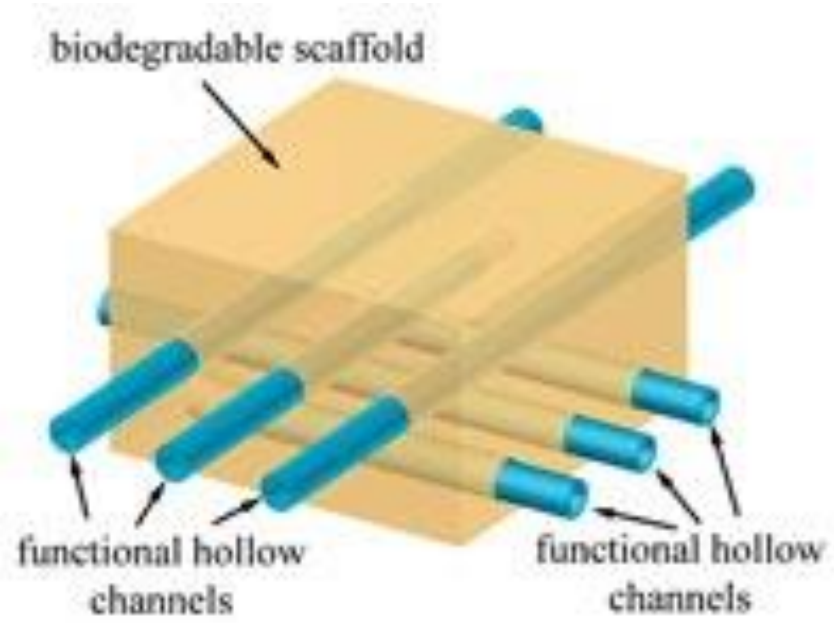
The implant could also be used to treat diseases such as arthritis and diabetes, and, potentially, to train other kinds of cells, including stem cells used to repair damage to the body.

Artificial Bone Marrow

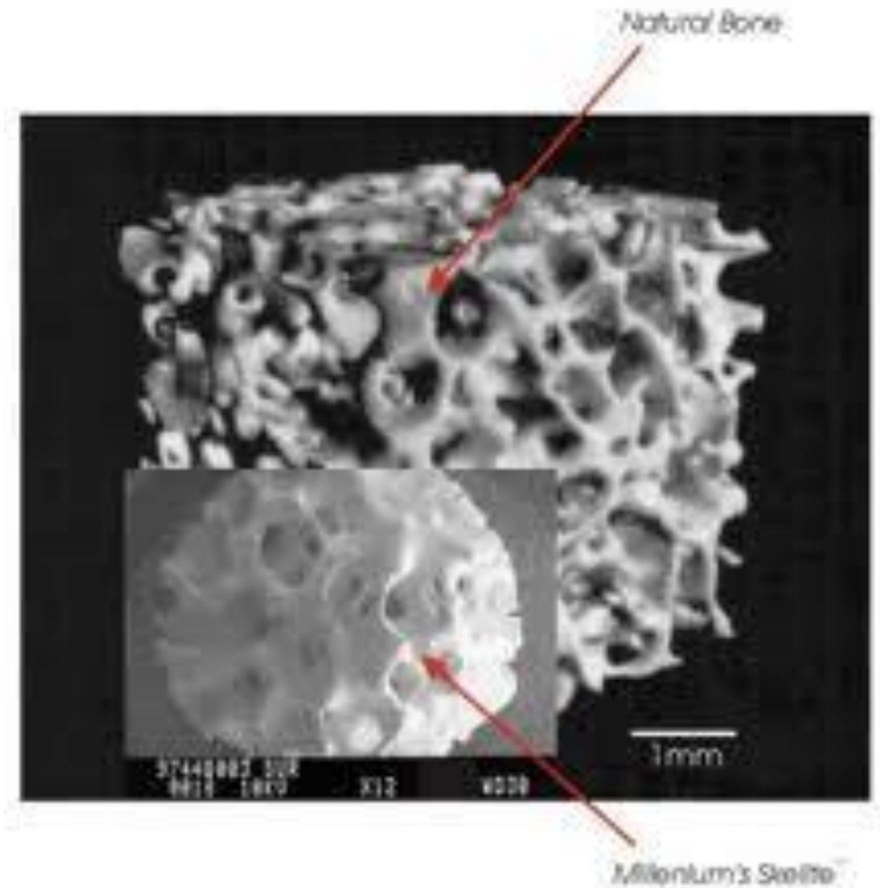


Artificial bone marrow that can continuously make red and white blood cells has been created in a University of Michigan lab.

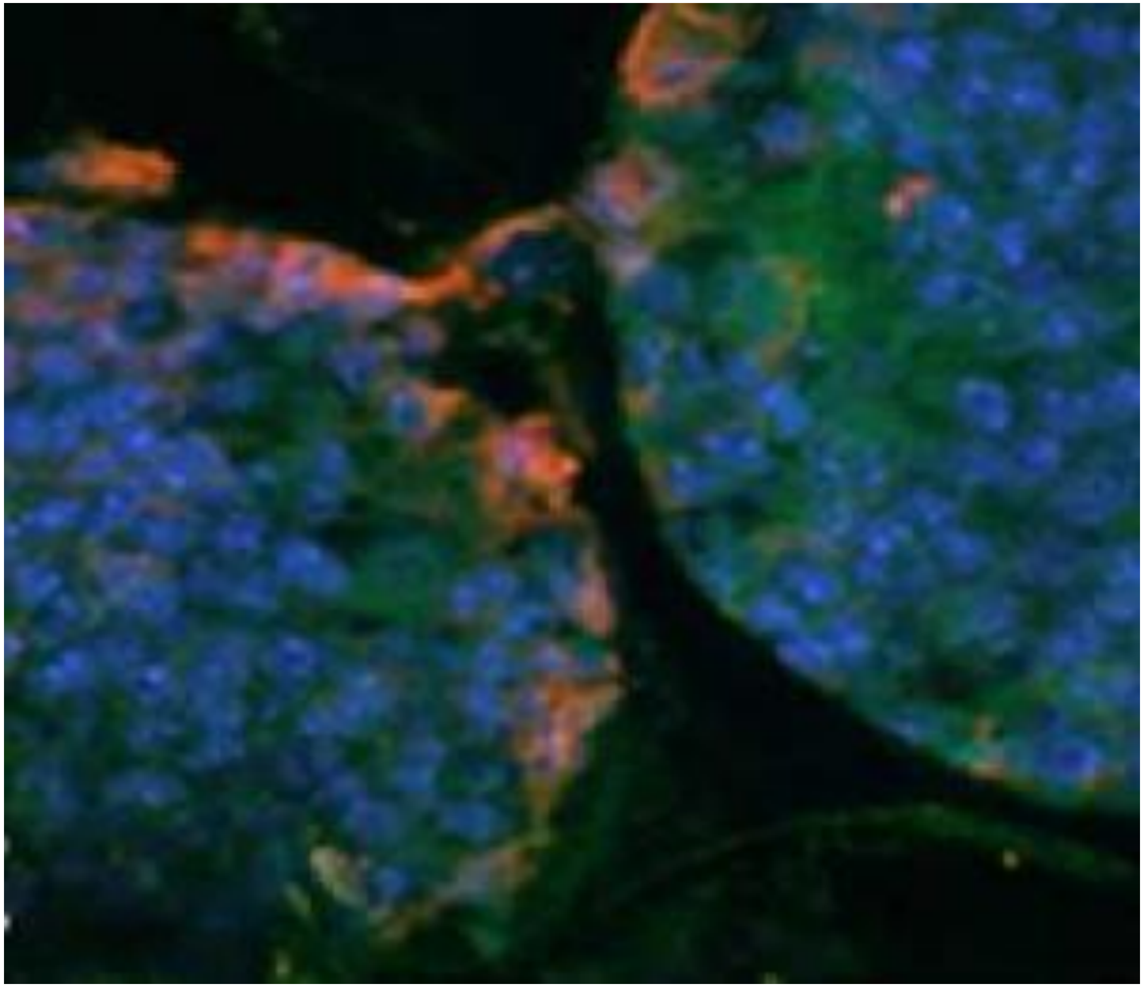




First, scientists create biodegradable scaffolds.



The scaffolds are then seeded with artificial bone marrow cells and osteoblasts, another type of bone marrow cell.



It is designed to function in a test tube.

Antifreeze Protein

A new protein discovered in tiny snow fleas by Queen's University researchers may lengthen the shelf life of human organs for transplantation.

Construction Applications

Construction

Conventional means of internal reinforcement for concrete member in buildings involve steel bars (Rebar).

Fiber Reinforced Polymer (FPR)

Liquid Wood

Liquid Wood

Most plastics are based on petroleum.

Liquid Wood

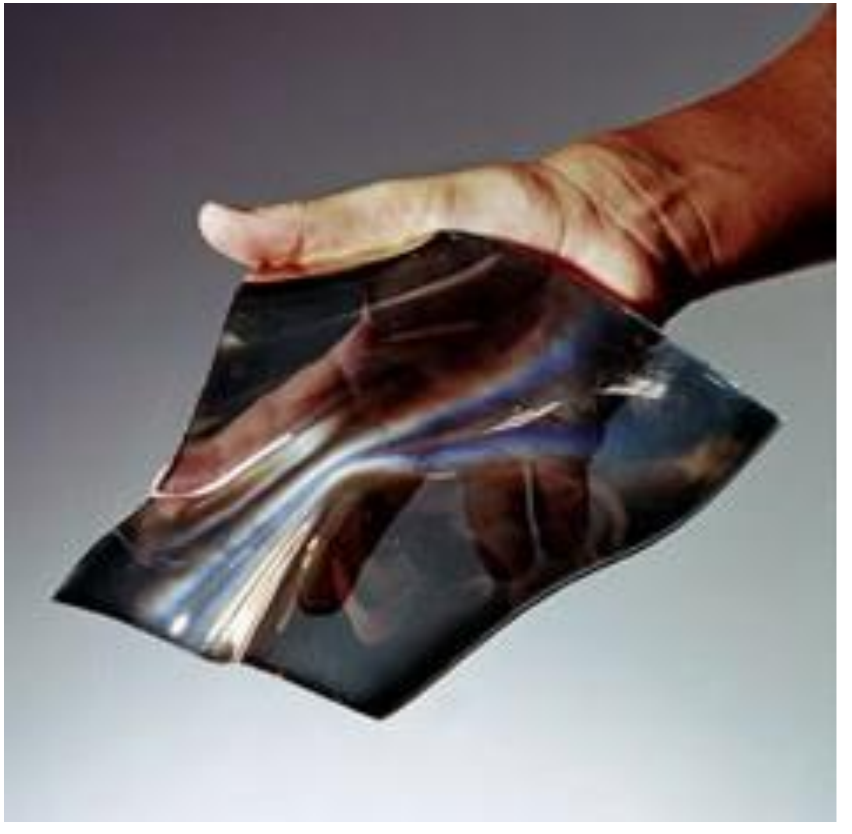
Wood

Wax

Hemp

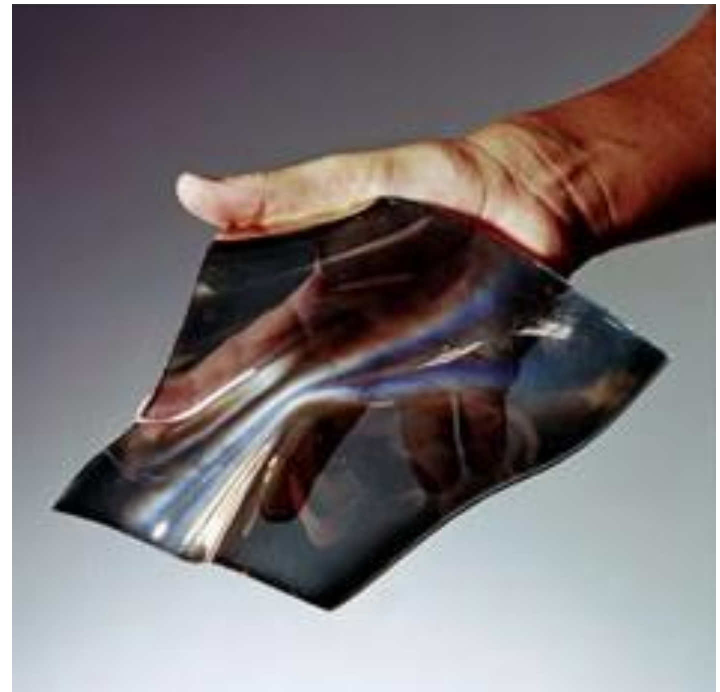
Produce plastic granulate that can be melted and injection-molded.

Metal Rubber



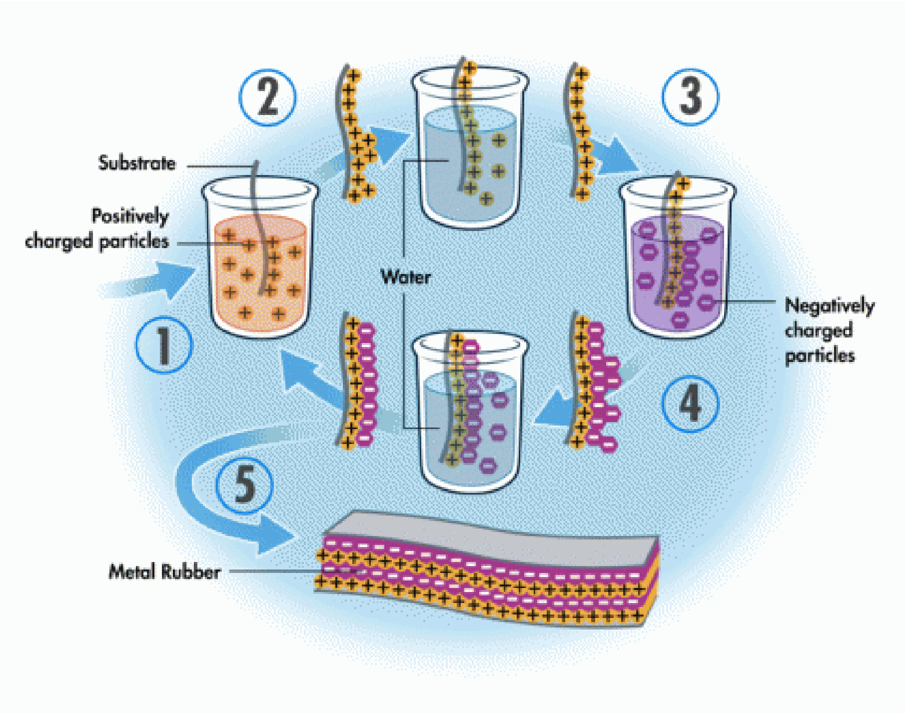
Polymer chemists have created a flexible, indestructible material called metal rubber.

Metal Rubber

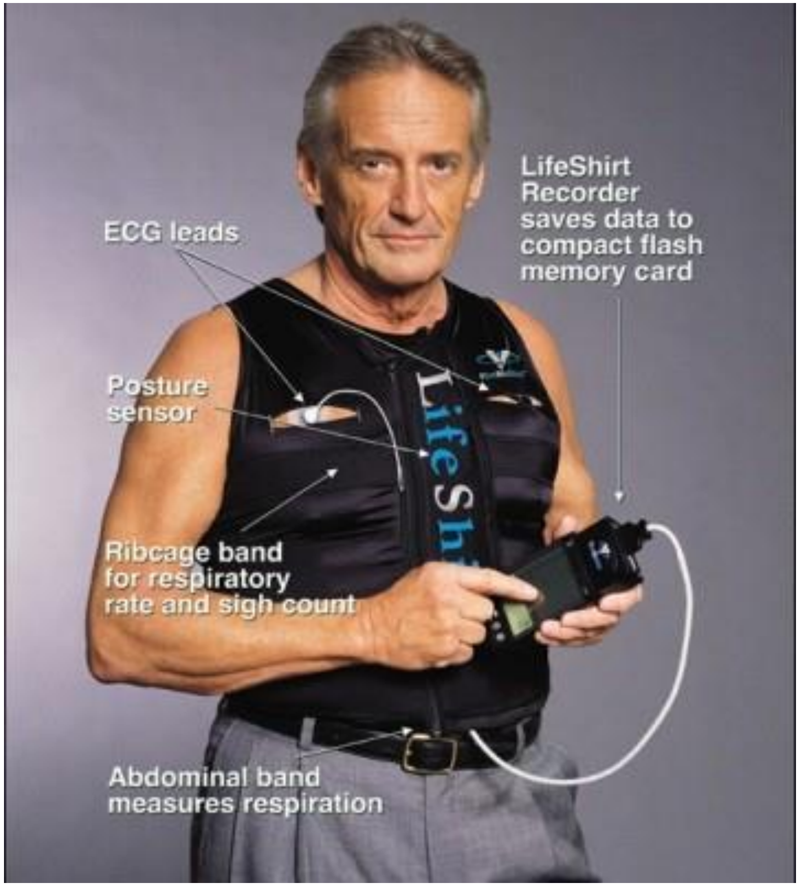
 

It can be heated, frozen, washed or doused with jet fuel, and still retain its electricity-conducting properties.

