worksheets to study ecological characteristics of POLYMERS for building construction

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Building Ecological Structure Conference
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ABSTRACT – Information regarding the ecological characteristics of polymers used for building construction are varied for as many types of polymers. From a designers viewpoint, a concise and general (always dangerous) understanding of the chemical basis for polymers might be helpful to understand the resulting energy, environmental, health and end reuse (disposition) characteristics of polymers. Hopefully, this *may* help fill in the blanks in studying the ecological characteristics of these esoteric chemicals.

REFERENCES –

Excellent explanations of polymer chemical terms for taken from **Macrogalleria** web site:
http://www.psrc.usm.edu/macrog/index.htm
Dept. of Polymer Science
University of Southern Mississippi

Environmental Build News:
PVC - Vol. 3 No. 1 Jan/Feb 1994
SIPS - Vol. 7 No. 5 1998

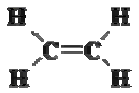
Toxicity:
Eco usa web site:
http://www.eco-usa.net/toxics/index.shtml

POLYETHYLENE

theromoplastic polymer; **vinyl** (monomer of double bonded carbon produces polymers of single bonded carbons)

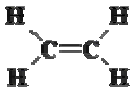
Monomer

Ethylene



Monomer derivation

Ethane
[*corrected in printed copy*]



Material resources

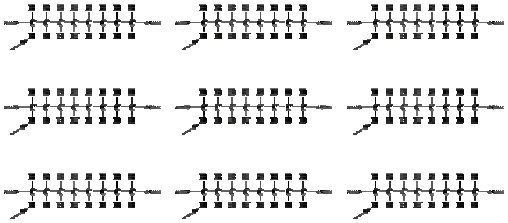
Ethane refined from **natural gas** and **crude oil** and once heated to 800°C and cracked, produces **Ethylene**.

Polymerization morphology

AMORPHOUS – *branching backbones* increases the free volume of the molecular structure, hence **LDPE**

[*corrected in printed copy*]

CRYSTALINE – Polymers with *linear backbones* allow backbones to be spaced closer, hence **HDPE.**



Uses

PLASTIC versatile as a plastic, especially films.
FIBER when formed with linear backbones.

Characteristics

MELTING 137°C
GLASS TRANSITION < negative 80°C; *rubbery state*
STRENGTH varies greatly with morphology
ULTRAVIOLET rapid degradation
HEAT low melting point
WATER very hydrophobic

Reuse

RECYCLE – Polyethylene, due to its simple composition, is technically the most recyclable of organic polymers.
DOWNCYCLE – Required in cases when co-mingled with other polymers.
DISPOSITION

Toxicity

PRODUCTION – Other than the general effects of the petrochemicals industry, polyethylene poses no specific toxins.
OCCUPANCY – polyethylene resin is not generally suspected of outgassing toxins.
DISPOSITION – Fire:

Energy

EMBODIED –.
CONSTRUCTION/OCCUPANCY –
DISPOSITION

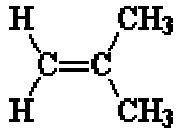
POLYISOBUTYLENE **thermoplastic** polymer; **vinyl** (monomer of double bonded carbon produces polymers of single bonded carbons); **butyl rubber**

Monomer

Monomer derivation

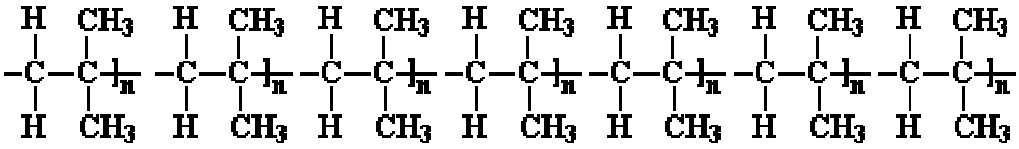
Material resources

isobutylene

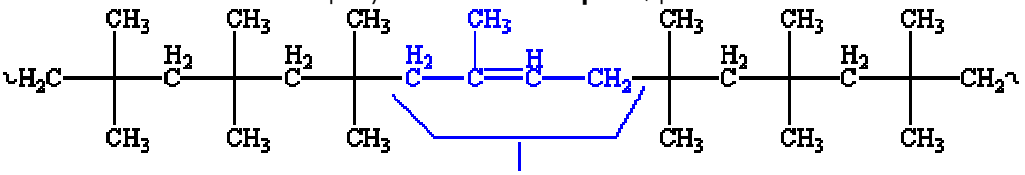


Polymerization morphology

HIGHLY AMORPHOUS – Cationic vinyl polymerization



COPOLYMERIZED – When copolymerized with **isoprene**, produces crosslinked *vulcanized rubber.*



