19th August 2020

Glass Evidence

Types of glass according to chemical contents

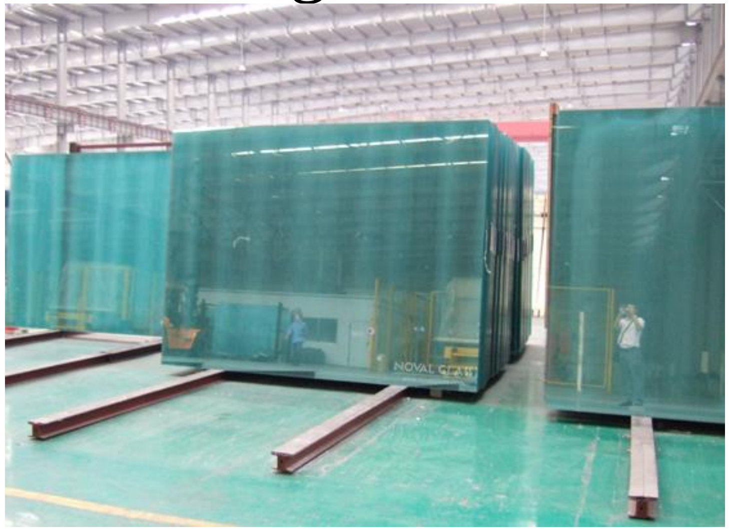
- The major content in all types of glass is **silicon dioxide**.
- Glass with **boron** content (Borosilicate glass) is resistant to breaking when heated or cool and is employed in laboratory glassware and cookware.
- Inexpensive **soda lime glass** is high in sodium and calcium content and is found as container and windows.
- The addition of high atomic number elements (**metals**) increases the refractive index (RI) of glass, causing it to sparkle and serve decorative and aesthetic purposes.