To make metal rubber, chemists and engineers use a process called self-assembly.



The material is repeatedly dipped into positively charged and negatively charged solutions. The positive and negative charges bond, forming layers that conduct electricity.



Uses of metal rubber include electrically charged aircraft wings, artificial muscles and wearable computers.

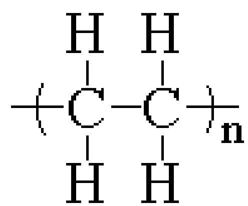
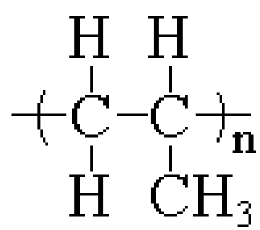
Industrially Important Polymers

These polymers are produced in high volume at very low cost.

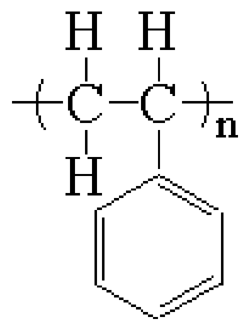
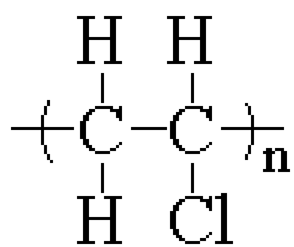
Industrially Important Polymers

About 85% of the world plastics consumption is from just four polymers.

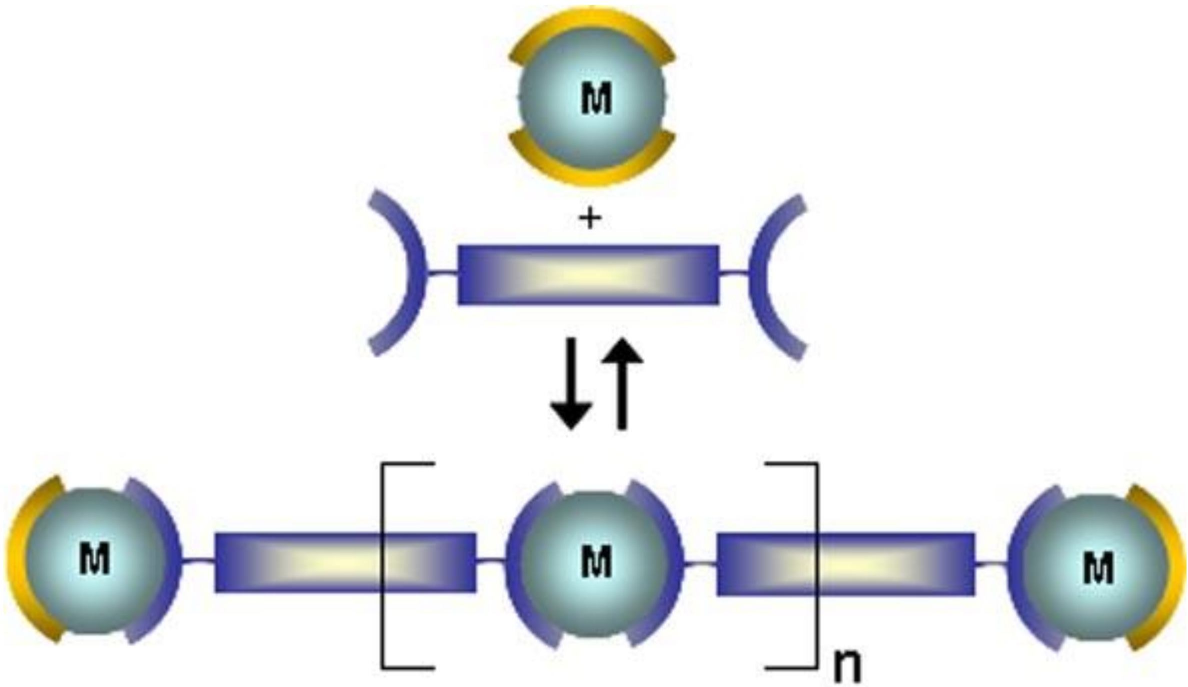
Industrially Important Polymers

POLYMER	MER	APPLICATIONS
Polyethylene **(PE)**		***electrical wire insulation, flexible tubing, squeeze bottles***
Polypropylene **(PP)**		***carpet fibers, ropes, pipes liquid containers (cups, buckets, tanks)***

Industrially Important Polymers

POLYMER	MER	APPLICATIONS
Polystyrene **(PS)**		***packaging foams, egg cartons, lighting panels, electrical appliance components***
Polyvinyl Chloride **(PVC)**		***bottles, hoses, pipes, valves, electrical wire insulation, toys, raincoats***

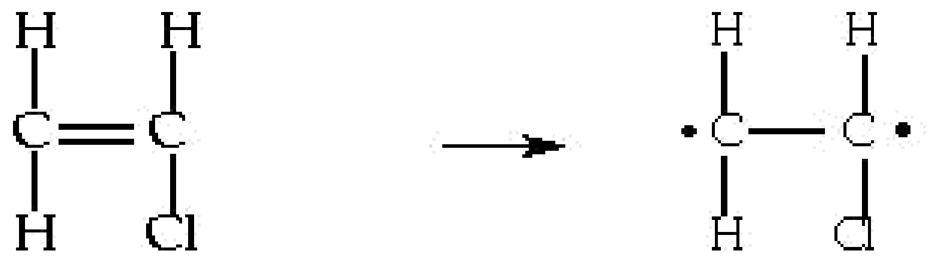
Polymer Formation



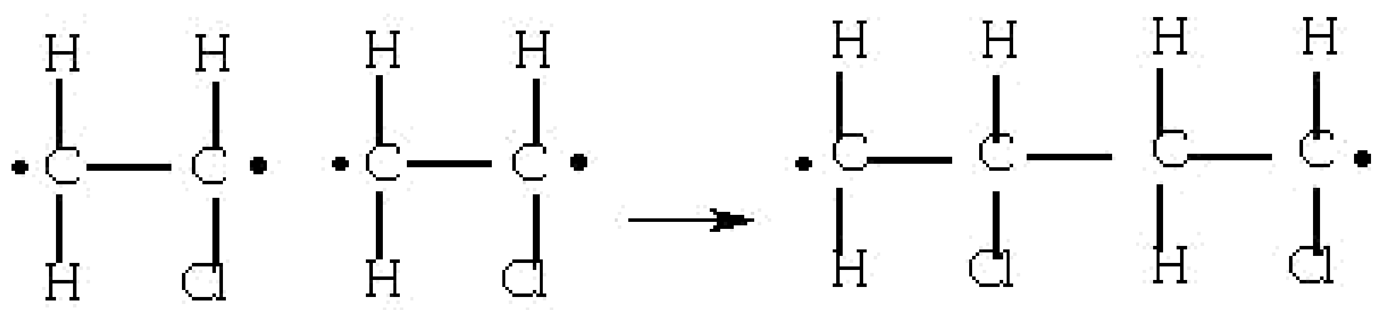
Polymerization

Free Radical Polymerization

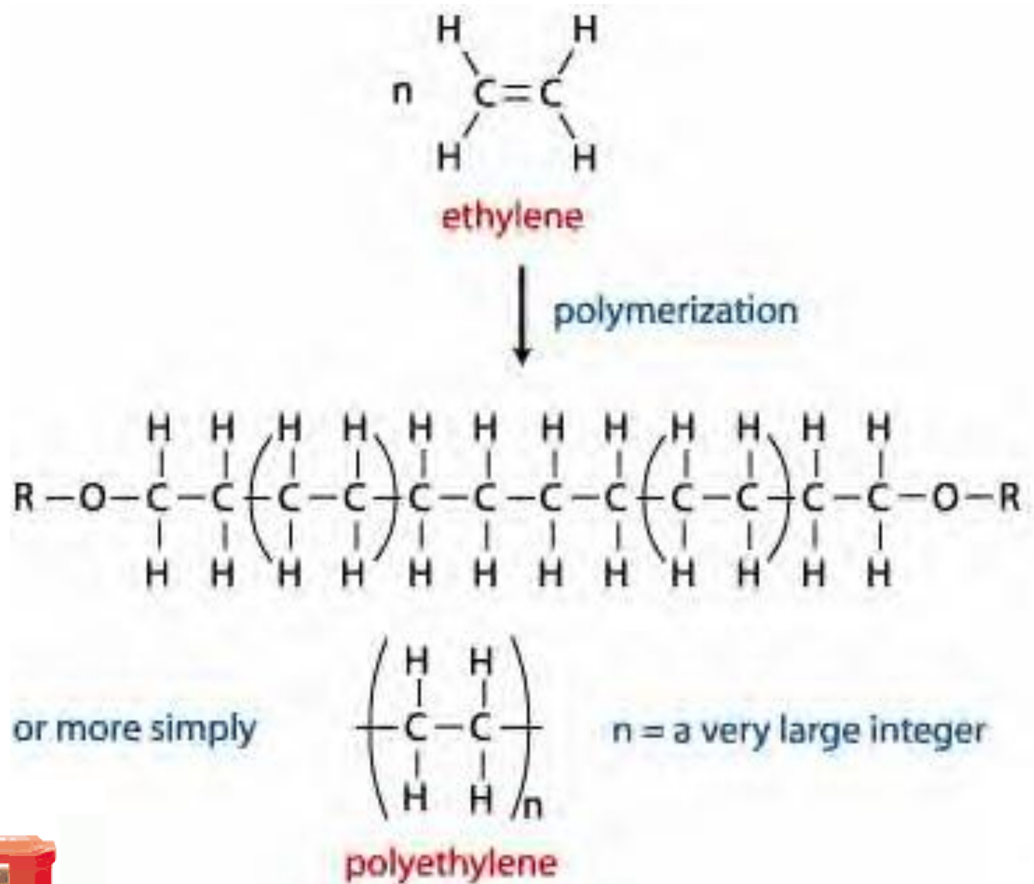
Two bonds between the two carbons ruptures.

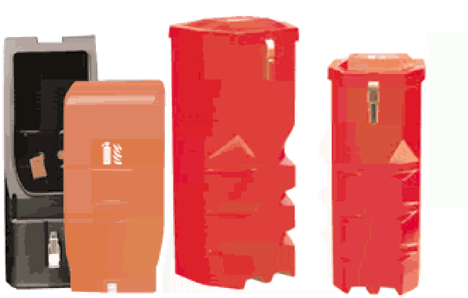


Two free radicals meet, they can form a dimer with a new covalent bond linking the two.