Uses

ELASTOMERS mastic; joint sealant; gas impermeable

Characteristics

MELTING NA (amorphous)
GLASS TRANSITION negative 73°C; *rubbery state*
STRENGTH slimppery
ULTRAVIOLET
HEAT
WATER hydrophobic

Reuse

RECYCLE –
DOWNCYCLE –
DISPOSITION –

Toxicity

PRODUCTION –
OCCUPANCY – Some formulations of butyl caulk are hydrocarbon solvent curing.
DISPOSITION –

Energy

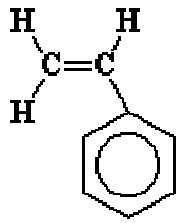
EMBODIED –
CONSTRUCTION/OCCUPANCY –
DISPOSITION –

POLYSTYRENE

thermoplastic polymer; **vinyl** (monomer of double bonded carbon produces polymers of single bonded carbons)

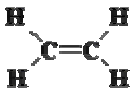
Monomer

Styrene

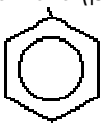


Monomer derivation

Ethylene



Benzene (phenol group)



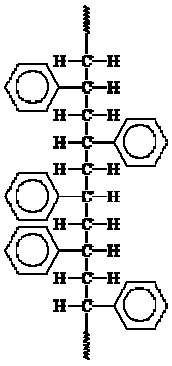
Material resources

Ethylene is produced by heating **Ethane** (C_2H_6) at 800°C. Ethane is refined from **natural gas** and **crude oil**.

Benzen is produced from naptha catalytic reformed **crude oil**.

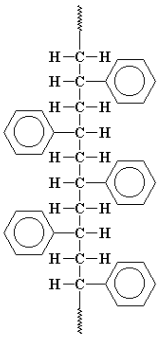
Polymerization morphology

AMORPHOUS – non-restrictive free radical vinyl polymerization produces random (atactic) phenol group arrangement on backbone



GRAPHTED - other polymers are connected to the backbone to form copolymers

CRYSTALINE - metallocene initiators (crystals of **Chlorine** and **Aluminum** or **Titanium**) allow controlled polymerization to produce alternating phenol groups (syndiotactic)



POLYSTYRENE

thermoplastic polymer; **vinyl** (monomer of double bonded carbon produces polymers of single bonded carbons)

Uses

PLASTIC versite uses as a plastic **.**

- Foamed with **blowing agents** to produce expanded and extruded polystyrene.

ELASTOMER when coplomerized with **butadiene** to produce higher impact strength characteristics

Characteristics

MELTING 270°C
GLASS TRANSITION 100°C
STRENGTH varies with morphology
ULTRAVIOLET rapid degradation
HEAT
WATER very hydrophobic

Reuse

RECYCLE – Polystyrene is technically very recyclable when in purer form without downcycling.
DOWNCYCLE – Required in cases when co-mingled with other polymers
DISPOSITION

Toxicity

PRODUCTION – Benzene is Department of Health and Human Services (DHHS) known human carcinogen. As many as 238,000 people may be occupationally exposed to benzene in the United States, mainly in the petrochemicals industry with exposure to the highly flammable and quickly evaporating colorless liquid as an atmospheric gas. **Styrene** is a possible but not confirmed human carcinogen and breaks down in the environment fairly quickly depending upon conditions.
OCCUPANCY – Without regard to **foaming agents**, polystyrene resin is not suspected of outgassing toxins.
DISPOSITION – Fire:

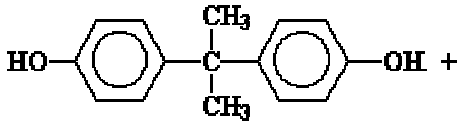
Energy

EMBODIED –.
CONSTRUCTION/OCCUPANCY –
DISPOSITION

POLYCARBONATE **theromoplastic** polymer; **vinyl** (monomer of double bonded carbon produces polymers of single bonded carbons); lexan ®

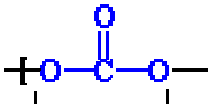
Monomer

bisphenol A



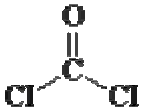
Monomer derivation

carbonate goup used to link



Material resources

phosgene



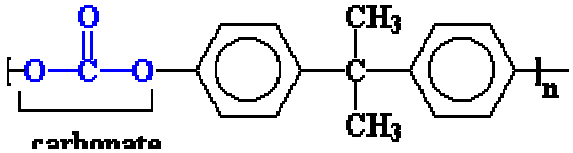
sodium hydroxide

+ NaOH

.

