

# Lecture 29 November 20, 2009

**Polymers: Synthesis, Properties, & Applications** 



### 3.091 Test #3 "celebration part 3" Monday, November 23, 2009



defects amorphous solids kinetics diffusion solutions acids & bases no orgo no polymers

Makeup test December 2 during class





Structure	Chemical Name	Trade Name or Common Name
(CH2CH2)n	polyethylene	
$(-CF_2-CF_2-)_n$	poly(tetrafluoroethylene)	Teflon
$(-CH_2-CH-)_n$	polypropylene	Herculon
CH <sub>3</sub> CH <sub>3</sub>		
$(-CH_2-C-)_n$	polyisobutylene	butyl rubber
$(-CH_2-CH)_n$	polystyrene	
$(-CH_2-CH-)_n$	polyacrylonitrile	Orlon
$(-CH_2-CH-)_n$	poly(vinyl chloride)	PVC
$(-CH_2-CH-)_n$	poly(methyl acrylate)	
CO <sub>2</sub> CH <sub>3</sub> CH <sub>3</sub>		
$(-CH_2-C-)_n$	poly(methyl methacrylate)	Plexiglas, Lucito
CO <sub>2</sub> CH <sub>3</sub> H H		
$(-CH_2-C=C-CH_2-)_n$	polybutadiene	
$(-CH_2-C=CH-CH_2-)_n$ H CH <sub>3</sub>	polychloroprene	neoprene
$(-CH_2-C=C-CH_2-)_n$ H	poly(cis-1,4-isoprene)	natural rubber
$(-CH_2-C=C-CH_2-)_n$	poly(trans-1,4-isoprene)	gutta percha

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View as acid /base reaction

HO - C - C - OH1,4 benzene dicarboxylic acid Terephthalic acid HOCH<sub>2</sub>CH<sub>2</sub>OH Ethylene glycol (1,2-Ethanediol) - 0 - bridges  $\begin{bmatrix} 0 \\ -C \\ -OCH_2CH_2O \end{bmatrix} + n H_2O$ A polyester (Dacron, Mylar)

poly (ethylene terephthalate) PET

Courtesy of John Wiley & Sons. Used with permission. Source: Spencer, J. N., G. M. Bodner, and L. H. Rickard. Chemistry: Structure and Dynamics. 2nd edition, supplement. New York, NY: John Wiley & Sons, 2003.



#### silicone rubber

#### TABLE P.2 Common Condensation Polymers

CH<sub>3</sub>

 $CH_3$ 

 $(-O-Si-)_n$ 



#### Siloxanes

Silicones



poly(dimethylsiloxane) PDMS



#### chain 1

chain 2

chain 3

"Mister Cellophane" from the musical *Chicago* 

Image from the film *Chicago* removed due to copyright restrictions.

### **Polythene Pam**

### (Lennon/McCartney)

Lyrics removed due to copyright restrictions. "Polythene Pam." The Beatles. *Abbey Road* (1969).



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-0-CH2-CH2-0-

poly(ethylene terephthalate) (PET)

Invented by J.R. Whinfield and J.T. Dickson, 1940. Uses: clothing, plastic films, plastic bottles

+CH2-CH2+

high-density polyethylene (HDPE)

Invented by Robert L. Banks and J. Paul Hogan, 1951. Uses: plastics of all kinds, high-strength fibers

HDPE

-+сн₂-сн-+п

poly(vinyl chloride)

Invented by Waldo Semon, 1926. Uses: water pipes, LP records, vinyl car tops

LDPE

+CH2-CH2+

low-density polyethylene (LDPE)

Invented by Eric Fawcett and Reginald Gibson, 1935. Uses: plastic films, bags

Courtesy of Chemical Heritage Foundation. Used with permission.



PS

OTHER



polypropylene (PP)

Invented by Robert L. Banks and J. Paul Hogan, 1951. Uses: fibers for rope, indoor-outdoor carpeting, plastics



polystyrene (PS)

Invented by Eduard Simon, 1839. Uses: rigid plastics of all kinds, polystyrene foams Hermann Staudinger 1922 (Nobel 1953)

> anything else, including items made from more than one kind of polymer

Courtesy of Chemical Heritage Foundation. Used with permission.

