Nobody sees glasses; only glass scientists see glasses

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Different glasses

Inorganic glasses – [Organic glasses (polymers)]

Window glasses
Lamps, lenses
TV and computer monitors
(Flat panel display—8 times in 7 years)
Glass bottles
Optical glasses
Optical fibers
Fibers for plastic composites and insulation
Semiconductors devices (SiO₂)
Natural glasses (geology)
Structure of glasses (SiO$_2$)

Crystal SiO$_2$  Glass SiO$_2$
Glass State; Solid? Liquid?

Glass is a liquid which did not crystallize at a lower temperature than its melting point. (metastable state)

This suggests that any material, including metal, and water can be made into a glass when cooled rapidly.
Viscosity changes with temperature.

Viscosity (difficulty to flow) of glasses change greatly with temperature. At high temperature, glasses become like honey; at low temperature glasses become rigid like rock. At an intermediate temperature, \( \sim 500^\circ C \), the glass can deform slowly and change its dimensions.

This characteristic is a great advantage for mass production of useful products; can cause difficulty in complicate device, e.g. flat panel display, production.
Can glass deform permanently at room temperature?

Antique Windowpanes and the Flow of Supercooled Liquids

Robert C. Plumb
Worcester Polytechnic Institute, Worcester, MA 01609


Flowing windowpanes: fact or fiction?

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Ancient glass plate production

Figure 1. The shapes of the 90° of molten glass: A, when gathered; D, blown; C, blown larger and flattened; and D, attached to the "pony" (known as a pony nipple) and the blow pipe removed before it was spun to the large disk shape in the flashing furnace. (From ref. 7.)

Figure 2. The glass blower enlarging the glass block, assisted by his helper in keeping the mass of molten glass centered. (From ref. 7.)

Figure 3. Expanding the open decanter shape to a 60-in.-diameter disk in the flashing furnace. (From ref. 7.)

Ancient glass plate manufacturing process
Can glass deform permanently at room temperature?

Fig. 6. Etched ¼ in. glass rod loaded to 125,000 psi by Phillips in 1936, as it looked in 1962 after 26 years under continuous load.

C.J. Phillips
Can glass turn into a stable crystal at room temperature?

Since glass state is in a metastable state, it would try to be more stable by transforming itself into a crystal.

Lybian desert glass; SiO$_2$ glass
The origin is not clear; million or more years old.
How old is an old glass, stone age glass?

Obsidian Hydration Dating
Science, 191, 347 (1976)
I. Friedman and W. Long

Hydration thickness,
\[ T = k t^{1/2} \]

Effects of temperature, obsidian composition were considered.
Hydration dating of glasses

W. A. Lanford
Science, 196 (1977) 975.

Fig. 1. Summary of the hydration thickness plotted versus the square root of the age of the glass test object, showing a qualitative correlation between age and hydration thickness. The straight line is the correlation expected for \( X^2 = Kt \) on the assumption that \( K = 3.3 \mu m^2 \) per 1000 years.
Hydration dating of obsidian

Obsidian Hydration data

By Ioannis Liritzis and Maria Diakostamatiou

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Diffusion profiles in obsidians from three different places of the world

Water concentration (g/mole/cc)

Chile
T=540

U.S.A.
T=1930

Mexico
T=650

Diffusion depth (cm)
Water in glass, which is not for drinking
Water in glass absorbs light

(Lambert-)Beer’s Law

\[ I = I_0 \times 10^{-\epsilon c d} \]

I: Transmitted light intensity
I₀: Incident light intensity
\( \epsilon \): extinction coefficient
C: concentration
d: thickness
Optical fiber, loss of signal by water

Glass can get tired in moisture

![Graph showing the relationship between applied stress and time to fracture.](image)

Fig. 31. Static fatigue of silica glass fibers at room temperature in air and in vacuo, and at liquid nitrogen temperature in vacuo: (●) in air at room temperature; (○) in vacuo at room temperature; (x) in vacuo at −196 °C; (---). A straight line approximation [115].

Optical fibers get tired faster?

Fig. 32. Static fatigue of silica communication fiber in DI water and in air with 85% humidity at 85°C [117]. The parameter $n$ represents fatigue resistance as in $\log(\text{applied stress}) = \text{constant} - (1/n) \log(\text{time of failure})$. Larger $n$ values indicate greater fatigue resistance.

How strong was a broken glass?

S.W. Freiman, p.31 in Glass Science and Technology, vol. 5, Ed. By D.R. Uhlmann and N.J. Kreidl

Freiman (1980)
Strength of broken glass can be estimated

\[ \sigma_f = A / \sqrt{r} \]

\[ \log \sigma_f = \log A - (1/2) \log r \]

Mecholsky et al., 1974

Best nuclear waste processing method?

Currently, nuclear waste is stored in liquid form in stainless steel containers—can leak

Vitrification—Billion dollar facilities
Savannah River, GA, Richland, WA

Bury the glasses in safe site (depository)
Yaca Mountain site
For thousands of years.
Space shuttle tiles are glass fibers

SiO₂ glass fibers bonded together.

- Has to withstand high temperature of 1300°C to protect astronauts
- Light weight
Can a glass be made stronger?

* A person living in a glass house should not throw a stone.

Glass jaw.

- Tempering
- Ion-exchange
Recent Severe Hailstorm in New Mexico

S. Jill Glass
Sandia National Labs.
Glass testing at Sandia National Laboratories

This video available for viewing on the IMI website at http://www.lehigh.edu/~inimif/resources.htm

Contact: S. Jill Glass, Sandia National Laboratories
Thermal tempering

- Glasses are heated to high temperature and then quickly cooled by jet of air.
- Glass can be made stronger by several times.
- Glasses shatter into pieces when broken.
Ion-exchange

Smaller Na\(^+\) ions in glass are exchanged with larger K\(^+\) ions from outside (molten salt).

Glass becomes stronger by 30 times or more.

Exchange of a Na-containing glass in a bath of molten KNO\(_3\) salt
Use of high strength glasses?

Glass can be made stronger.

With improved strength, glass products can be made thinner and lighter weight.

For example, containers--Competition of glass, plastic and metal. Glasses were the main container materials. Then metals and plastics became popular.

With high price of oils, and electricity, glass containers may become popular again.
Conclusions

- Glasses are used in a variety of different technological fields. Also, it poses interesting (philosophical questions)
- The glass state is considered one of the remaining frontier of science.
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