Polymerization morphology

AMORPHOUS – interfacial polymerization



Uses

PLASTIC very durable transparent glazing

Characteristics

MELTING NA (amorphous)
GLASS TRANSITION 150°C; *glassy state*
STRENGTH
ULTRAVIOLET little degradation
HEAT good resistance
WATER very hydrophobic

Reuse

RECYCLE –
DOWNCYCLE –
DISPOSITION –

Toxicity

PRODUCTION – Possible risk of exposure to **phosgene gas.**
OCCUPANCY – Chlorine in the phosgene is removed with the **sodium** in the carbonate linking process, hence these chemicals are not present in the end use polymer.
DISPOSITION – Fire:

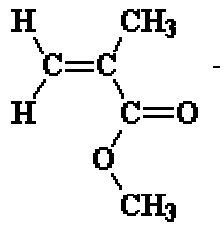
Energy

EMBODIED –.
CONSTRUCTION/OCCUPANCY –
DISPOSITION

POLY METYL METHACYLATE **theromoplastic** polymer; **vinyl** (monomer of double bonded carbon produces polymers of single bonded carbons); lucite ®; plexiglass®

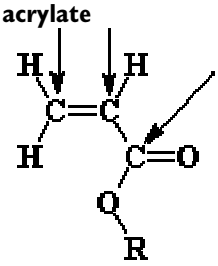
Monomer

Methyl methacylate



Monomer derivation

acrylate

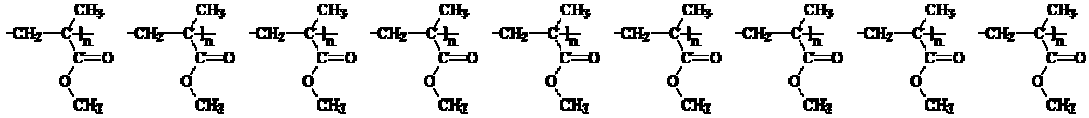


Material resources

Polymers formed of **acrylate** monmers are commonly called **acrylics**.

Polymerization morphology

AMORPHOUS – free radical vinyl polymerization



Uses

PLASTIC very durable transparent glazing

Characteristics

MELTING NA (amorphous)
GLASS TRANSITION 120°C; *glassy state*
STRENGTH
ULTRAVIOLET some degradation
HEAT
WATER very hydrophobic

Reuse

RECYCLE –
DOWNCYCLE –
DISPOSITION

Toxicity

PRODUCTION –
OCCUPANCY –
DISPOSITION – Fire:

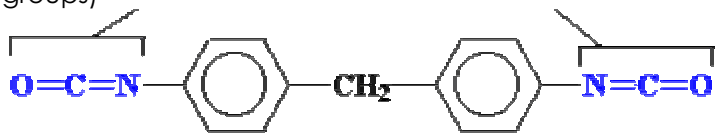
Energy

EMBODIED –.
CONSTRUCTION/OCCUPANCY –
DISPOSITION

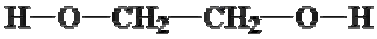
POLYURETHANE **theromosetting** polymer created with linkages of urethane

Monomers

DIISCOCYANATE (carbon cahins ending in two cyanate groups)



DIOL (carbon cahins ending in two alcohol groups) such as **ethelene glycol:**

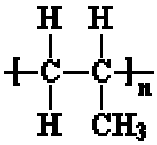


other diols are **propylene glycol** (used in urethane foam insulation) and **poly(ethelene glycol)** which itself, as a polymer, can be large.

Monomer derivation

methyl diiscocyanate (**MDI**; a diiscocyanate) is made by reacting **nitobenzene** with **formaldehyde** and **phosgene**.

propylene glocol [*corrected in printed copy*]

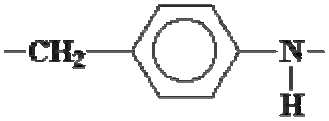


(a diol) is made by oxidizing **propylene** (the same vinyl monomer used to make **polypropylene**)

Material resources

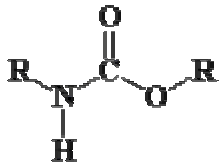
propylene is refined from **crude oil**

benzene (from crude oil) is combined with **nitric acid** (from natural gas) to produce **nitobenzene**

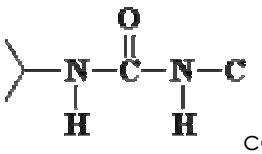


Polymerization morphology

URETHANE LINKAGE
typical of urethanes:

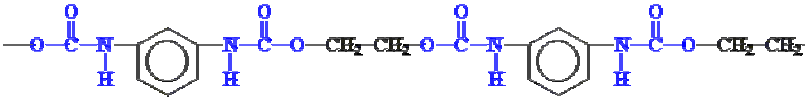


UREA LINKAGE
typical of ureas,



can also be used to link other polymers which make up polyurethane.

Urethane linkage can be used to combine large range of different iscocyanates and diols.



BLOCK COPOLYMER morphology allows each iscocyanate or diol to in turn be made of other polymers.