### Wallace Carothers

- \* b. April 27, 1896, Burlington, Iowa
- \* B.S., Tarkio College (gen. sci. & Eng.)
- \* Ph.D., U. of Illinois
- \* lecturer Harvard



- \* head of fundamental research in organic chemistry at DuPont; synthesis of long-chain molecules similar to cellulose and silk
- \* invented neoprene 1931: synthetic rubber
- \* invented nylon 1937: Synthetic fiber
- \* m. February 1936
  \* d. April 29, 1937, Philadelphia
  62 technical publications
  69 patents



### Wallace Carothers (1896 – 1937)

Courtesy of the Hagley Museum and Library. Used with permission.

### nylon rope pull:

\* beaker synthesis of nylon 6,6 by condensation polymerization:

- \* industrially this reaction is conducted at 280°C in the absence of solvents
- \* lab demo uses two immiscible solvents (water and hexane) and dissolves a reactant in each: reaction occurs only at the interface

 $H_2N-(CH_2)_6-NH_{2(aq)} +HO_2C-(CH_2)_4-CO_2H_{(hexane)}$ 

 $\Rightarrow$  -NH(CH<sub>2</sub>)<sub>6</sub>NH-C(CH<sub>2</sub>)<sub>4</sub>C- + H<sub>2</sub>O



		norbornene	isoprene
	(°C)		
b.p. H <sub>2</sub> O	100	elastic	elastic
T <sub>g</sub> norbornene	40		
room temp	21	tough	elastic
T <sub>g</sub> isoprene	-70		
b.p. N <sub>2</sub>	-196	tough	tough

## pattern of adoption

wonder substitution innovation concern carbolic acid

#### formaldehyde

phenolic resin

AT breakfast, your wife pours you a cup of coffee; the handle she takes hold of on the percolator is of made Bakelite, as well as the button under the table she presses for service, and the twinlight plug from which are carried the wires to the toaster.

The Material of a Thousand Uses BAKELITE

Advertisement, 1926.



#### Plastics in 1940

Misonal defense is smoking out the "plastic plane" and much more. Plastinger a \$500,000,000-a-year business now, and growing up fast.

Somewhere the series are rearry and up of the infant U.S. phonics isolating theory and a series of the series of t

CALL IT "AN AMPRICAN DRUGAR OF VENN" Bronness discriming processing of the second control of the backbards development are up from the photo to obmentalised developments are uppercent the functions receipting juncpendiate, ending packets of the area worth of proteins, are easily transferried and packets. Note below, for control, are easily transferried and packets. Note below, or proteins, the easily transferried and packets. Note below, or proteins the analysis transferried and backbard on teaching planes for groups for house to 8 continues.

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Jake Belling and and



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#### room of sprayed polyurethane foam by Douglas Deeds for "Plastic as Plastic" exhibition at Museum of Contemporary Crafts, New York, 1968

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# Plastics: The Future Has Arrived After only a century of plastics, man has created the completely abstract, totally synthetic environment. P. Harr, Hechsleich, B.

# plastic

- the Greek πλασσειν = to shape
   cognates include "potter"
   πλαστικος = can be shaped (malleable?)
- Samuel Johnson wrote:
  - "Benign Creator, let Thy plastick hand Dispose its own effect."

US annual prod<sup>n</sup> of polymers: 100 billion lb = 50 million tons 3 - 4 million tons recycled

### cf. steel - US annual prod<sup>n</sup>: 140 million tons - 80 million tons virgin metal - 60 million tons recycled scrap

US annual prod<sup>n</sup> of polymers: 100 billion lb = 50 million tons 3 - 4 million tons recycled

cf. aluminum - US annual prod<sup>n</sup>: 4 million tons 1 million tons recycled 62% return rate on UBCs (DFE)

### american a cultural plastic h i story

jeffrey meikle

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3.091SC Introduction to Solid State Chemistry Fall 2009

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