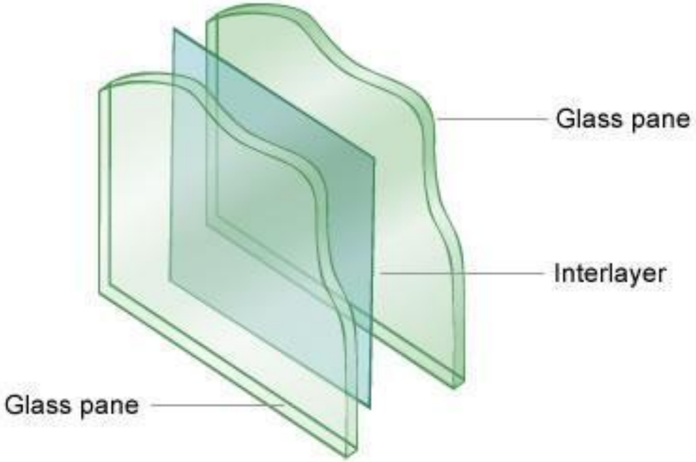
Soda lime glass

Cobalt glass for decoration

Types of glass according to structure

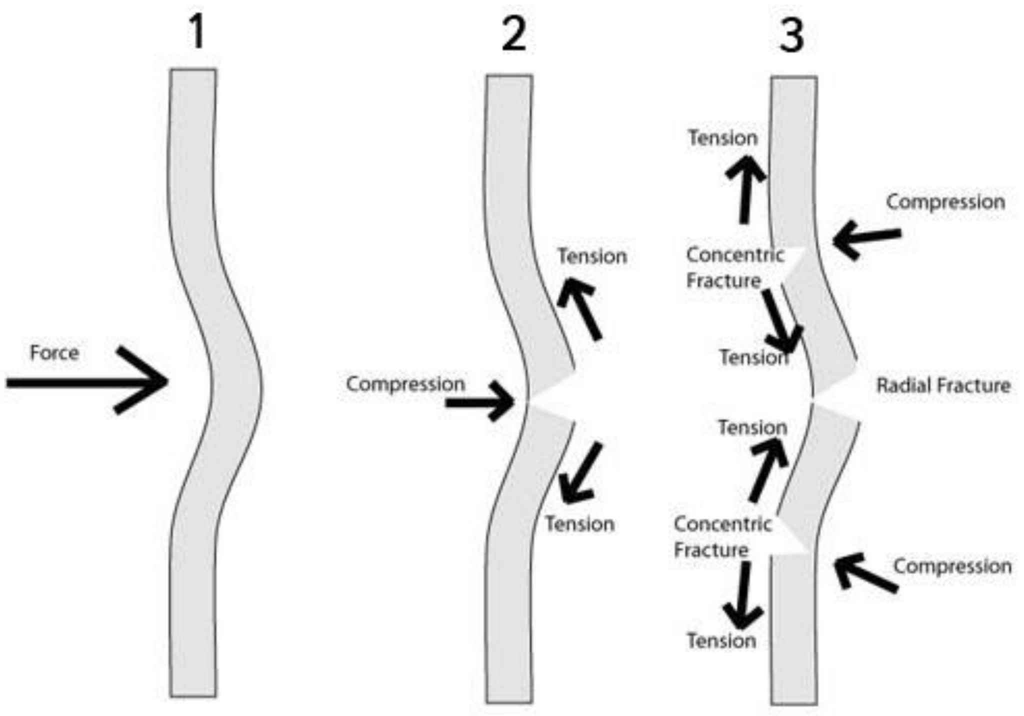
- The glass contents are still composed of SiO_2, Na_2CO_3, $CaCO_3$ and other oxides.
- **Flat glass** : used in doors and windows
- **Laminated glass** : used in windshields, two sheets of glass with plastic between them.
- **Tempered glass** : used in car side windows, cell phone protector and designed to break into tiny pieces.





How do glass windows break?

- Each force causes a deformation that may leave a visible mark or fracture the glass. This can be used to determine the direction and amount of force.
- Glass acts initially as an elastic surface and bends away when a force is applied. When the force increases beyond its tensile strength, it cracks.
- When glass is deflected, it has one face under **compression** and **tension**. Whilst the resistance of glass to compressive stress is extremely high, its resistance to tensile stress is significantly lower.



http://www.sqaacademy.org.uk/pluginfile.php/34022/mod_resource/content/2/Glass/fractures.html