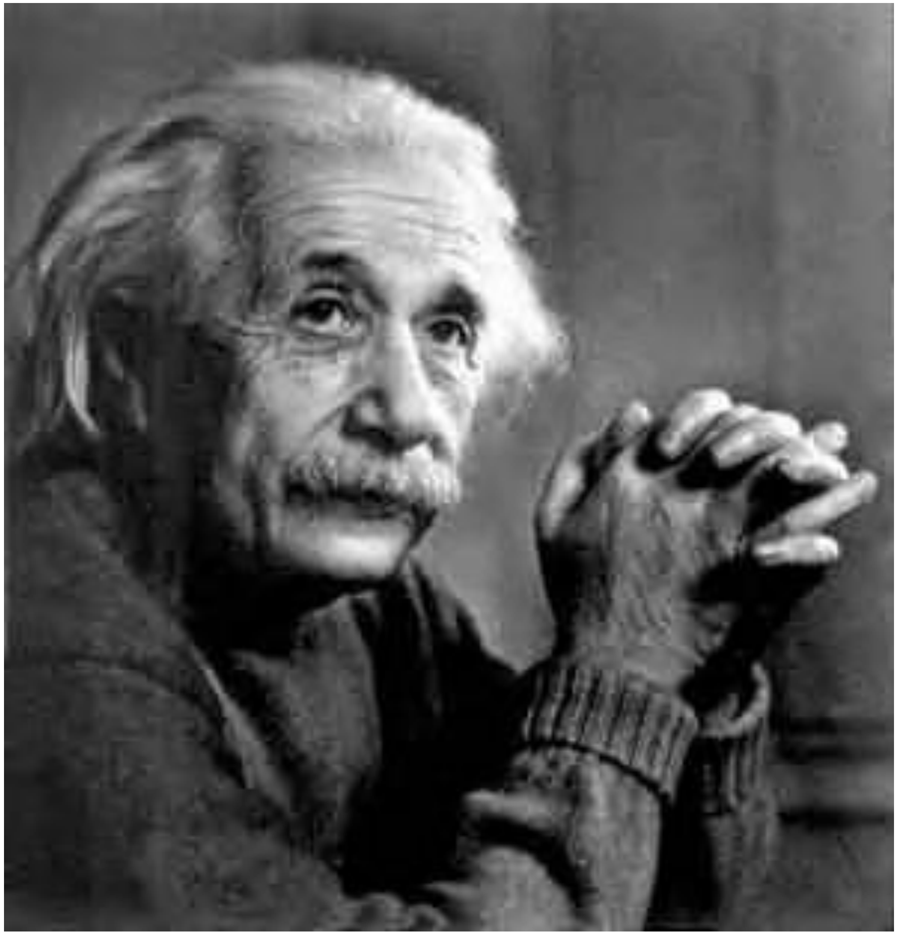


Free Radical Polymerization





Lab: Free Radical Polymerization

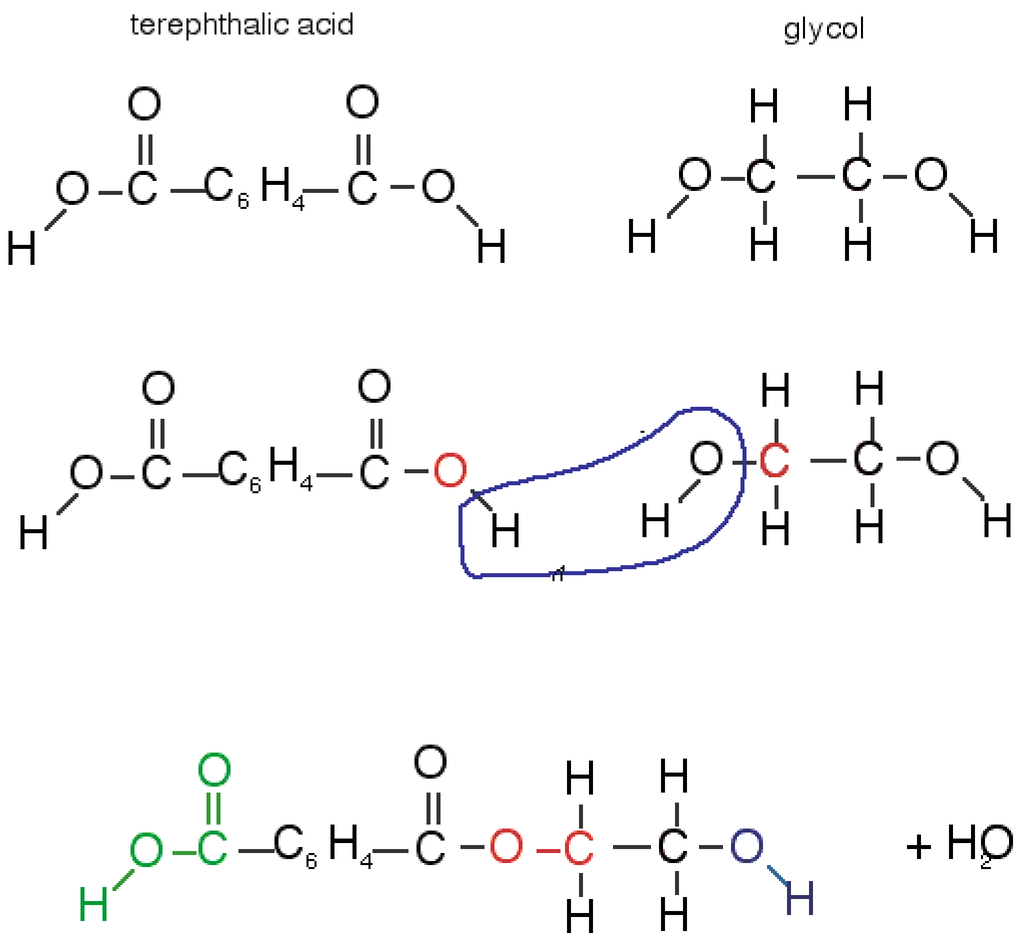


Lab: Free Radical Polymerization

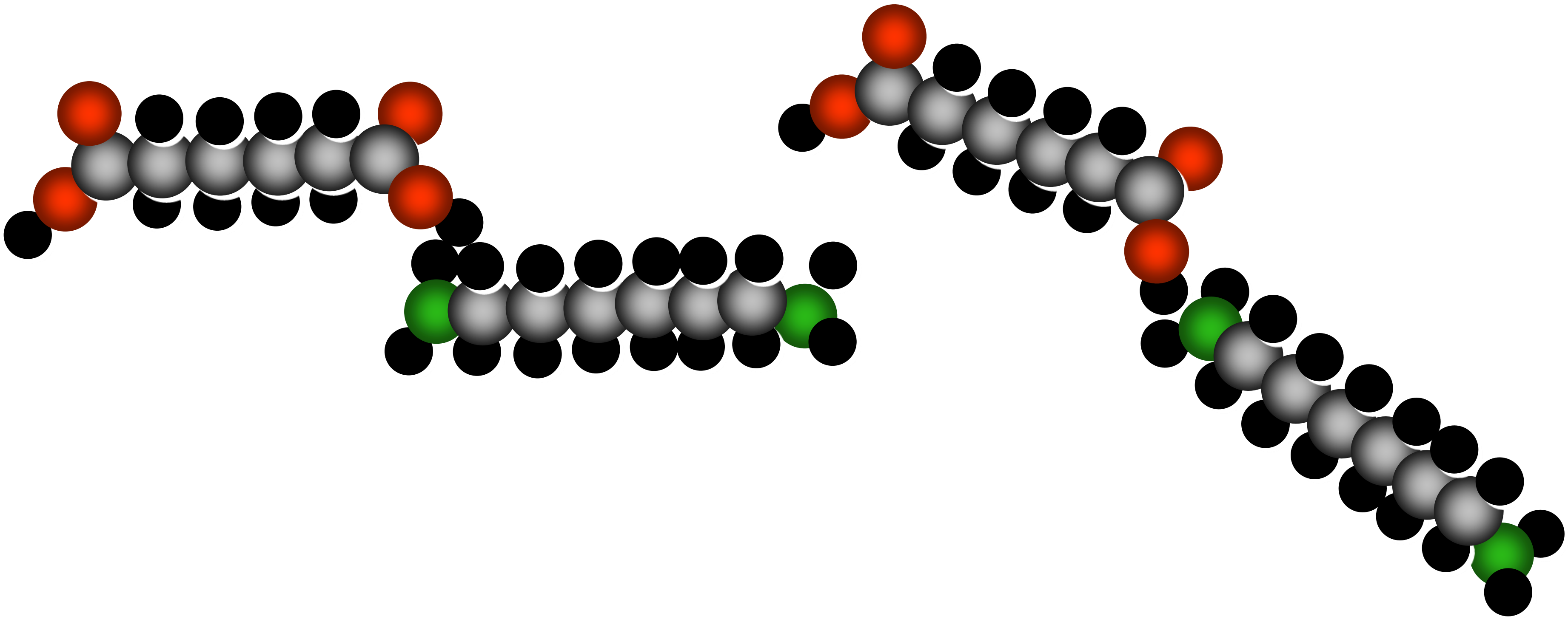
Data Chart

NAME	STRUCTURAL FORMULA
Vinyl Chloride	
Divinyl Chloride	
Trivinyl Chloride	
PVC	

Condensation Polymerization

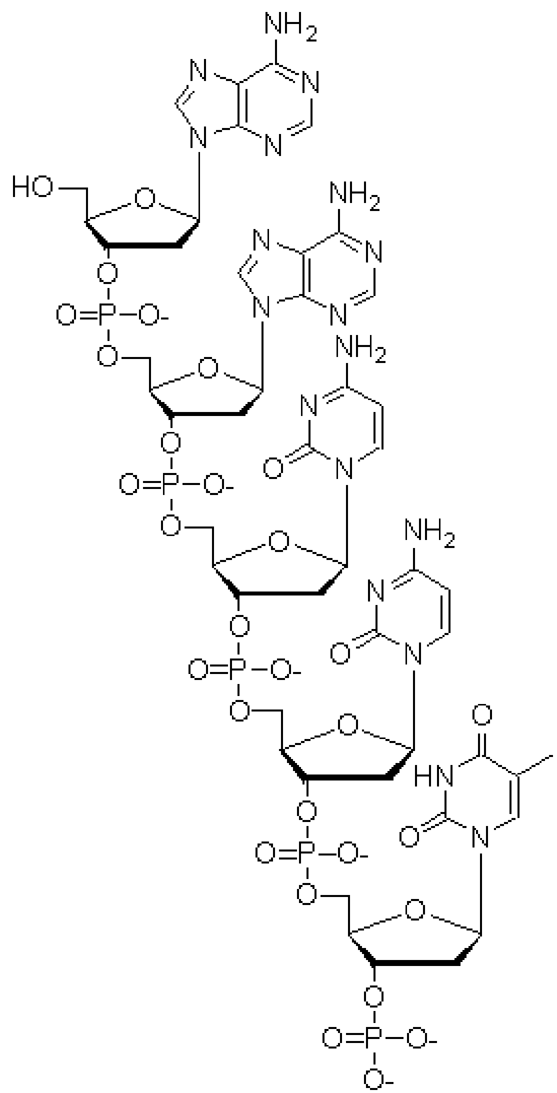


Dacron



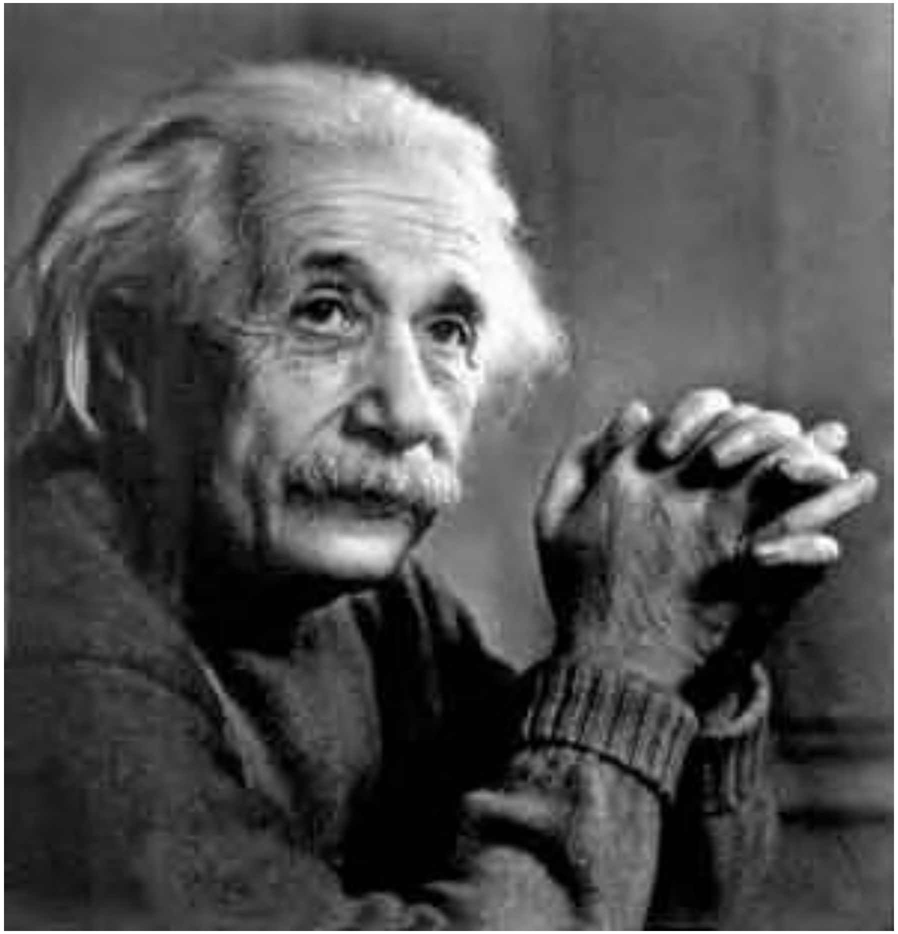
Condensation Polymerization

Condensation Polymerization



Protein

Lab: Condensation Polymerization

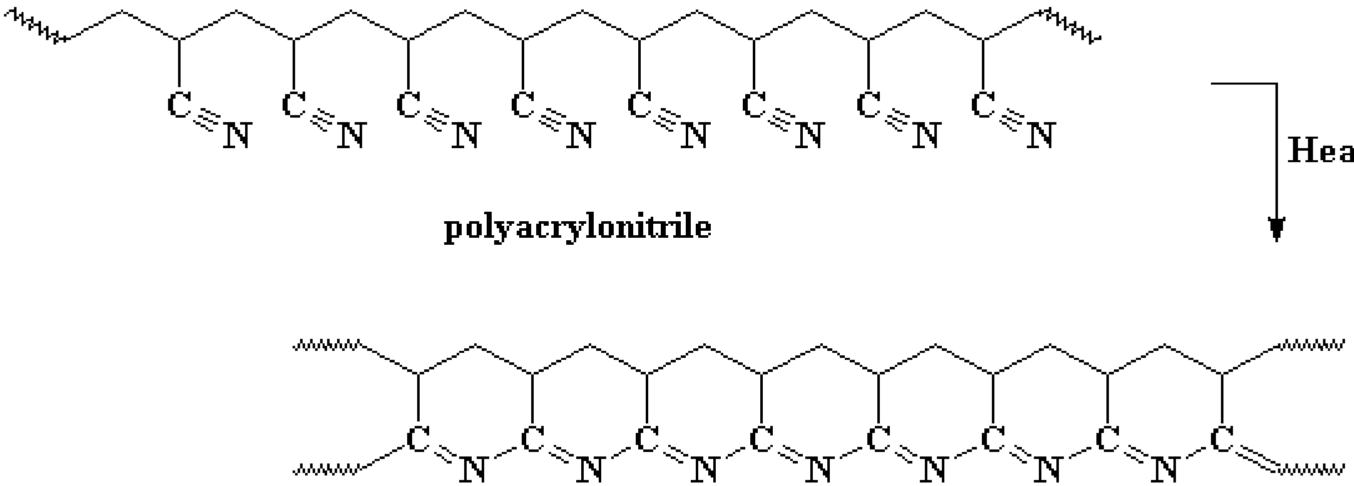


Lab: Condensation Polymerization

Data Chart

NAME	STRUCTURAL FORMULA
Amine	
Carboxyl	
Amino Acid	
Protein	

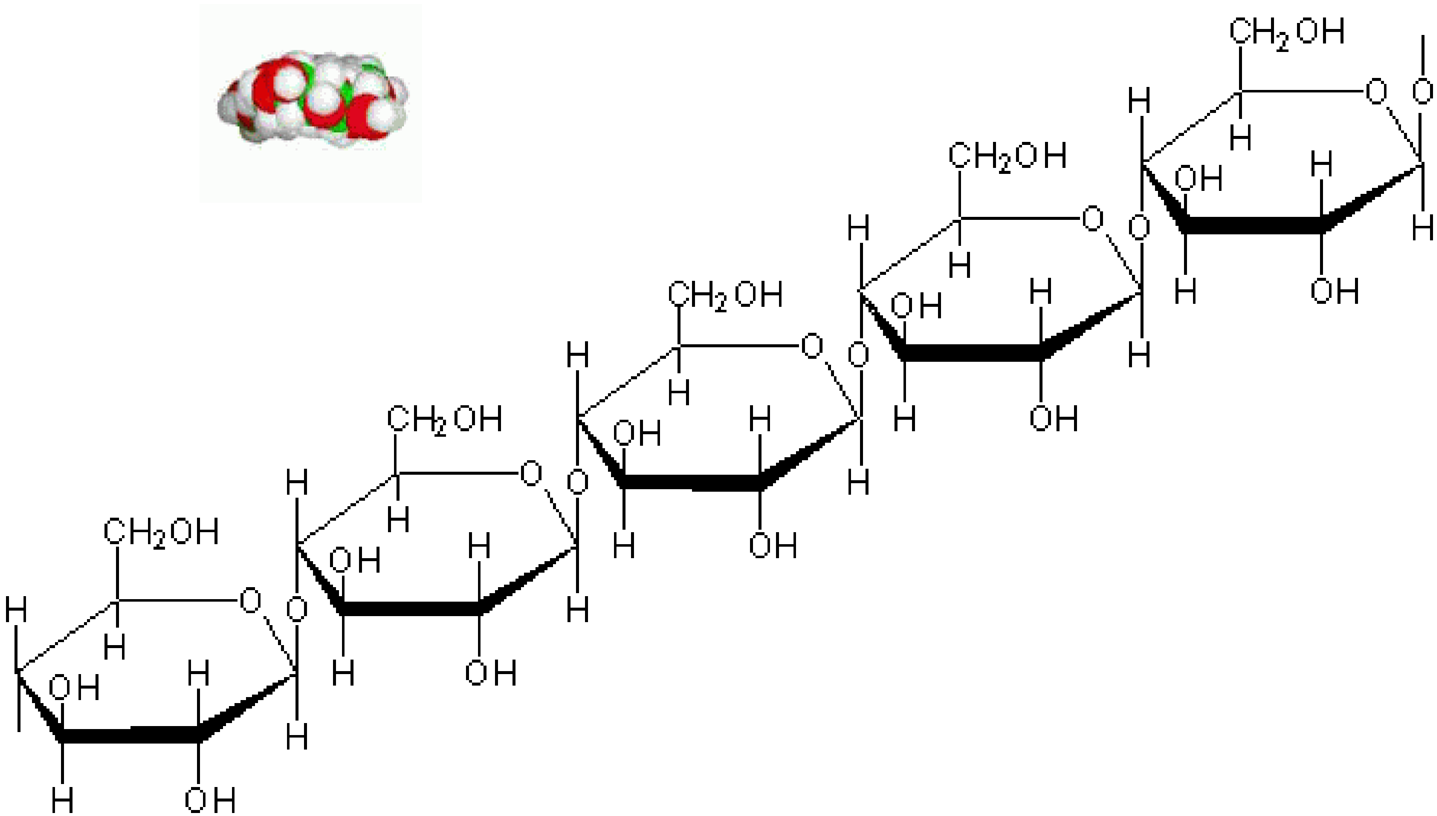
Which Type Polymerization?

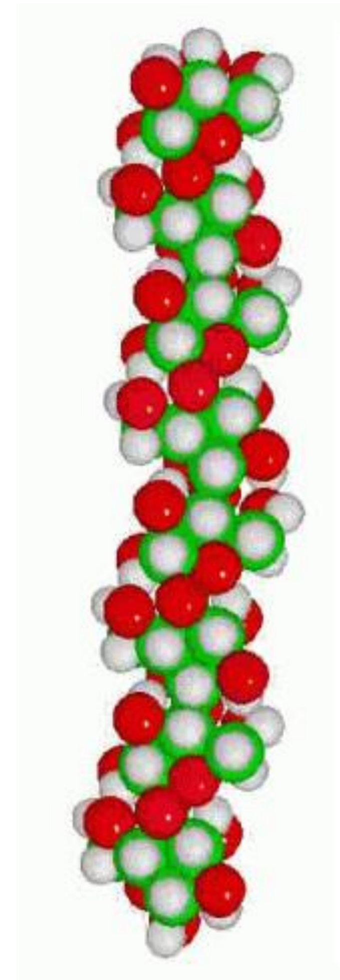


Carbon Fiber Production

Free Radical Polymerization Condensation Polymerization

Chain Length Factors

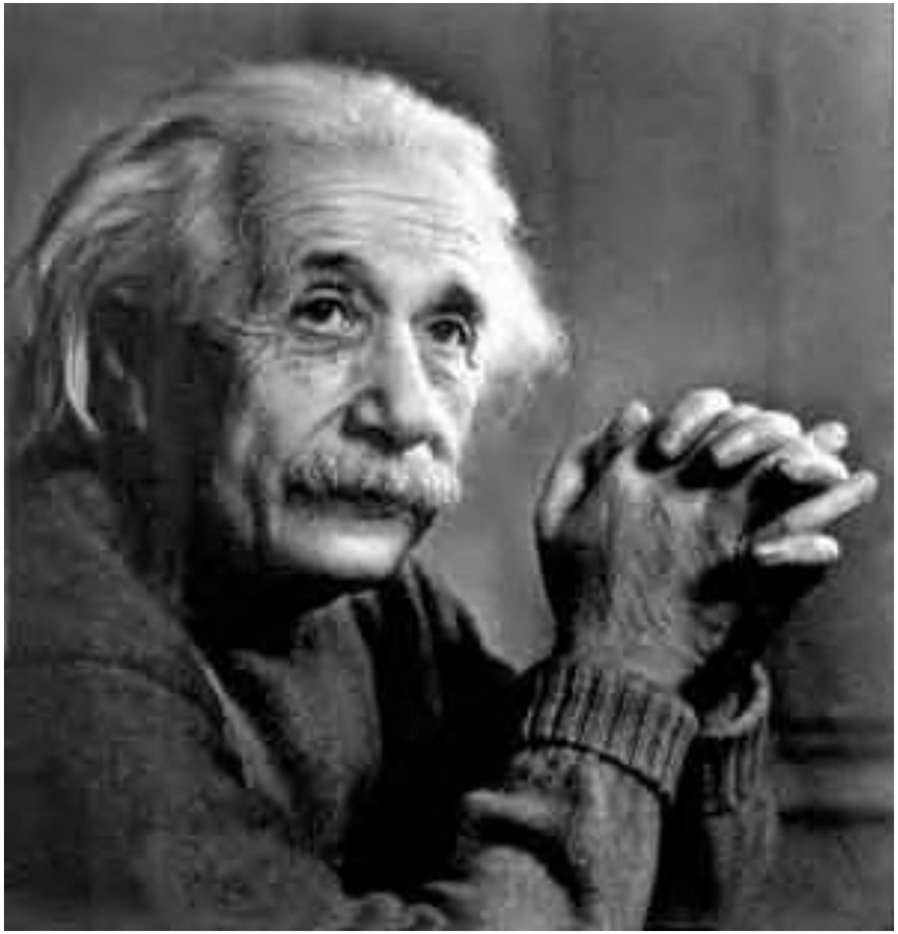




Chain Length Factors

Number of Monomers & Initiators.

