Lecture 1: Glass All Around Us: An Overview of Glass and Some Contemporary Applications

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Glass - a Word With Many Meanings
-a Ubiquitous Material with many faces
and in many places

Some common examples:
## Glass – An Enabling Technology for Greatest Engineering Achievements of the 20th Century

**National Academy of Engineering identified**

20 Greatest Engineering Achievements of the last Century

<table>
<thead>
<tr>
<th>Achievements</th>
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</thead>
<tbody>
<tr>
<td>1. Electrification</td>
<td></td>
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<td>2. Automobile</td>
<td></td>
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<td>3. Airplane</td>
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<td>4. Water Supply and Distribution</td>
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<tr>
<td>5. Electronics</td>
<td>11. Highways</td>
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<tr>
<td>7. Agricultural Mechanization</td>
<td>13. Internet</td>
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<tr>
<td>9. Telephone</td>
<td>15. Household Appliances</td>
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<tr>
<td>10. Air Conditioning and Refrigeration</td>
<td>16. Health Technologies</td>
</tr>
<tr>
<td>11. Highways</td>
<td>17. Petroleum and Petrochemical Technologies</td>
</tr>
<tr>
<td>12. Spacecraft</td>
<td>18. Laser and Fiber Optics</td>
</tr>
<tr>
<td>13. Internet</td>
<td>19. Nuclear Technologies</td>
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</tbody>
</table>

More than half of these utilize advances in glass as an enabling technology! And this list does not include lighting.

**A Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives**

[http://www.greatachievements.org/](http://www.greatachievements.org/) See also timeline
Contributions of Glass to 20th Century Mechanical Engineering Achievements

Am. Soc. Mechanical Engineers (ASME) has also published a list of the 17 most significant mechanical engineering achievements of the past century. Four of the 17 are directly related to glass technology:

- Bottle Manufacturing
- Glass Manufacturing
- Ribbon Machine (for manufacturing light bulbs)
- Xerography

http://www.asme.org/Communities/History/Resources/20th_Century_Achievements.cfm
Some Important Properties of GLASS
- you likely already know from experience

Hard
Brittle (cracks and chips rather than deform)
Usually clear (or transparent)
Resistant to corrosion (acids and bases)
Good insulators (electrical and thermal)
Softens gradually and can be formed on heated
   (vs rapid melting of crystals at $T_{\text{melt}}$)

Pause for melting demo
Amorphous vs. Crystalline Structure and Its Influence on Properties

• Glass is an amorphous solid and unlike the crystal does not have a repeating molecular structure
• An amorphous solid resembles a frozen liquid
  ➢ Results in the gradual softening vs. sharp melting
• Without crystals there are no crystal boundaries or defects to deform
  ➢ Results in brittle fracture

Structure and properties will be a regular, repeated theme of the course


Most Common Glasses are Mixtures of Silica and Other Oxides

The most common, soda lime glass is cartooned below:

\[ \text{SiO}_2 \text{ (Sand)} + \text{Ca CO}_3 \text{ (Lime)} + \text{Na}_2\text{CO}_3 \text{ (Soda Ash or Washing Soda)} \]

Glass made for SiO\(_2\) alone (fused Silica) has excellent properties but requires enormous temperatures (> 2000º C) to melt and process.
### Some Common Types of Oxide Glass and their Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Silica</th>
<th>Soda-lime-silicate</th>
<th>Borosilicate</th>
<th>Pb-silicate-borate</th>
<th>Aluminosilicate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting</td>
<td>~2200°C</td>
<td>~1450°C</td>
<td>~1650°C</td>
<td>~900-1400°C</td>
<td>~1650°C</td>
</tr>
<tr>
<td>Max service temperature</td>
<td>~1000°C</td>
<td>~500°C</td>
<td>~520°C</td>
<td>~270-460°C</td>
<td>~700°C</td>
</tr>
<tr>
<td>Thermal exp coefficient</td>
<td>5.5×10⁻⁷/°C</td>
<td>~90×10⁻⁷/°C</td>
<td>30-50×10⁻⁷/°C</td>
<td>~90-150×10⁻⁷/°C</td>
<td>~50×10⁻⁷/°C</td>
</tr>
<tr>
<td>Chemical durability</td>
<td>vvv good</td>
<td>good</td>
<td>v good</td>
<td>good</td>
<td>vvv good</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>vvv low</td>
<td>low</td>
<td>low</td>
<td>v low</td>
<td>v - vvv low</td>
</tr>
<tr>
<td>Working range</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>long</td>
<td>------</td>
</tr>
<tr>
<td>UV - transparency</td>
<td>high</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Refractive index</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>high</td>
<td>------</td>
</tr>
<tr>
<td>Elastic modulus</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>COST</td>
<td>high</td>
<td>v low</td>
<td>medium</td>
<td>low</td>
<td>medium</td>
</tr>
</tbody>
</table>

### APPLICATIONS
- **Furnace tubes, crucibles for Si melting, UV windows**
- **Container, flat, incandescent/fluorescent lamps**
- **Chemical labware, pharmaceutical/cosmetics ware, auto headlamps**
- **'Crystal' ware, art/intricate shapes, sealing glasses**
- **Halogen lamp, Fiber-reinforced plastics**
A Walk Through Some Contemporary Applications of Glass
Sampling the Scope of this Enabling Material

Intended to show the wide range of less well known applications of glass. Many of these will be covered in future lectures, others are meant just to wet your appetite for further reading. All lectures will continue to blend the science with the applications and provide the background for your deeper understanding of these and other glass technologies.
Optical Fiber Communication – Enabling the Internet

The Glass Optical Fiber

Kao – 2009 Nobel Prize for inventing

Allows data on light to be sent
Very fast (40G/sec in use)
Very Far (100 km typical)
at 0.2 dB/km – loses half power in 10Km (~ 7 miles).