Compressive strength and Tensile strength

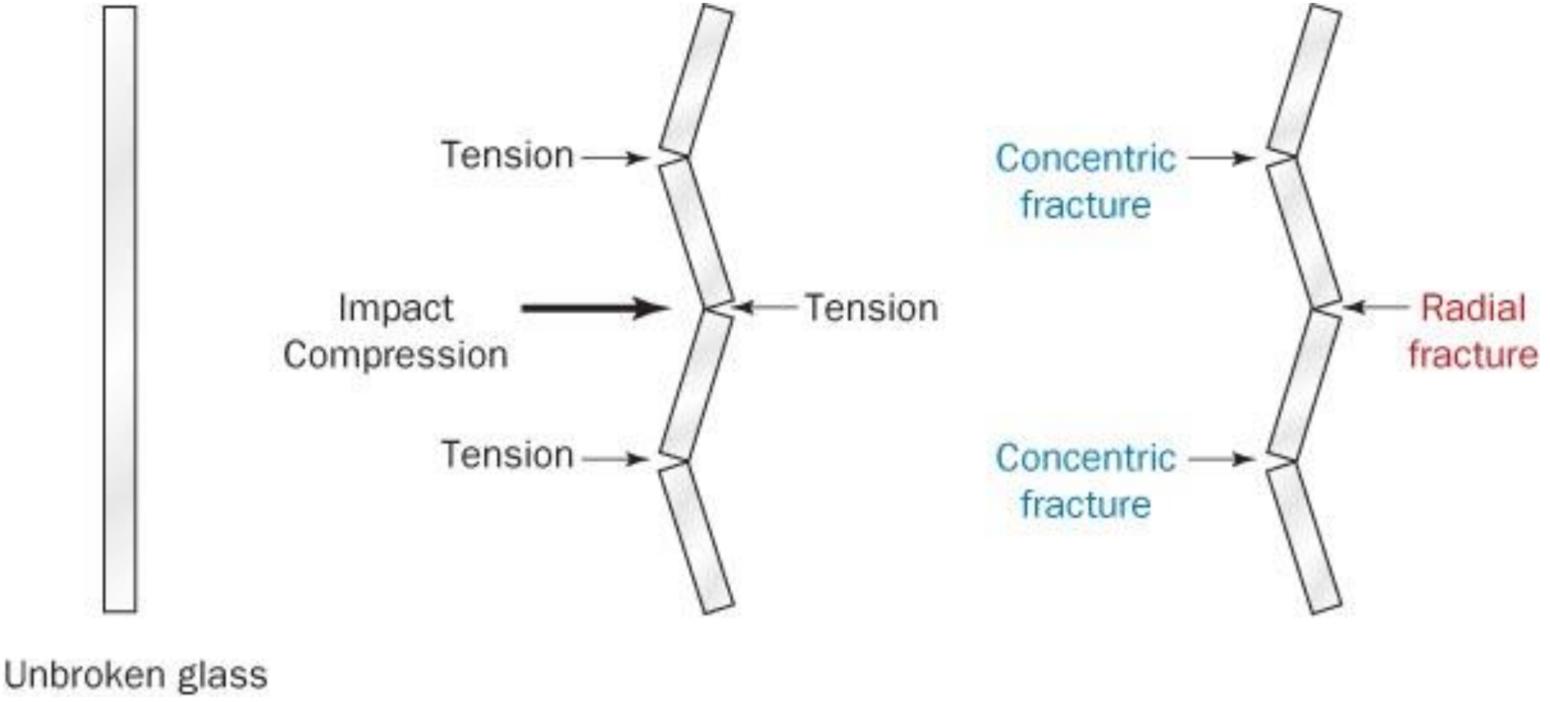
- The compressive strength of glass is extremely high: 800 - 1000 MPa.
- This means that to shatter a 1 cm cube of glass, it requires a load of some 10 tonnes.

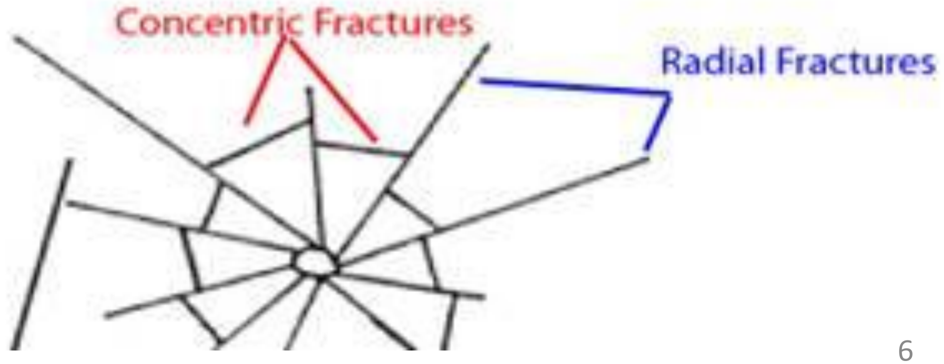
- The ability of a material to resist a force that tends to pull it apart.
- It is usually expressed as the measure of the largest force that can be applied in this way before the material break apart.
- The practical tensile strength is about 27 MPa to 62 MPa.