Lab: Building Sweet Polymer Chains

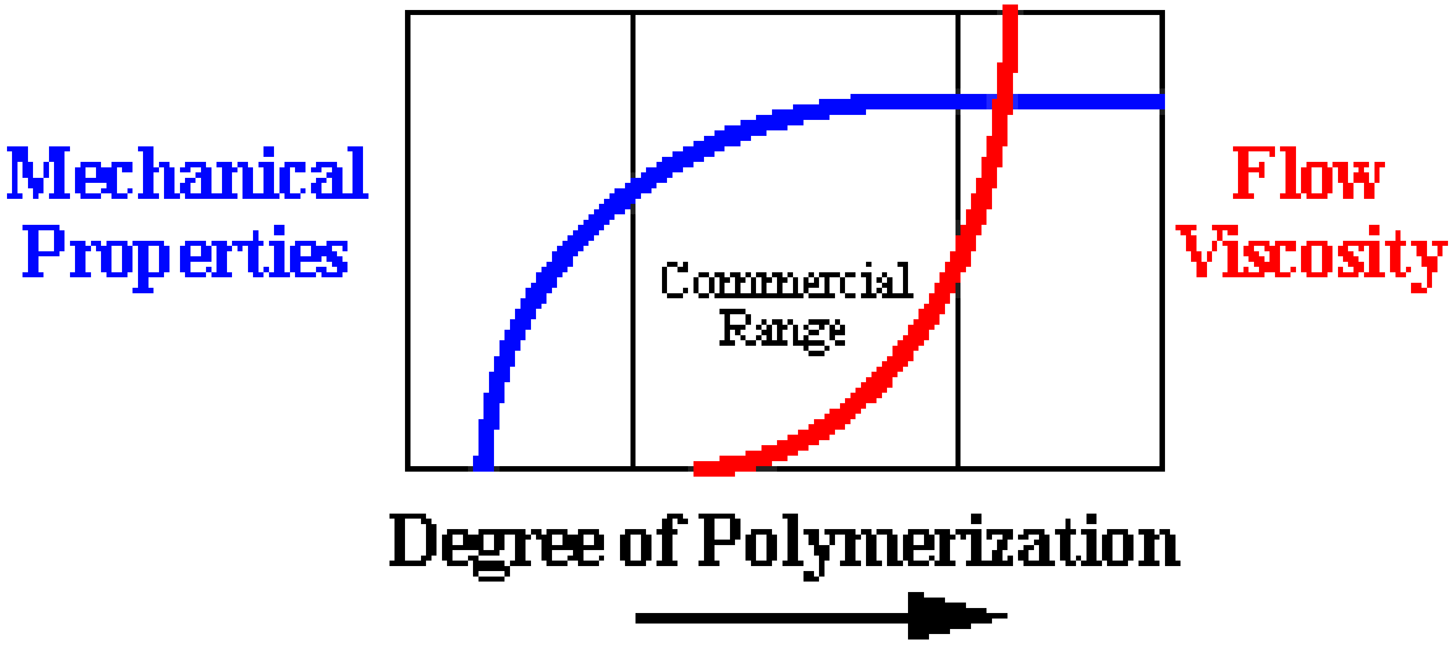


Lab: Building Sweet Polymer Chains

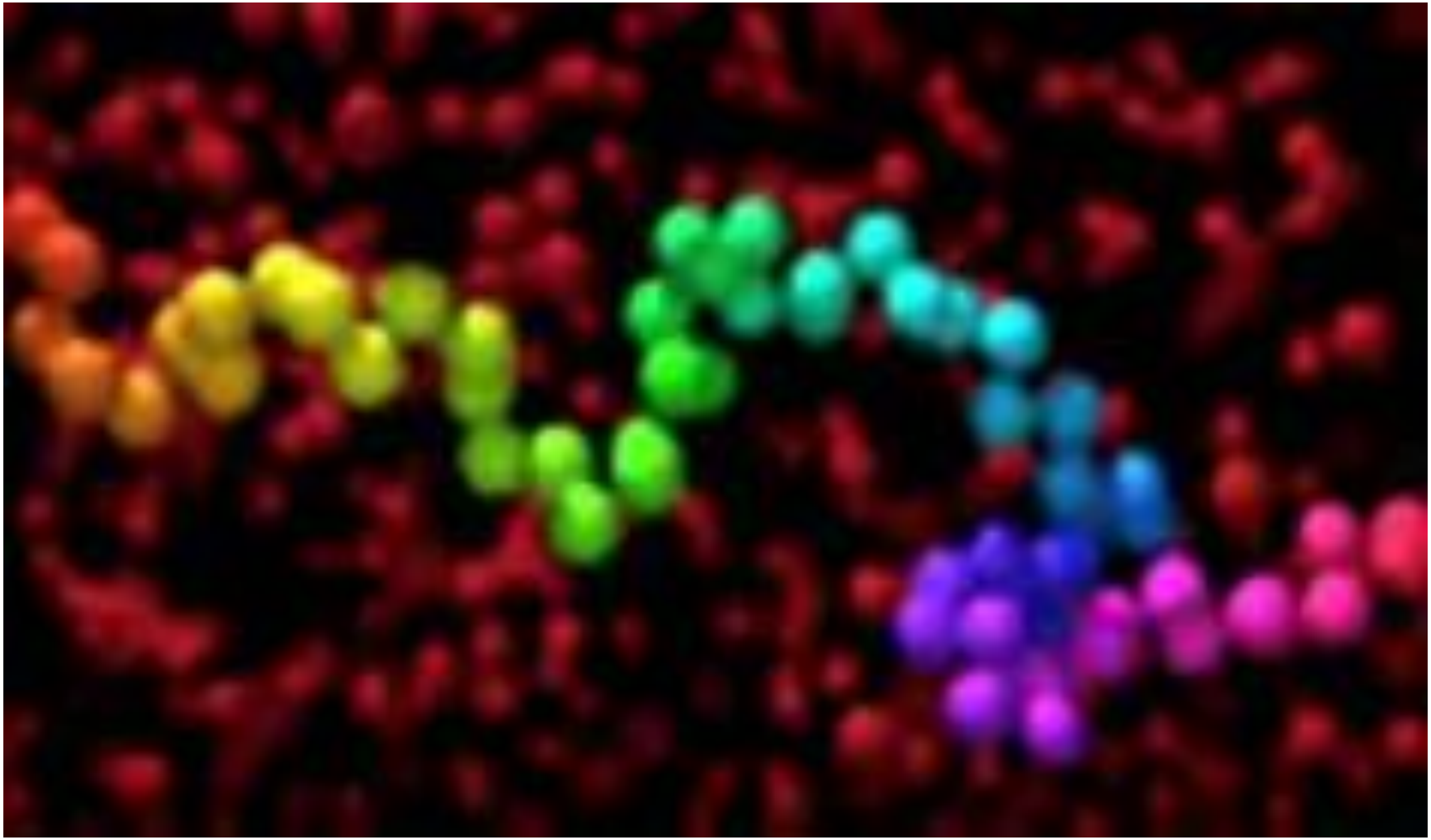
Data Chart

Bag #	Number of Initiators	Number of Chains	Chain Length (# of Monomers)	
1				
2				
3				