POLYURETHANE **theromosetting** polymer created with linkages of urethane

Uses

FOAM – the diiscocyanate portions can produce rigid crystalline structures providing to be engineered for different physical characteristics; joint sealants; coatings.Diiscocyanate links when block copolymerized produces very crystalline structure.
ELASTOMER – the diol portions can produce rubbery and flexible sections allowing polyurethanes to be engineered for different physical characteristics; joint sealants; coatings.
FIBER – The rigid crystalline diiscocyanate portions used in combination with rubbery diol portions can produce fibers with special properties; spandex

Characteristics

MELTING NA
GLASS TRANSITION NA
STRENGTH varies widely with morphology
ULTRAVIOLET rapid degradation
HEAT
WATER generally hydrophobic

Reuse –

RECYCLE – The diiscocyanate portions of polyurethane are themosetting and can not recycled into polymenrs again.
DOWNCYCLE – Rigid foam can be ground only for use as filler in other processes.
DISPOSITION

Toxicity

PRODUCTION – Benzene is a Department of Health and Human Services (DHHS) known human carcinogen. As many as 238,000 people may be occupationally exposed to benzene in the United States, mainly in the petrochemicals industry with exposure to the highly flammable and quickly evaporating colorless liquid as an atmospheric gas. **Iscocyanate** in the liquid form can cause pylmenory endima and other accute injury or death. Possible risk of exposure to **phosgene gas.**
OCCUPANCY – Without regard to **foaming agents**, polyurethane resin is not suspected of outgassing toxins. However polyurea resins often used to make up polyurethane do outgass **urea formaldehyde**
DISPOSITION – Fire: Iscocyanate, when burned, can produce toxic gases.

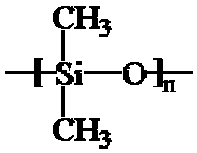
Energy

EMBODIED –.
CONSTRUCTION/OCCUPANCY –
DISPOSITION

POLY(DIMETHYL SILOXANE) **theromoplastic** inorganic (non-carbon) polymer; a "silicone"

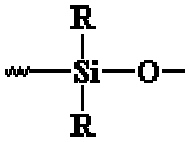
Monomer

dimethyl siloxane



Monomer derivation

siloxane (the backbones of silicone are alternating silicone and oxygen)



Material resources

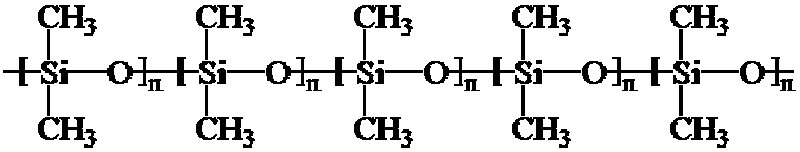
silioxane

Methane refined from **natural gas** and **crude oil**.

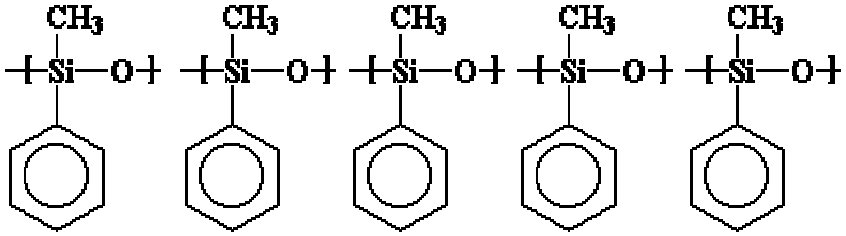
Polymerization morphology

POLYSILOXANES are similar to the chemical structures of carbon chains in forming polymers. Any organic group can attached to the backbone.

poly(dimethyl siloxane)



polymethylphenylsiloxane



formed with phenol groups (analogous to polystyrene)

POLY(DIMETHYL SILOXANE) **theromoplastic** inorganic (non-carbon) polymer; a "silicone"

Uses

ELASTOMER – The nature of oxygen and silicone bonds making up the backbone of polysiloxanes is very flexible; joint sealant.

Characteristics

MELTING NA (amorphous)
GLASS TRANSITION negative 130°C; *rubbery state*
STRENGTH great varieties of morphology allows extremely stiff formulations; structural silicone glazing
ULTRAVIOLET
HEAT great varieties of morphology allows extremely resistant formulations; aerospace heat tiles
WATER can be very hydrophobic; joint sealant

Reuse

RECYCLE –
DOWNCYCLE –
DISPOSITION –

Toxicity

PRODUCTION – Varies widely with organic groups attached.
OCCUPANCY – Varies widely with organic groups attached.
DISPOSITION – Fire:

Energy

EMBODIED –.
CONSTRUCTION/OCCUPANCY –
DISPOSITION –