2012

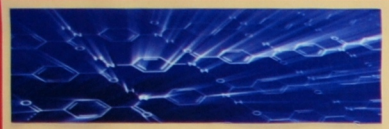
Mechanochemically Active Polymers

Laura Ward
Parkland College

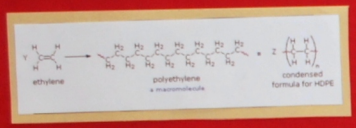
Mechanochemically Active Polymers

Laura Ward
Parkland College
Chemistry 102-001
Christina Beatty

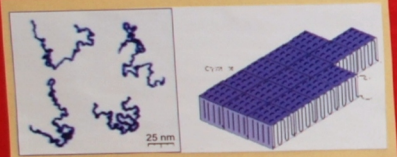
What are Polymers?



- Polymers are large molecules composed of many basic repeating units called monomers.
- Molecular Weights can range from 10,000 to over 100,000 amu.
- Polymers are typically organic, covalently bonded molecules.
- Composed mainly of Carbon, Hydrogen, Oxygen, Nitrogen and Silicon atoms.



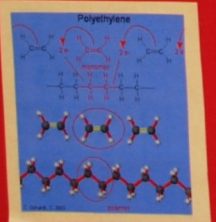
Molecular Arrangement



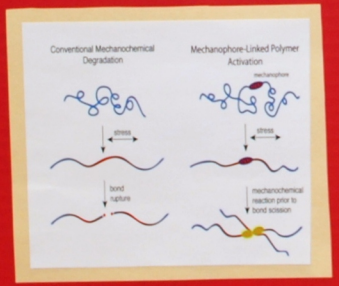
- The molecular structure of polymers varies by type from crystalline to amorphous.
- Crystalline polymers have atoms arranged in a set order or pattern.
- Amorphous polymers have a completely random molecular arrangement.
- Engineers alter the properties of polymers by changing the molecular arrangement.

Polymerization

- Monomers react to form polymers via the process of polymerization.
- The simplest of this type of reaction is called addition polymerization.
- Involves the movement of electrons by splitting a double bond into a single bond.

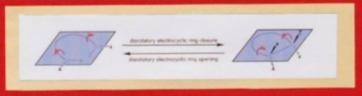


- Mechanochemically active polymers have been designed to contain clusters of chemically sensitive groups called mechanophores.
- Mechanophores are added directly to the backbone of the polymer
- Mechanophores allow for more selective breaking of covalent bonds when a force is applied without weakening the overall material.

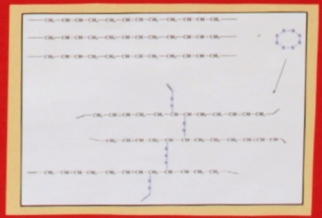


Mechanophores

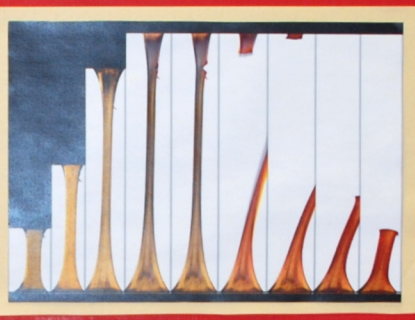
- Mechanophores also have the advantage of being able to respond to stress and react to change color before failing.
- This reaction occurs through the process of electrocyclic ring closure.
- In this process a pi bond is converted into a ring forming sigma bond.



Cross-Linking



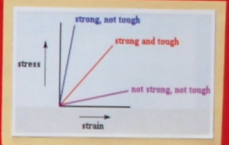
- During polymerization the addition of heat, specific molecules, or irradiation can allow for bonds to form between the polymer chains.
- Such cross-linking improves the strength and durability of the polymer and increases its functionality.
- Links polymer chains so they cannot move past each other.



Mechanical Properties

Strength vs. Toughness

- Tensile strength measures how far a material can be stretched before it fails.
- Compressional strength conversely measures how far a material can be compacted.
- **Measures how much force is required to break a material.**
- The toughness of a material is the area under a stress-strain curve.
- A material that is strong but not tough is said to be brittle. Brittle substances are strong, but cannot deform very much.
- **Measures how much energy is required to break a material.**



Stress & Strain

- Whenever a force is applied to a material some degree of deformation takes place.
- A material will return to its original condition until a specific amount of force is applied, once past that point deformation is permanent.
- How a polymer reacts to stress depends on its viscoelastic properties.
- Once a critical stress is reached the material will fail.

Conclusion

- The main goal of polymer engineering is to produce materials that are able to heal themselves when exposed to a damaging stress.
- Awareness of mechanical state through mechanophores is an important intermediate to that step.

Applications include:

- Incorporation into ropes used in rock climbing.
- Use in airplane fuselages to detect damage.
- Use in essentially any polymer or polymer composite product to detect damage.

Sources

- Burdge J.; Chemistry, 2nd ed.; McGraw-Hill: New York, 2011; 1000-1009
- http://autonomic.beckman.illinois.edu/Nature_Concept2.html, Beckman Institute, University of Illinois at Urbana-Champaign, "Mechanochemically Active Polymers," Copyright 2009
- Kucharski T.; Boulatov R. The Physical Chemistry of Mechanoresponsive Polymers. J. Mater. Chem. [online] 2011, 21, 8237-8255
- Polymers. http://www2.chemistry.msu.edu/faculty/reusch/VirtTxtJml/polymers.htm (accessed 3/14/12).
- Polymer Crystallinity. http://faculty.uscupstate.edu/llever/Polymer%20Resources/Crystalline.htm (accessed 3/12/12).
- Potisek, S.L.; Davis, D.A.; Sottos, N.R.; White, S.R.; and Moore, J.S. Journal of the American Chemical Society. 2007, 129, 1380-1388.