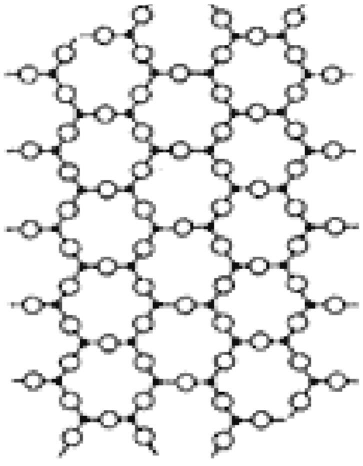
Degree of Polymerization



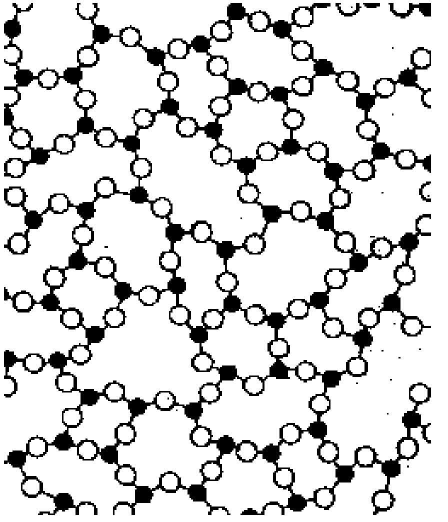
Polymer Structure



Polymer Atomic Arrangement

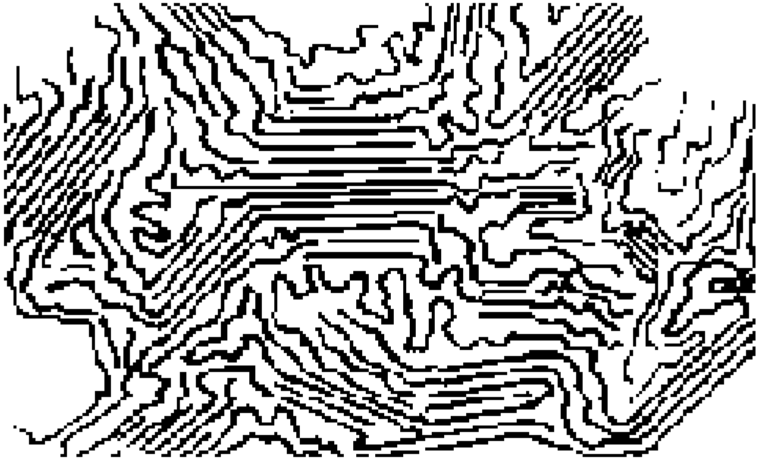


Crystalline

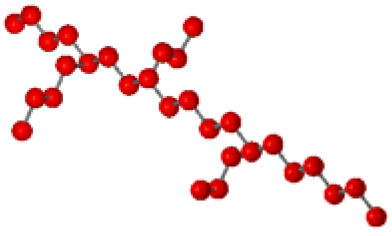


Amorphous

Semi-crystalline

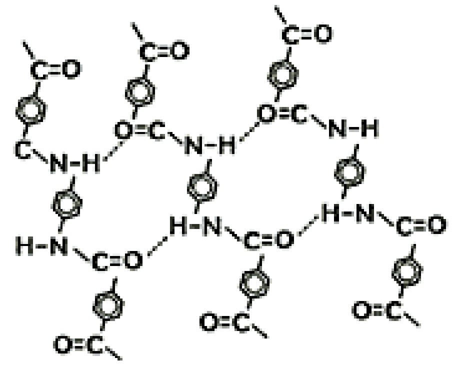


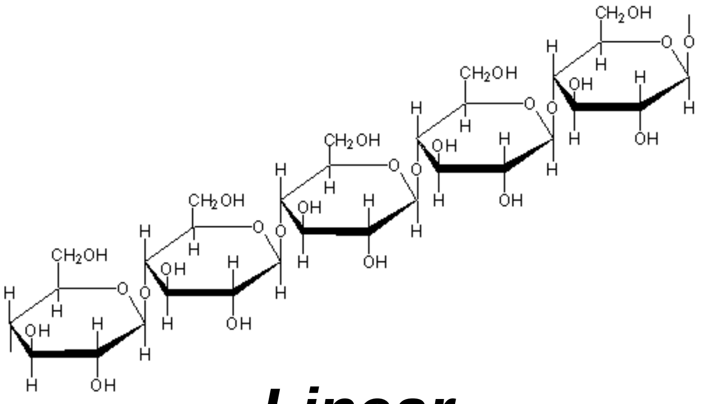
Chain Structures



Branched

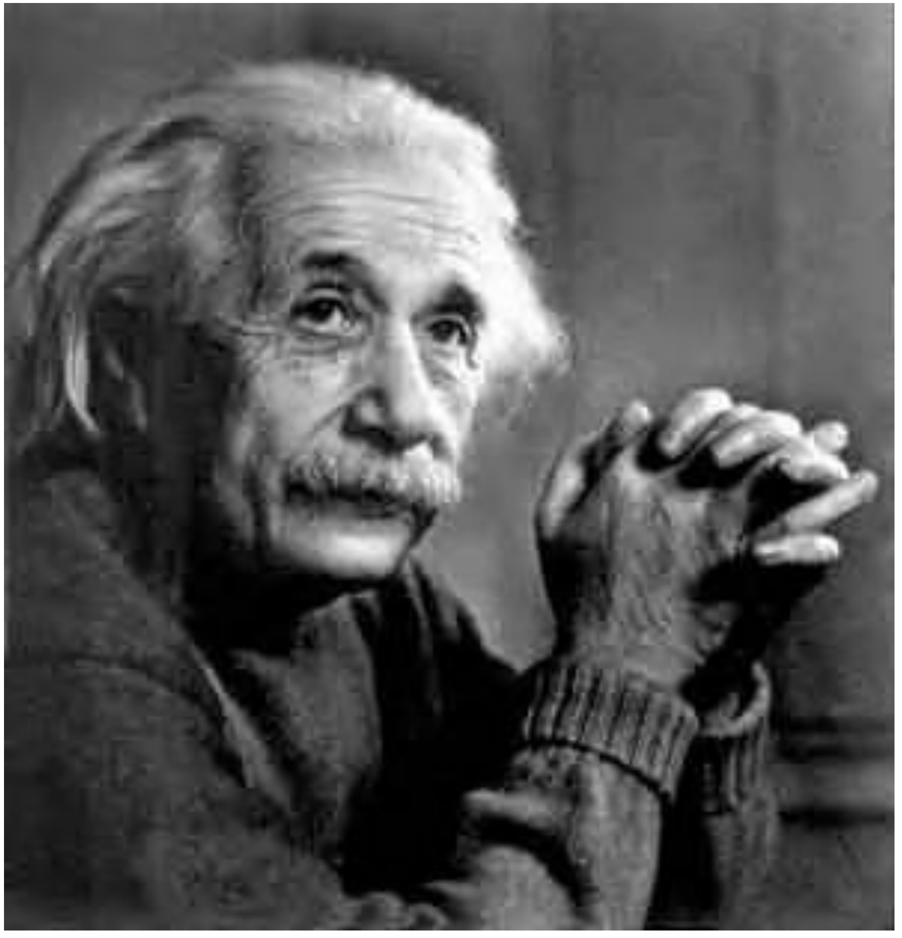
Cross-Linked



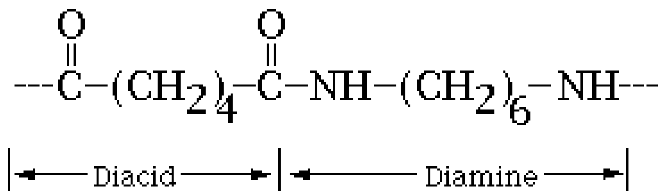


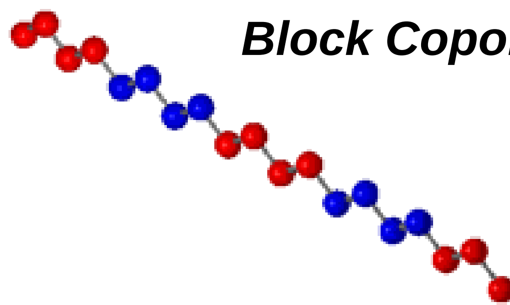
Linear

Lab: Silly Polymer

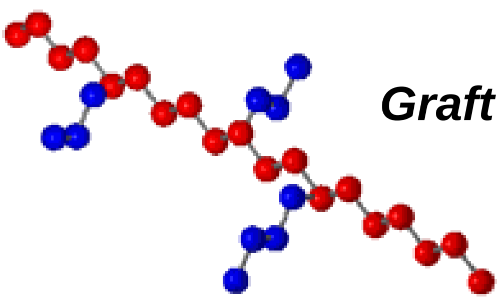


Copolymers

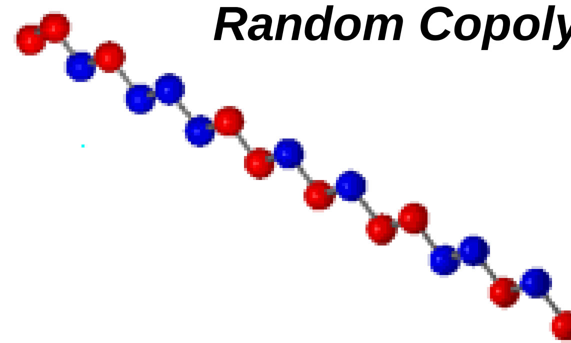




Block Copolymer

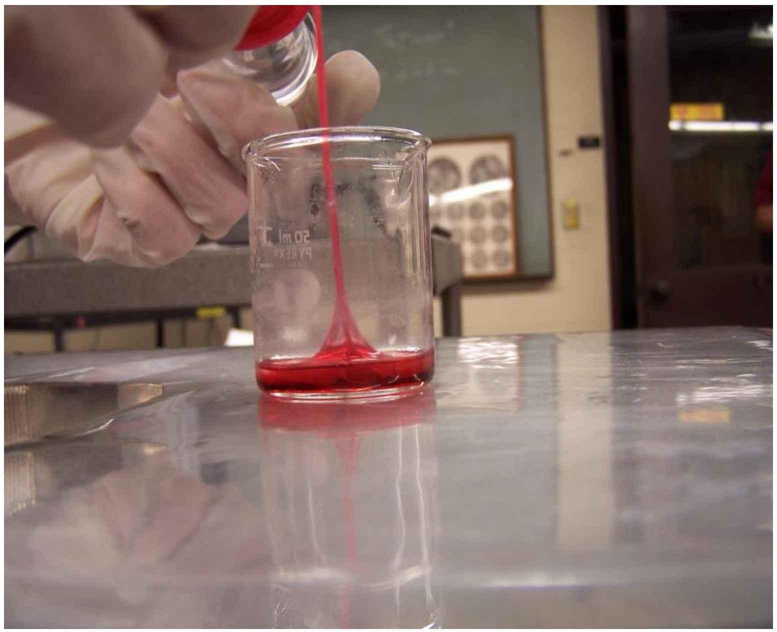


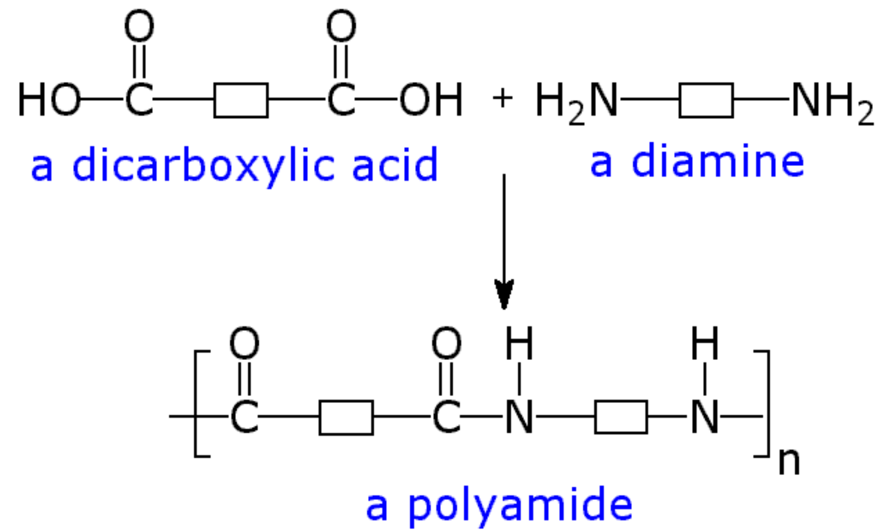
Graft Copolymer



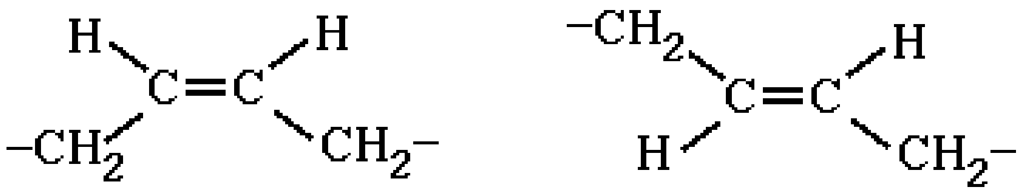
Random Copolymer

Nylon




HO—C(=O)—□—C(=O)—OH + H_2N—□—NH_2
a dicarboxylic acid
a diamine
a polyamide
n

Polymer Configuration



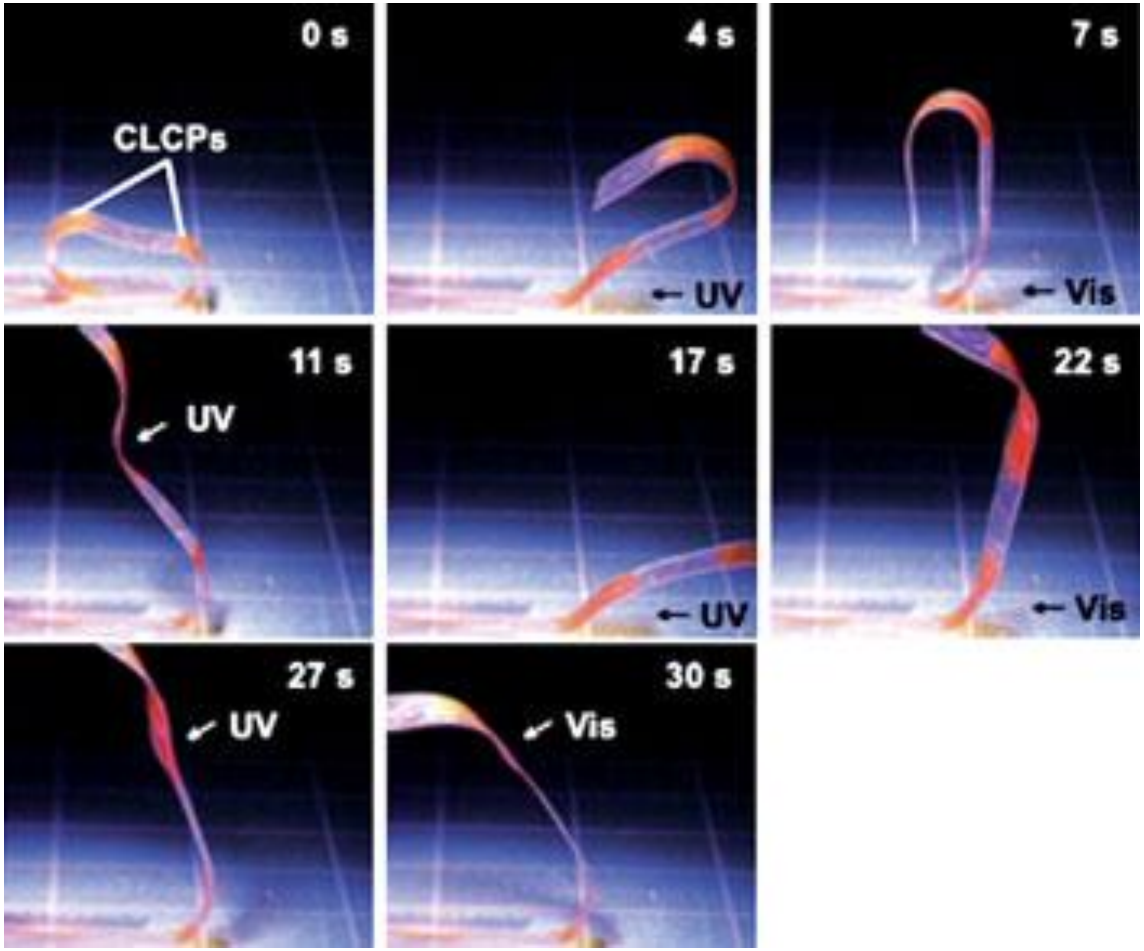
cis

trans

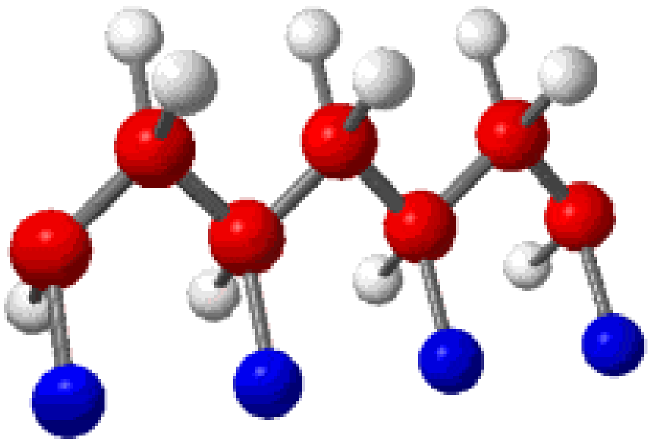
The *cis* configuration arises when substitute groups are on the same side of a carbon-carbon double bond.

***Trans* refers to the substitutes on opposite sides of the double bond.**

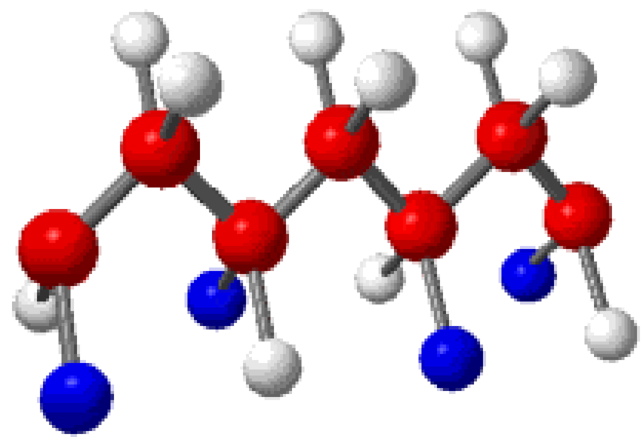
Photomobile Polymer



Stereoregularity



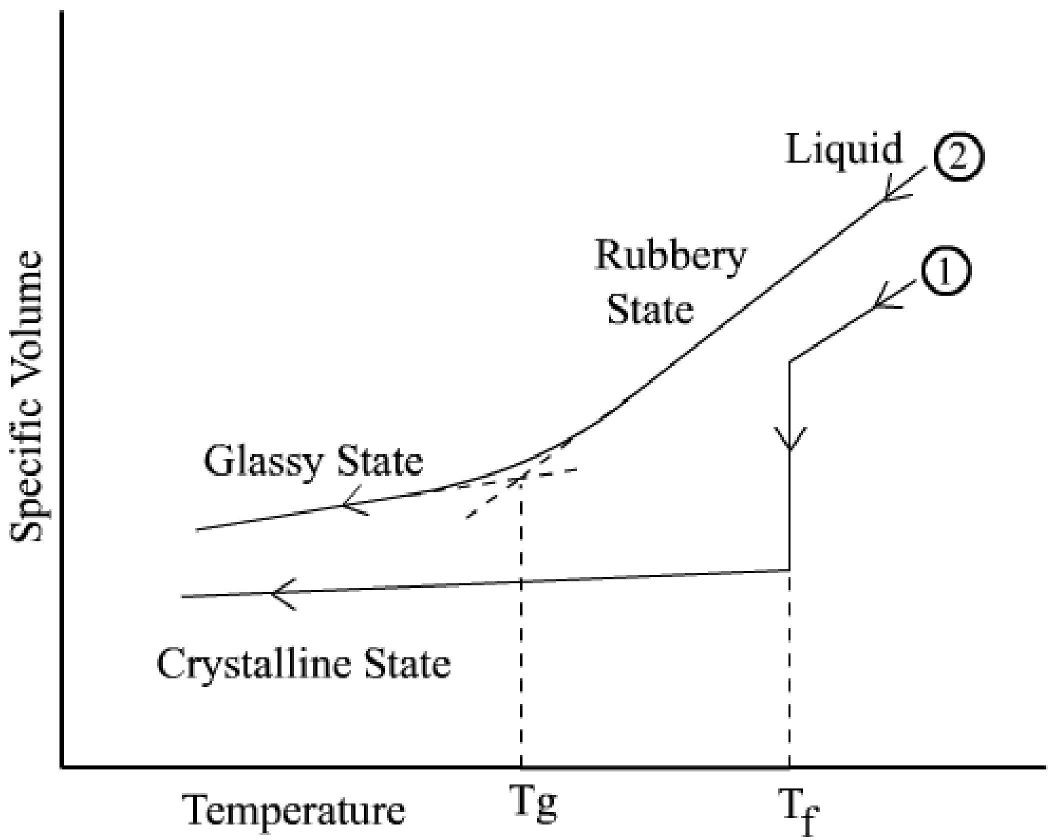
Isotactic



Syndiotactic

Atactic = ?

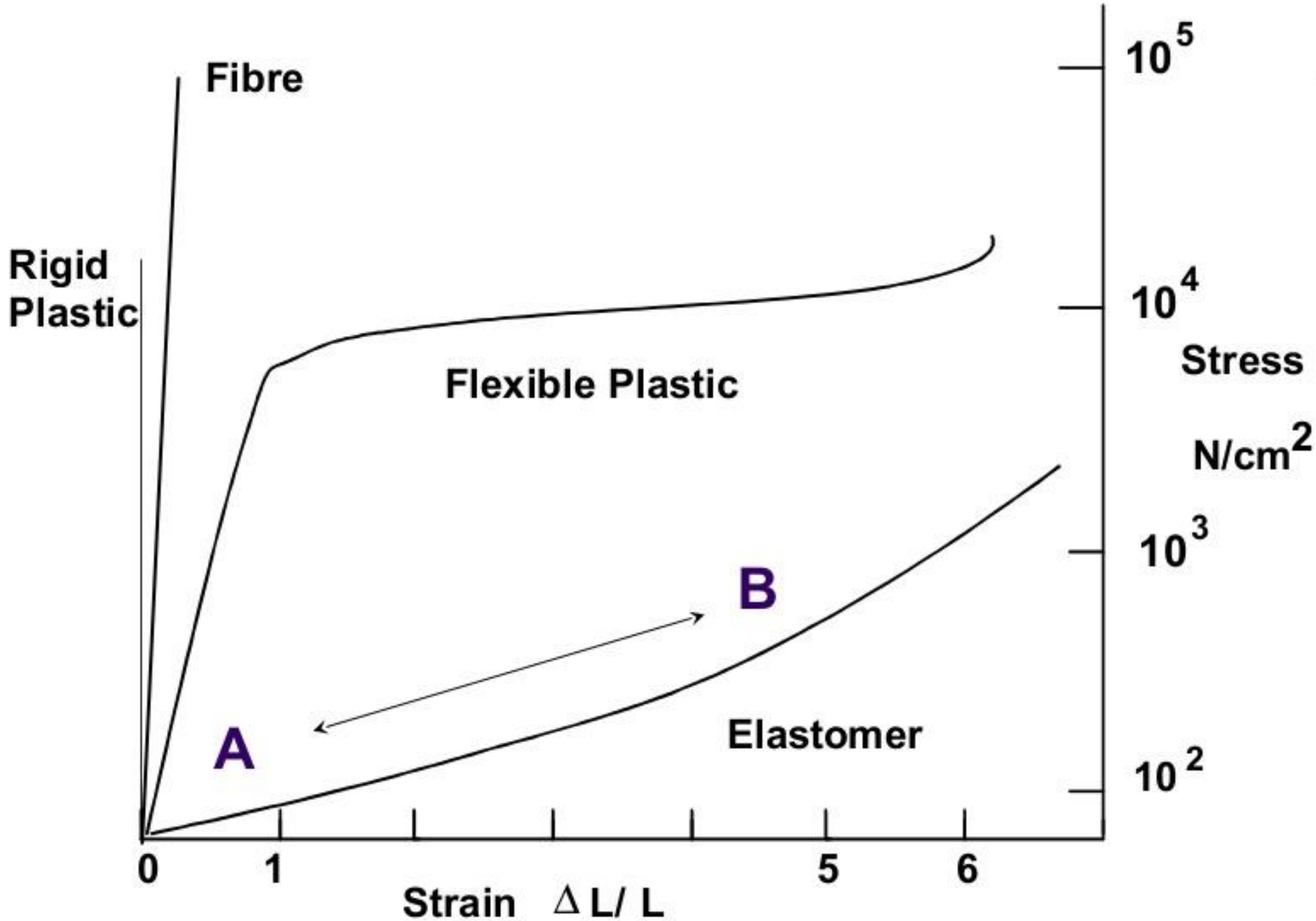
Thermal Transitions



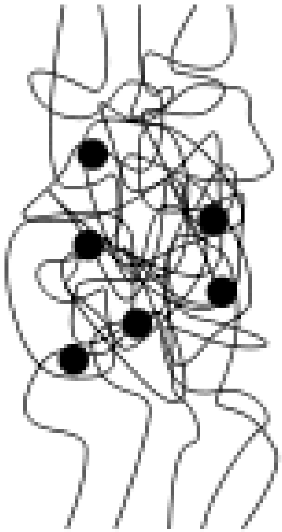
Elastomers

Elastomers show a high degree of elasticity.