Light is guided down the fiber
Via total internal reflection
Actual fiber has high index core.

An excellent tutorial by ARC Electronics at http://www.arcelect.com/fibercable.htm
While most glass applications require the avoidance of crystallization to achieve high transparency and good flow properties for formability, some very important applications incorporate controlled crystallization to achieve improved properties such as low thermal expansion and toughness.

Corning® Pyroceram® Glass-Ceramic

Originally developed in 1950’s for use in missiles nose-cones. This glass-ceramic is extremely durable, corrosion resistant and has a very low coefficient of expansion. It is also transparent to radar, which made it ideal for use as nose-cones on anti-aircraft missiles.

Vision-ware from Corning see-through glass-ceramic material withstands temperature extremes.

Stovetops of Ceran (Schott)
Other applications for controlled crystallization

Laser Witting in Glass – induced crystallization

For optical waveguides and other photonic applications

Sm$_2$O$_3$-Bi$_2$O$_3$-B$_2$O$_3$ glass

Sm$_x$Bi$_{1-x}$BO$_3$ crystal

T. Komatsu, Nagaoka Univ., Japan

Ce:YAG GC for the white LED and Solid State Lighting

As-made Ceramized

Research by S. Tanabe, Kyoto Univ., Japan
Using fast pulsed lasers to draw 3-D images from tiny micro-cracks in glass

The points are tiny (.1mm) fractures created by a pulsed laser beam focused within the glass block. Image created by scanning the laser spot with a computer-controlled mirror. Commercial nano second pulsed lasers systems are available for the artist and small business. Typical writing speed ~300,00 dots/min (5K pulses/sec). E.g. http://g-star.en.made-in-china.com/
Chalcogenides are the active materials used in DVD-RW.

Laser power controls the switching between amorphous and crystalline states.

Ge-Sb-Te (GST)

High power → amorphous

Medium power → crystalline
Bio-Active Glass for Bone Implant and Dental

The British company, OSSPRAY, has developed a dental bioactive calcium sodium phosphosilicate material that, in addition to polishing teeth, re-mineralizes them.

From Med Gadget, Tuesday, July 8, 2008

Biocompatible, bioactive glass is one focus of research at the IMI at Lehigh University. The glass may one day be used as scaffolding for aiding bone growth and healing in people with injuries.

Applications: Bone Implant - Orthopedic, dental and bone graft
Porous glass for bone scaffold – which provides cell adhesion, critical cell nutrients and gradually erodes away as bone cells take over.
DurmaFuse glass material was developed at Missouri Univ. of Science and Technology
Anti-Bacterial glass

AntiBacterial glass by AGC Flat Glass Europe is a major innovation. The antimicrobial action of the silver ions inside the glass eliminates 99.9% of all bacteria that form on its surface whilst also preventing the spread of fungi. This remarkable property makes it perfect for places where strict hygiene is a must (bathrooms, hospitals, ...).


Planibel float glass with an antibacterial surface

Glass can retain the Ag ions, which would leach from plastic.
Strong Glasses for displays – Gorilla Glass

Thin chemically strengthened glass

Corning’s Ultra-strong Gorilla Glass debuts on the iPhone4

http://www.tipb.com/2010/06/28/iphone-4-review/
Micro-etchable Glass for Microfluidics

Micronit’s Microfluidic Technology

Tiny micro-channels in glass allow for complex analyses and reactions to be accomplished with micro quantities. Can mix, separate, make drops, and can incorporate metallic heaters and electrodes as well.

Photo-active Chalcogenide Glasses
For Photolithography to the nano-scale

Ch Glasses can be written with light or e-beam to produce very fine structures in the glass. Subsequent etching can remove the unexposed glass. Greyscale capability useful for lenses and other devices.

Non-oxide Chalcogenide glasses such as As$_2$S$_3$

Thin film Micro Fresnel Lenses
Low-Emissivity Glass Windows
Keeping UV out and Warmth In


For more detailed discussion see Lecture 4 from IMI’s Glass In Energy Course at:
http://www.lehigh.edu/imi/GlassInEnergy.html
Watch "A Day Made of Glass" and take a look at Corning's vision for the future with specialty glass at the heart of it. 5 ½ minutes at
http://www.youtube.com/watch?v=6Cf7IL_eZ38

Many other resources on our IMI website at:
http://www.lehigh.edu/imi

See especially our Glass Education for Students, Teachers & General Public
http://www.lehigh.edu/imi/libraryglassedu.html

Follow-up questions and comments to Bill Heffner at wrh304@lehigh.edu

END Lecture 1

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