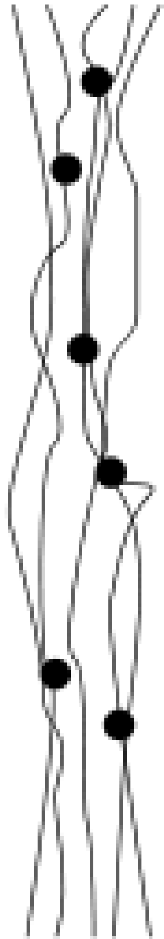
Mechanical Properties



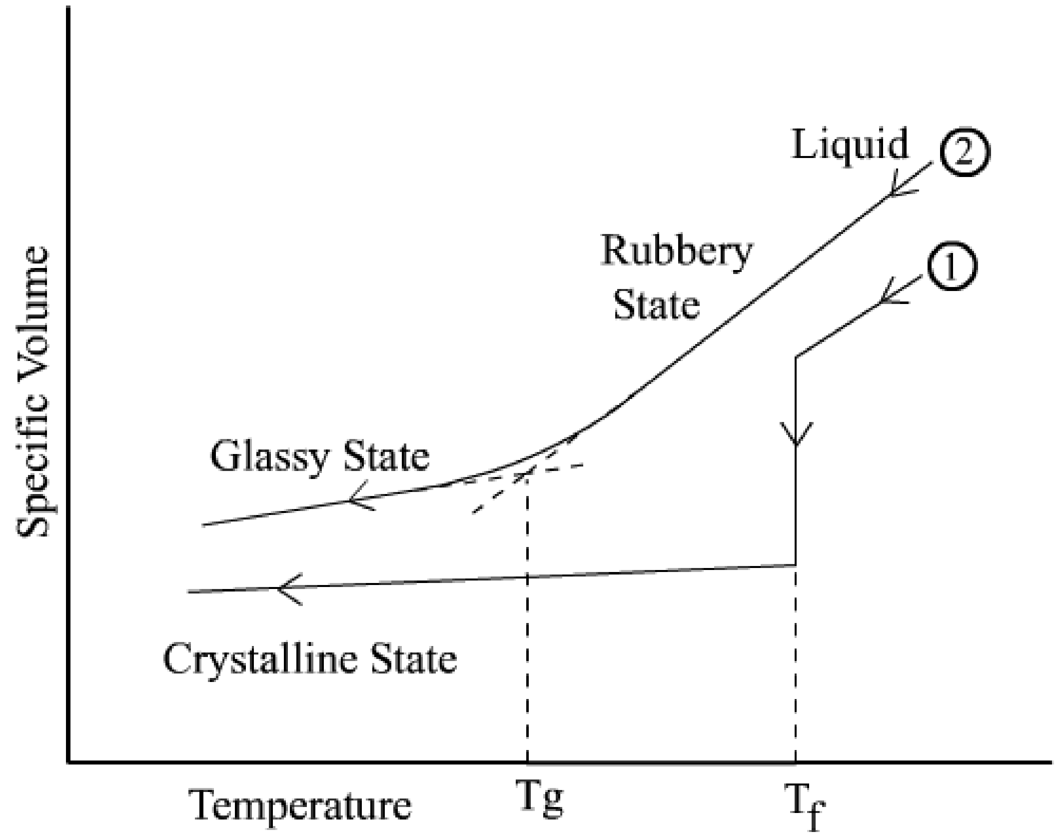
Elastomers



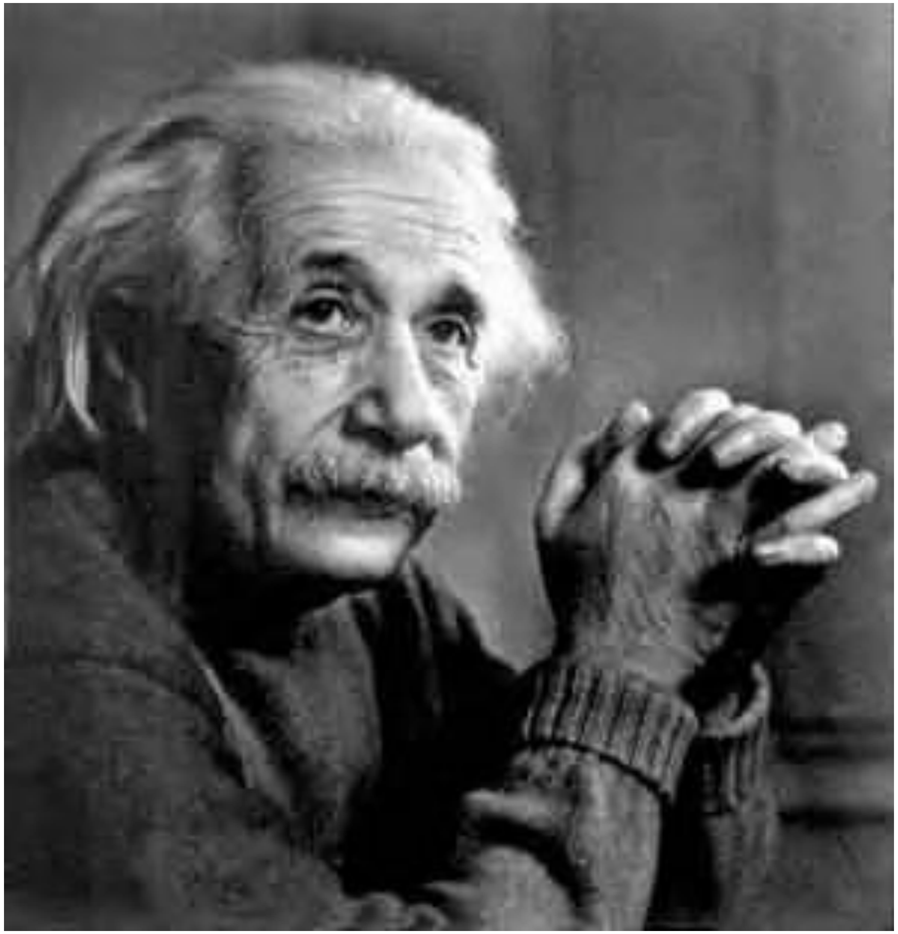
A



B



Lab: ☺ & ☹ Balls

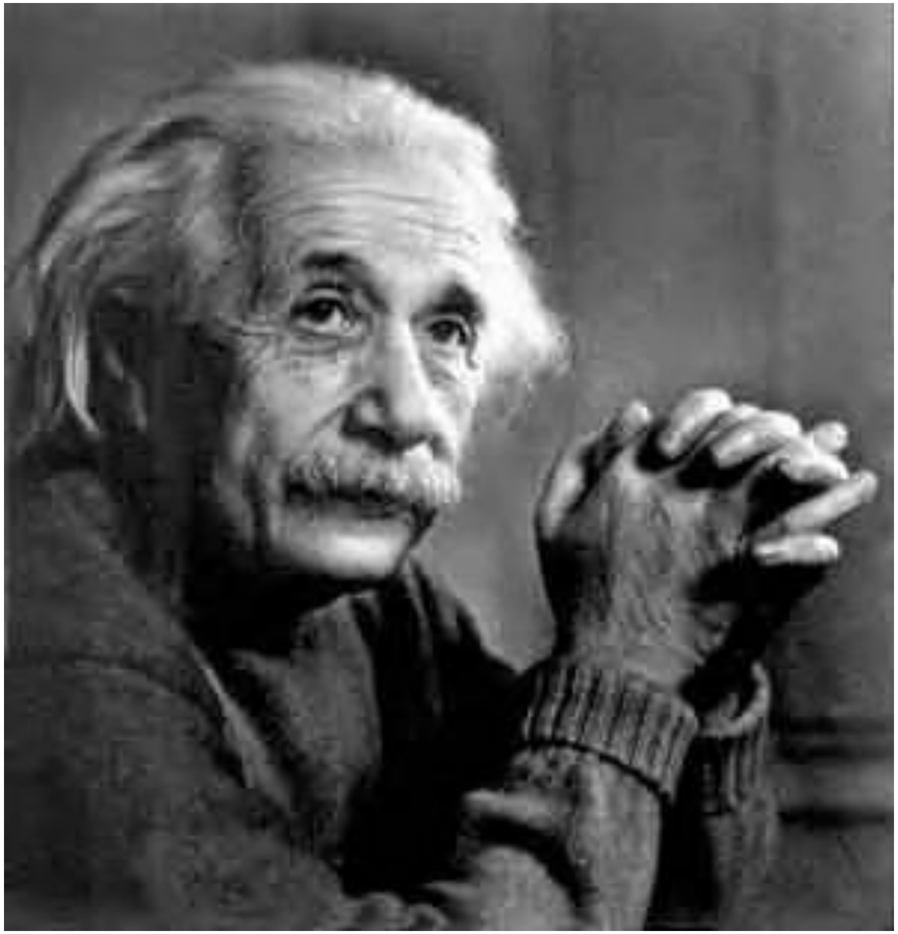


Lab: ☺ & ☹ Balls

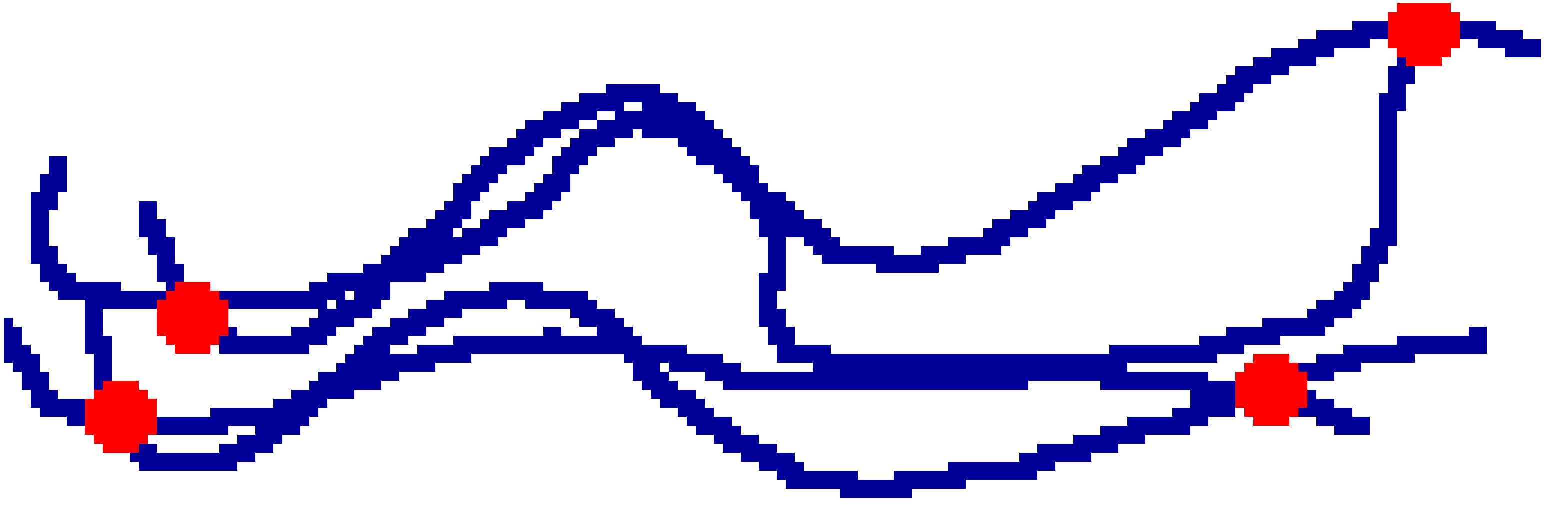
Data Chart

Test Ball	Coefficient of Restitution
☺	
☹	
☺	
☹	
☺	
☹	

Lab: Elastomers-The Inside Story



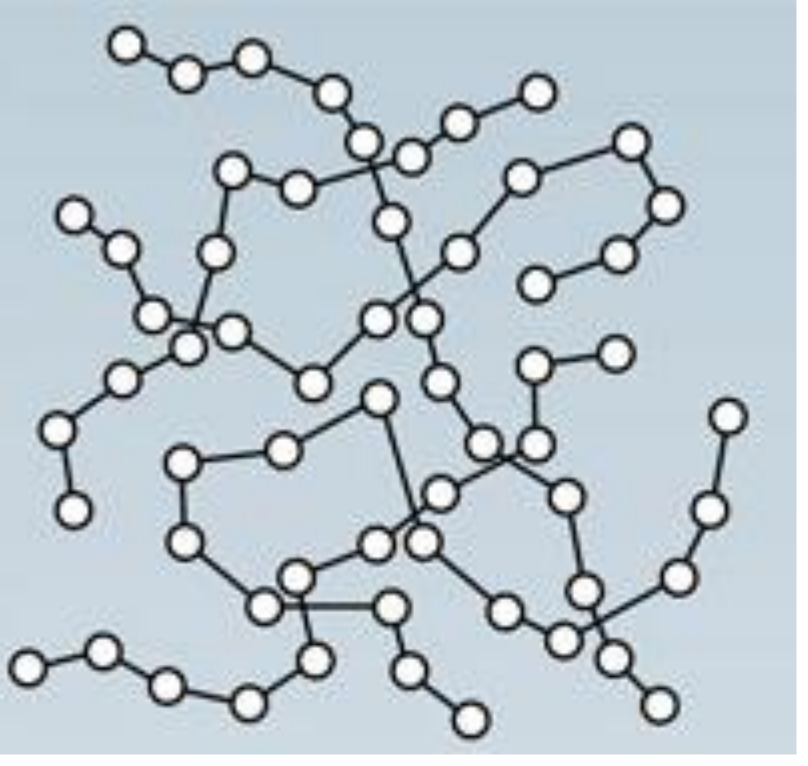
Elastomers



Are usually thermosets but may be thermoplastics.

Response to Heat

Thermoplastic   Softens or melts with heat



The polymer chains start to relax as they gain energy. They lose some of their crystallinity.

Thermoplastics

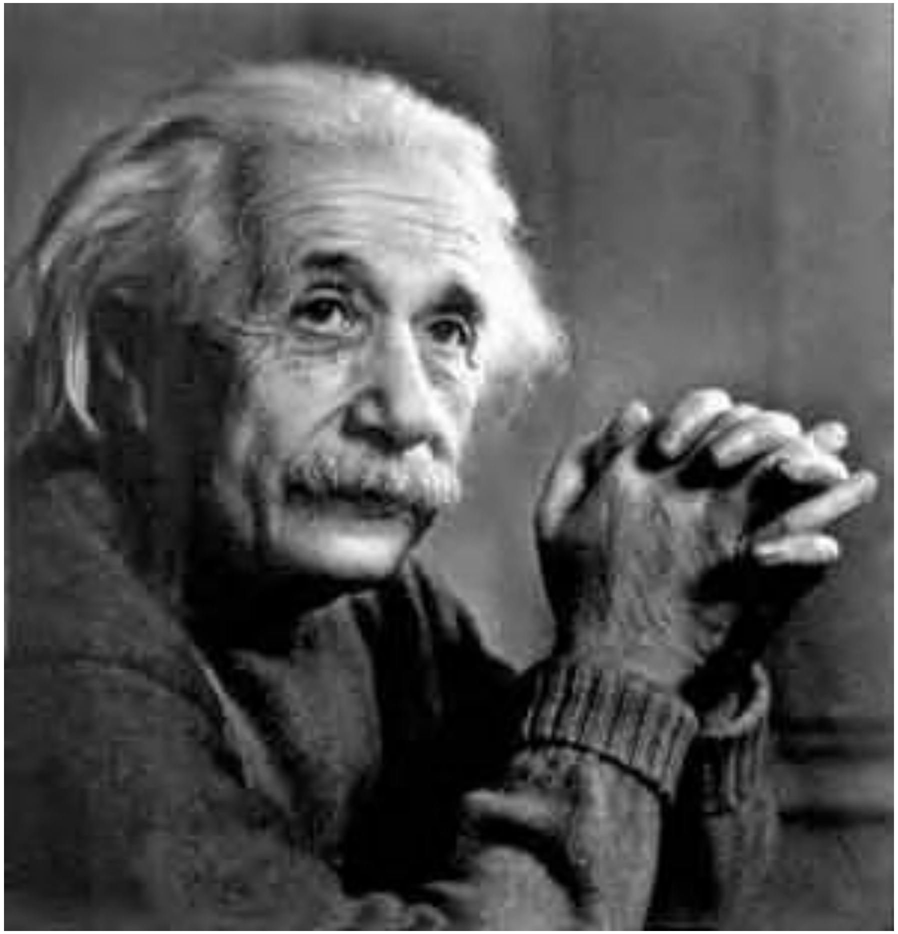
Styrofoam

PVC

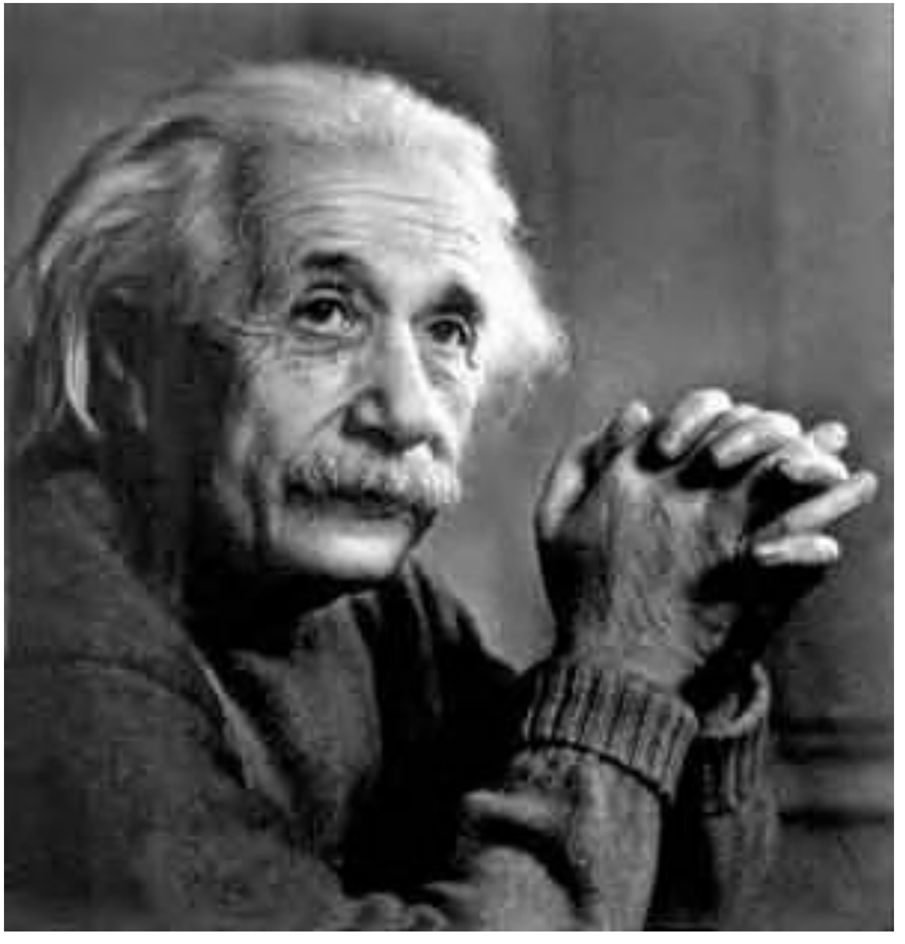
Nylon

Thermoplastics can be reformed and recycled.

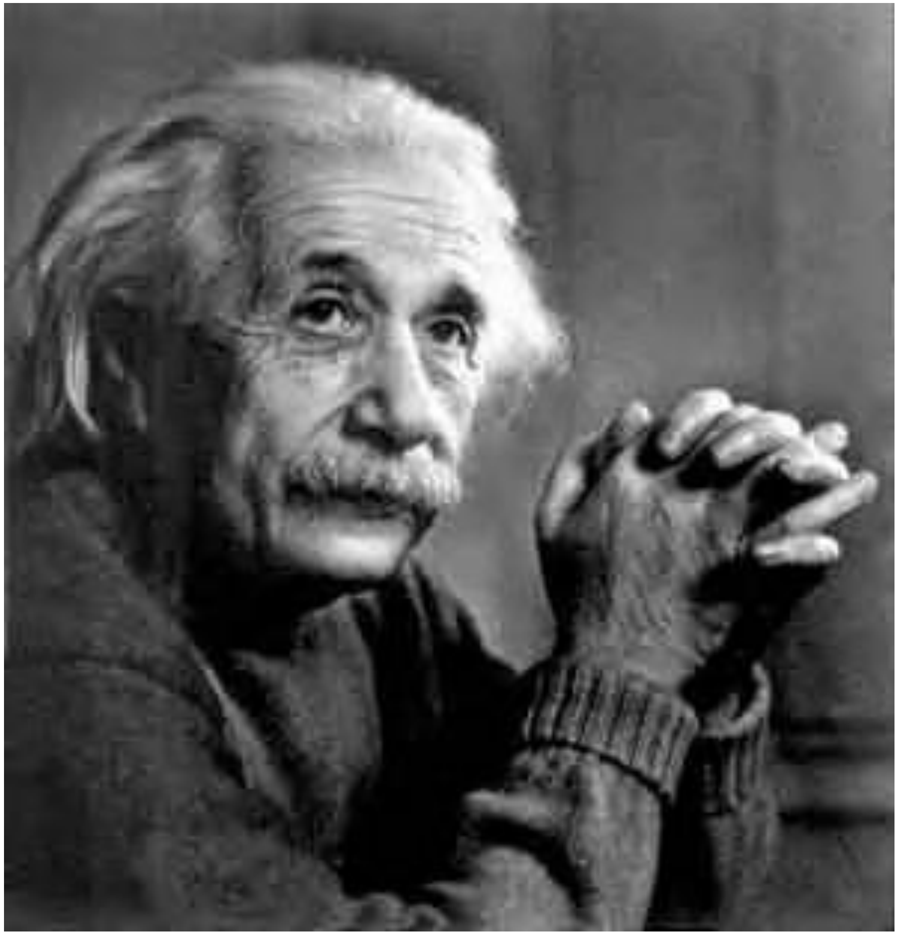
Lab: Shrink to Fit!



Lab: Shrink to Fit 2!



Lab: Thermoplastics



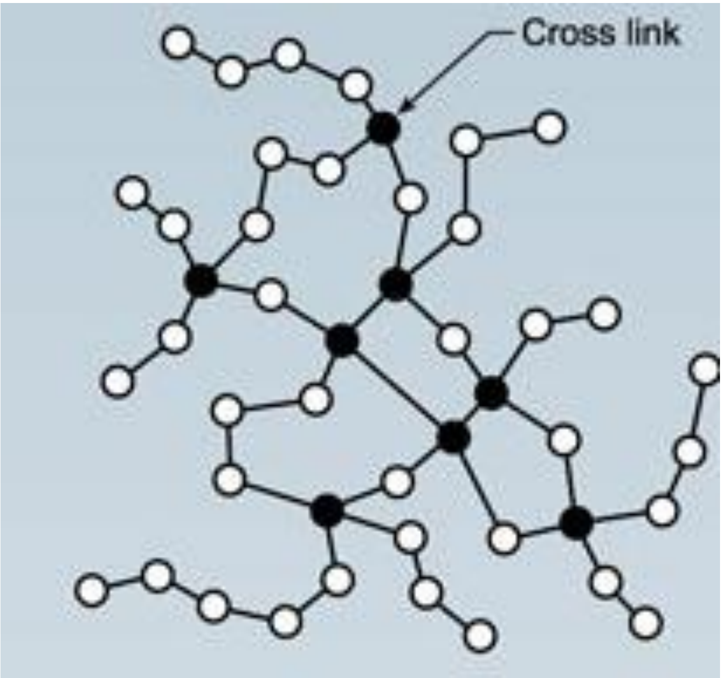
Lab: Thermoplastics

Data Chart

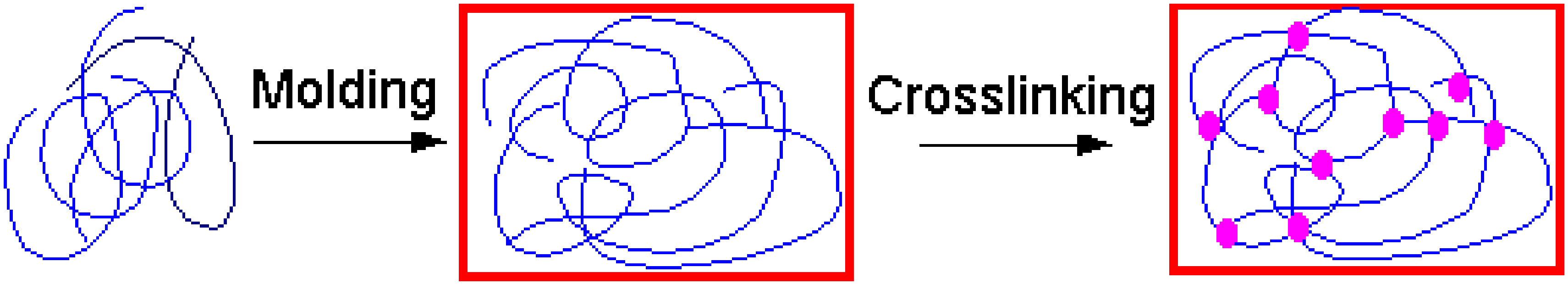
Before Heating	
After Heating	
After Cooling	

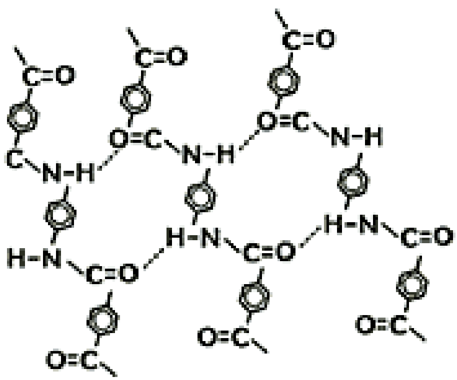
Response to Heat

Thermoset Sets with chemical reaction



Thermosets



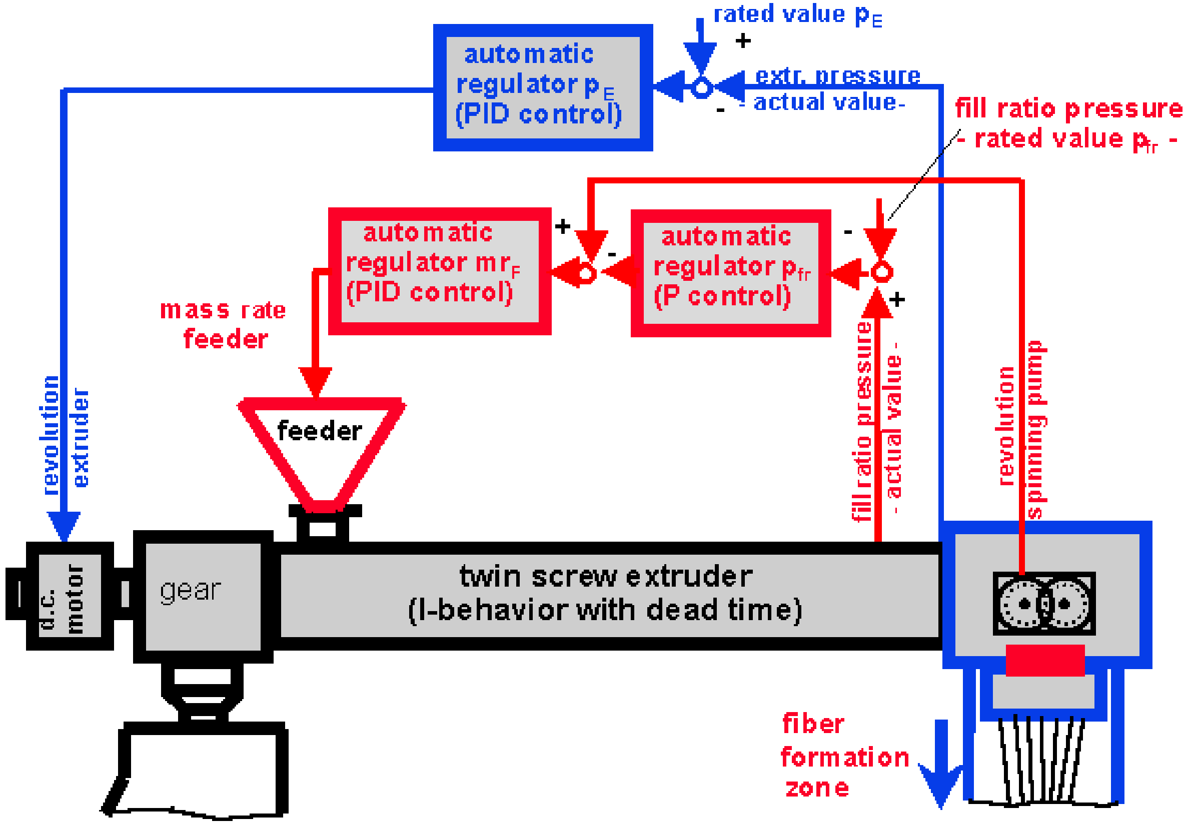


Thermosets are not recyclable and are more brittle.

Polymer Production

Polymers are formed by many low temperature processes.

Extrusion

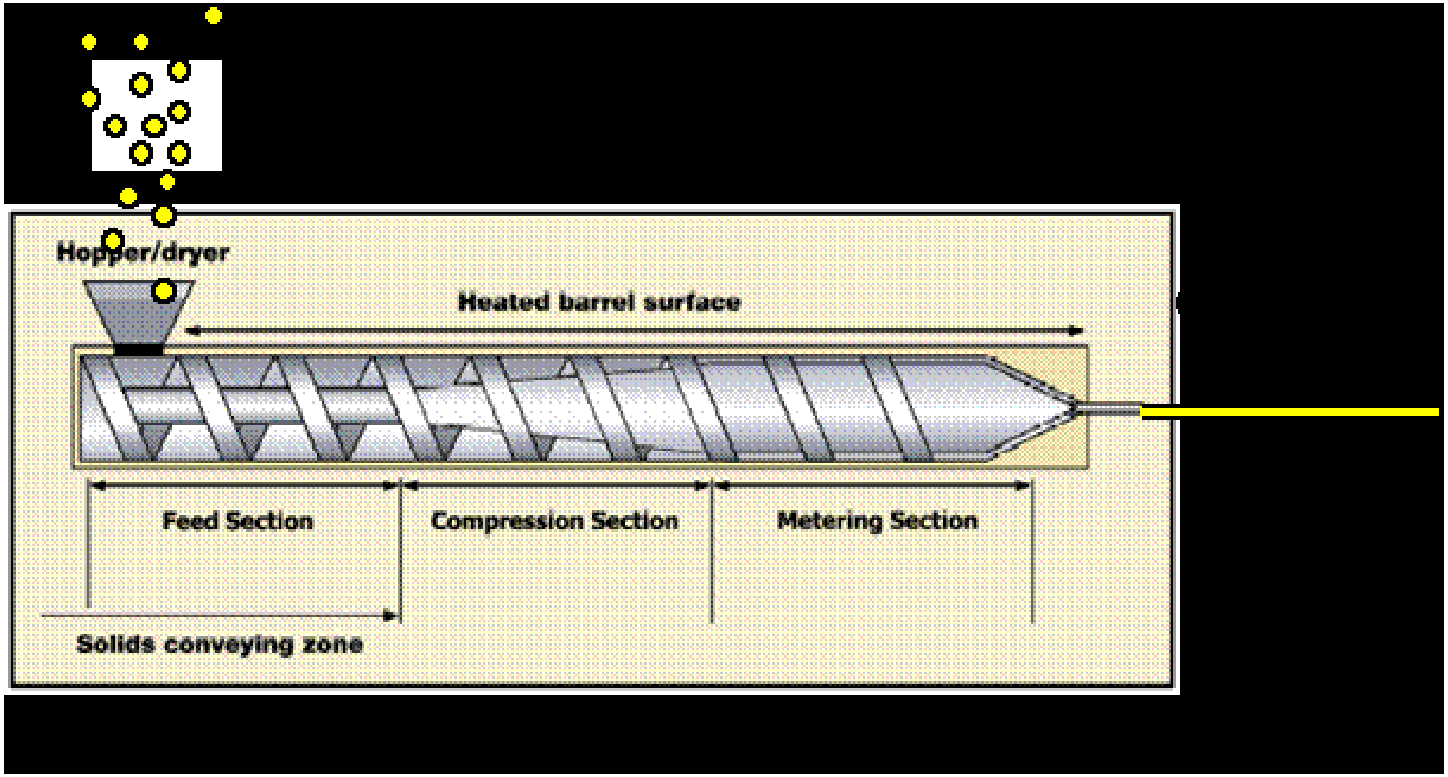


The polymer is heated to the liquid state and forced through a die under pressure.

Extrusion

This results in an endless product of constant cross section.

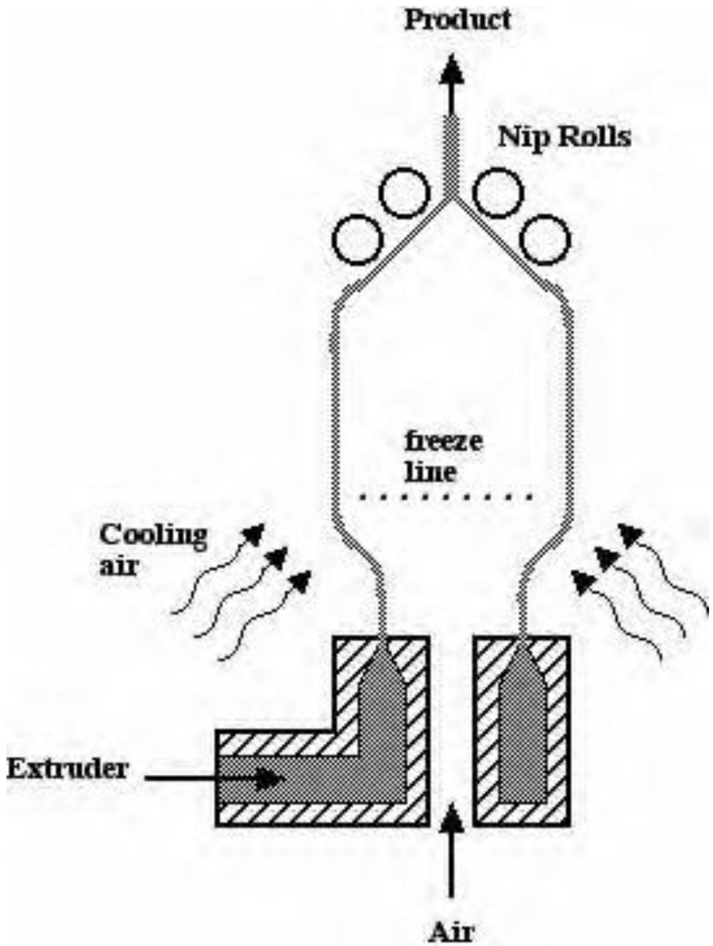
Extrusion



60% of all polymers are prepared this way.

Examples include: tubing, pipes, window frames, insulated wire.

Film Blowing

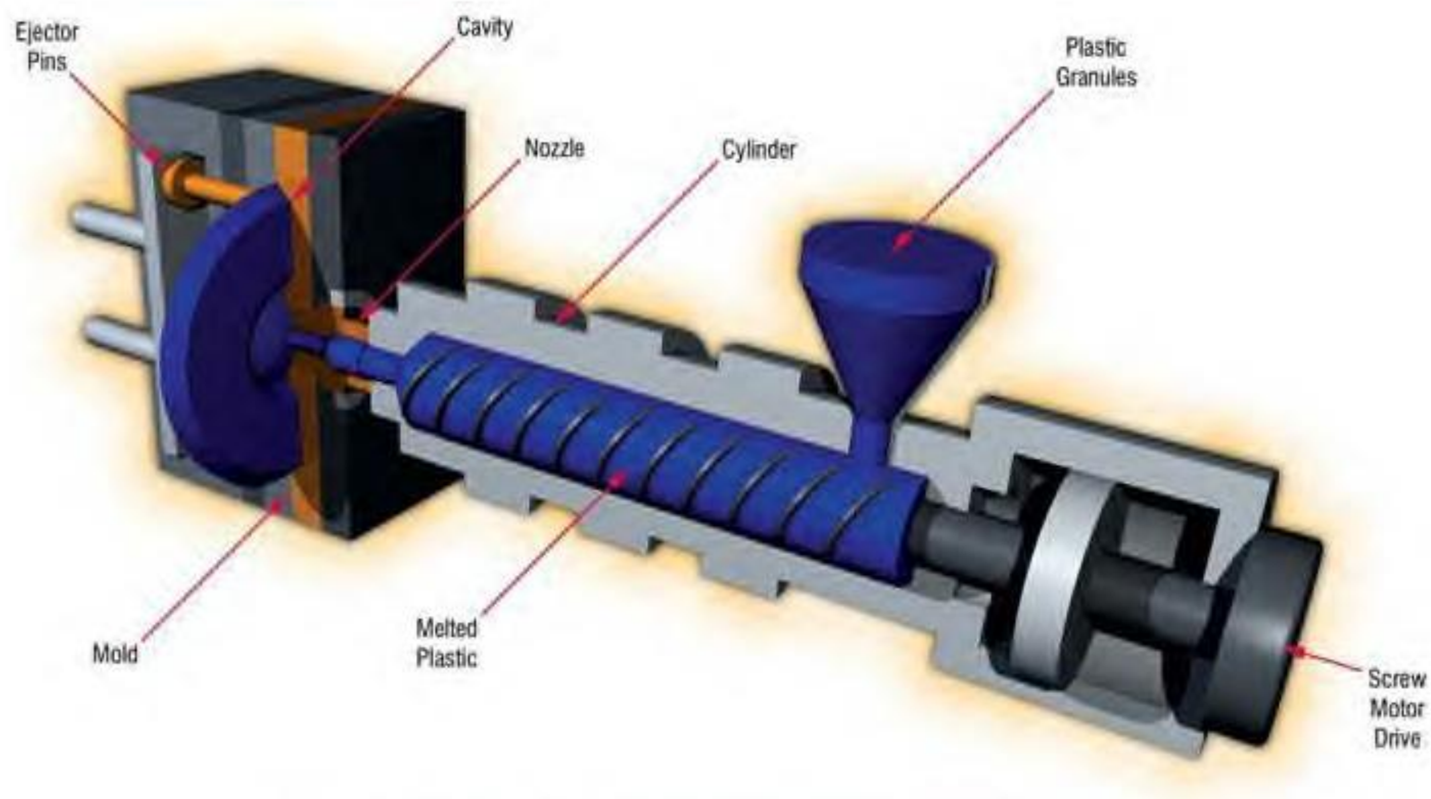


The material coming out of the die is blown into a film.

This process is used extensively with polyethylene and polypropylene.

An example is plastic wrap.

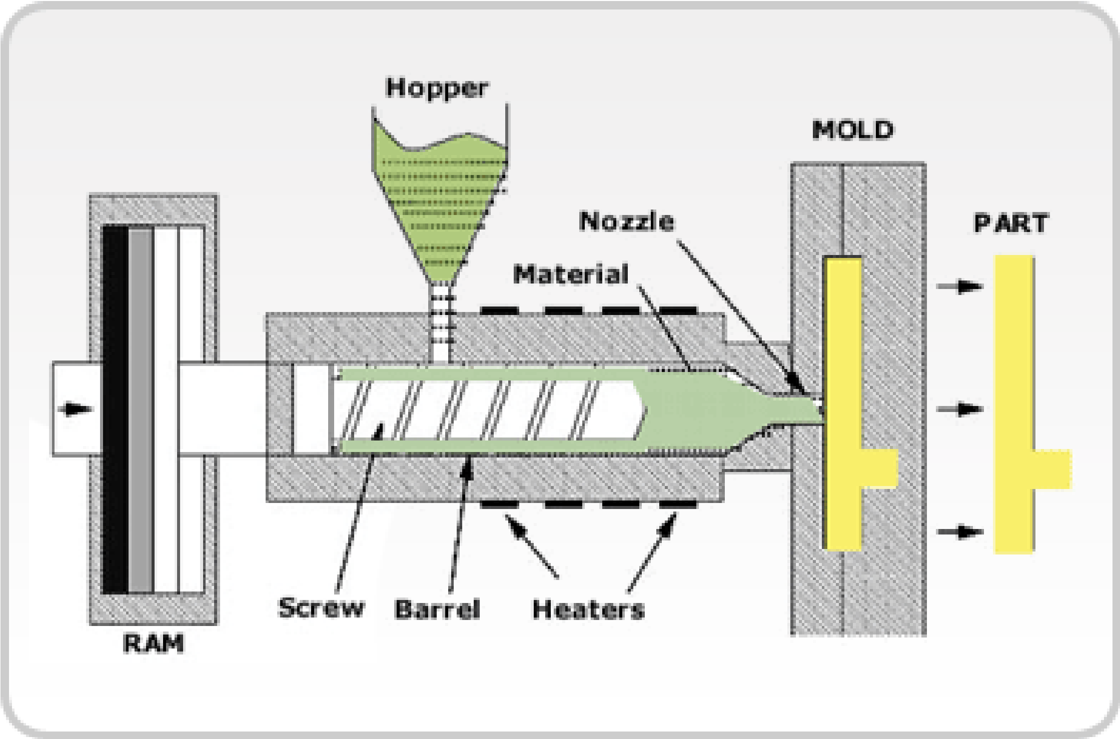
Injection Molding



Cutaway View of the Injection Molding Process

Similar to extrusion, the polymer is heated to the liquid state, but it is prepared in metered amounts.

Injection Molding

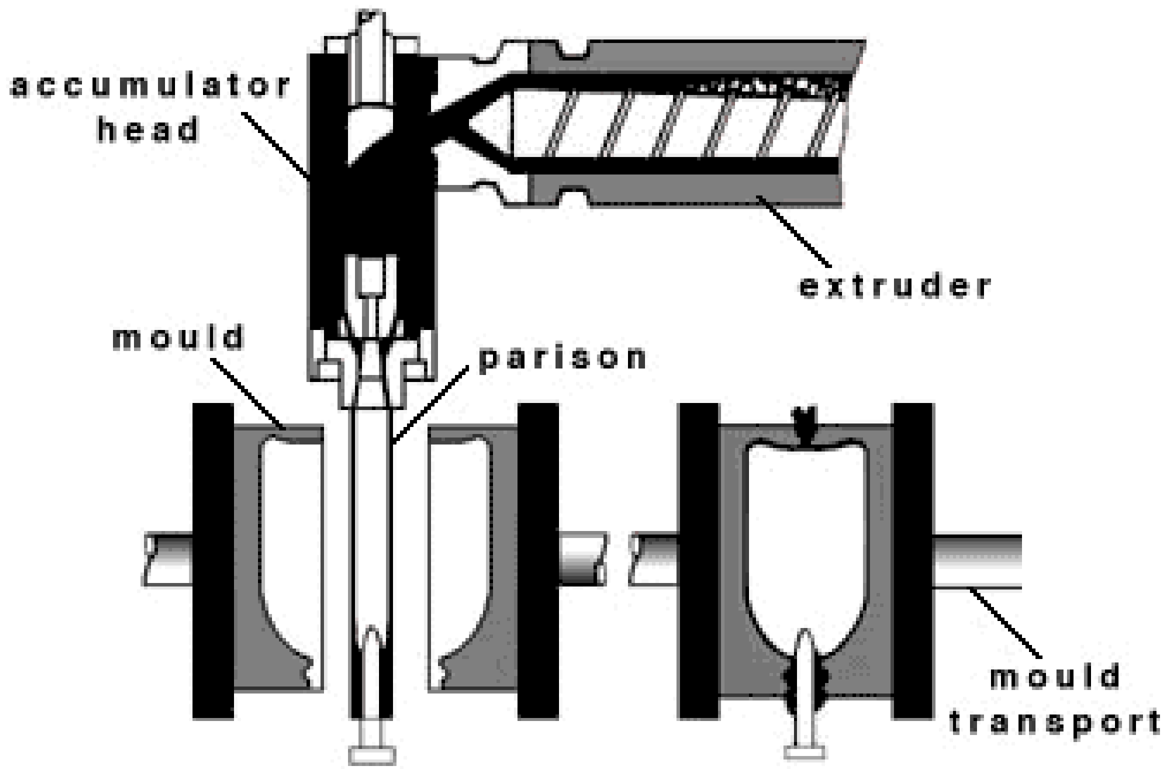


The melt is forced into a mold to create the part. It is not a continuous process.

Injection Molding

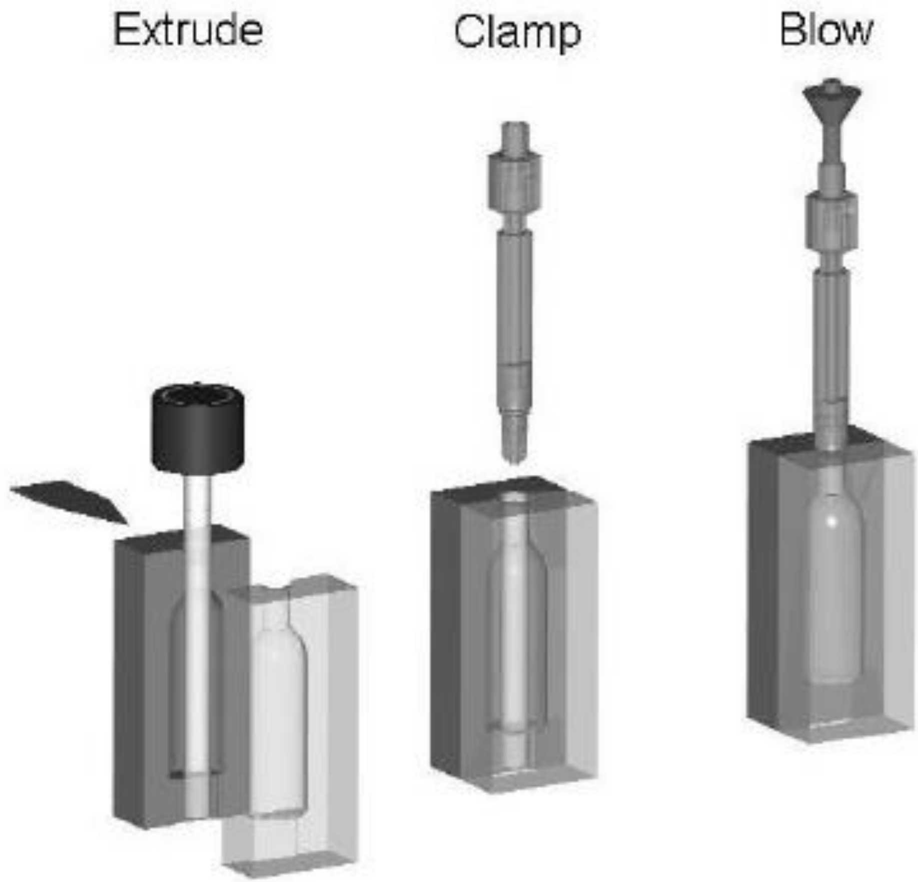
Many toys are made by injection molding.

Blow Molding



A melted polymer is put into a mold.

Blow Molding

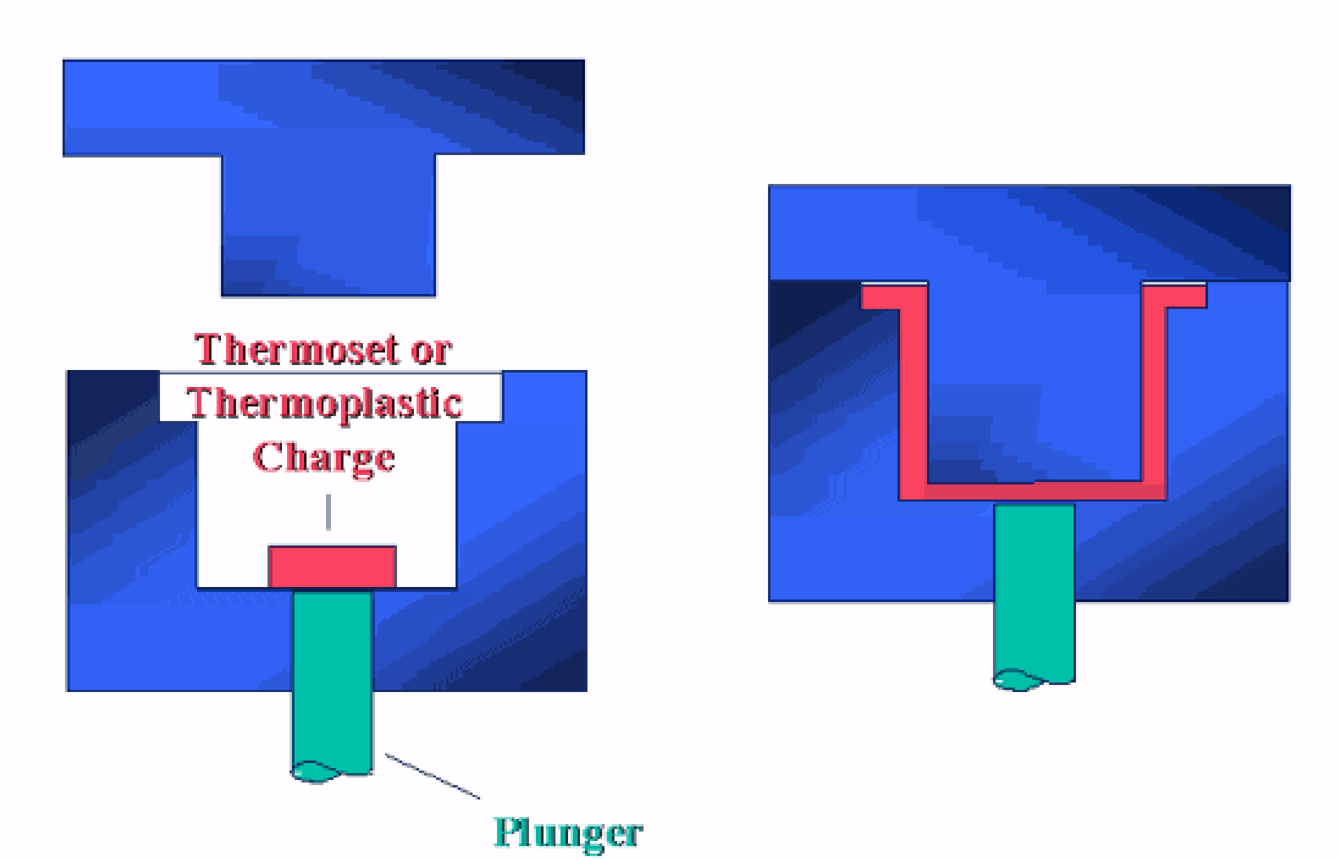


Compressed air is used to spread the polymer into the mold.

Blow Molding

This process is used to make many containers such as plastic soda containers and milk jugs.

Compression Molding



A solid polymer is placed in a mold, the mold is heated and puts pressure on the polymer to form the part.

Reaction Injection Molding