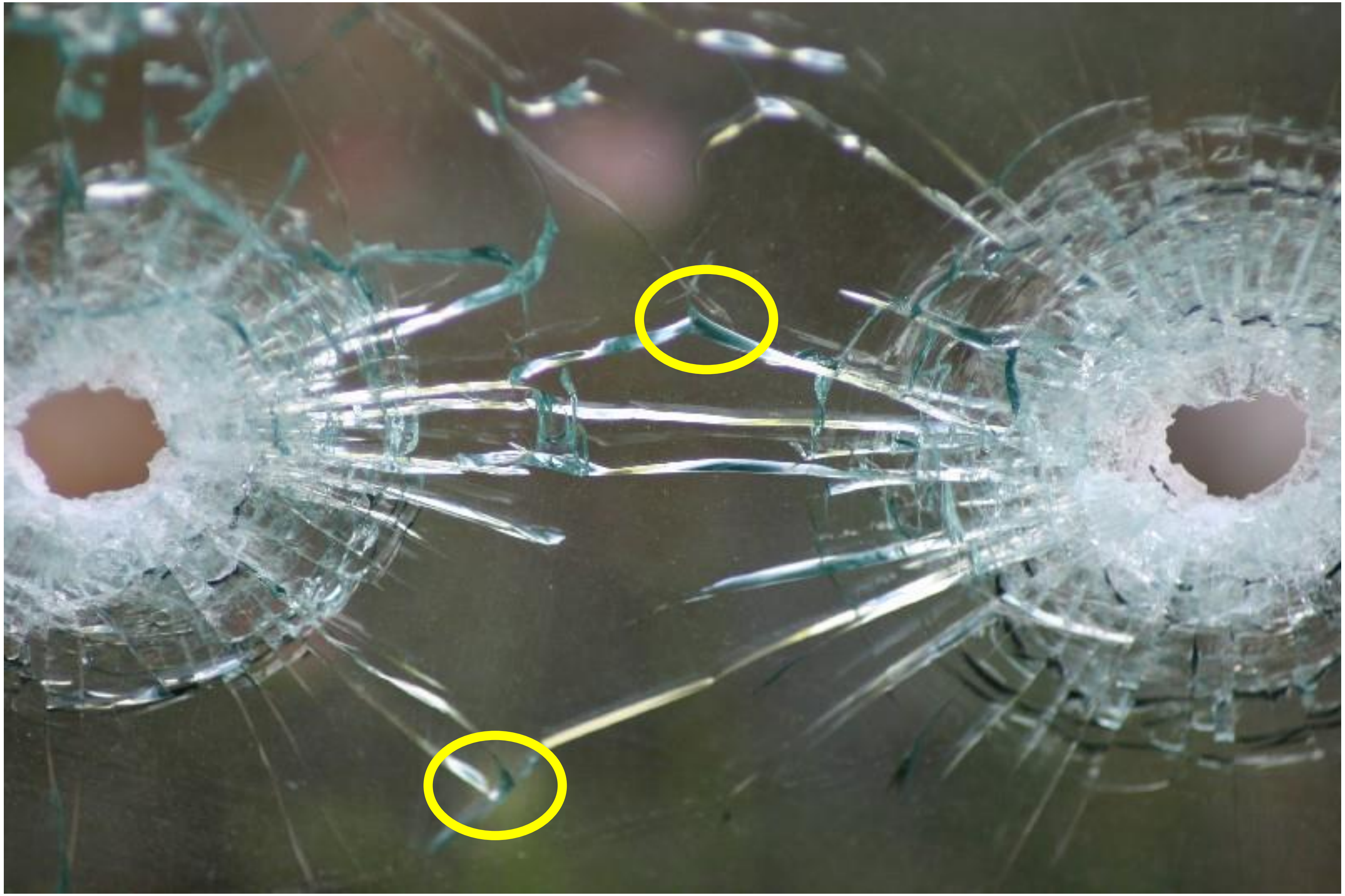
Note : Most glass breakage is due to tensile strength failure.

Fracture patterns in broken glass

- Being an amorphous solid, glass will not break into regular pieces with straight line fractures
- **Radial fractures** form first and are propagated in short segments on the side opposite the force.
- **Concentric fractures** come later from continued pressure on the same side as the force applied.







- Fracture patterns provide clues about the direction, rate, and sequence of the impacts.
- Which bullet hole was created first?

http://www.khaosod.co.th/view_newsonline.php?newsid=TVRNMU16VTRPRFUzTnc9PQ==&subcatid=

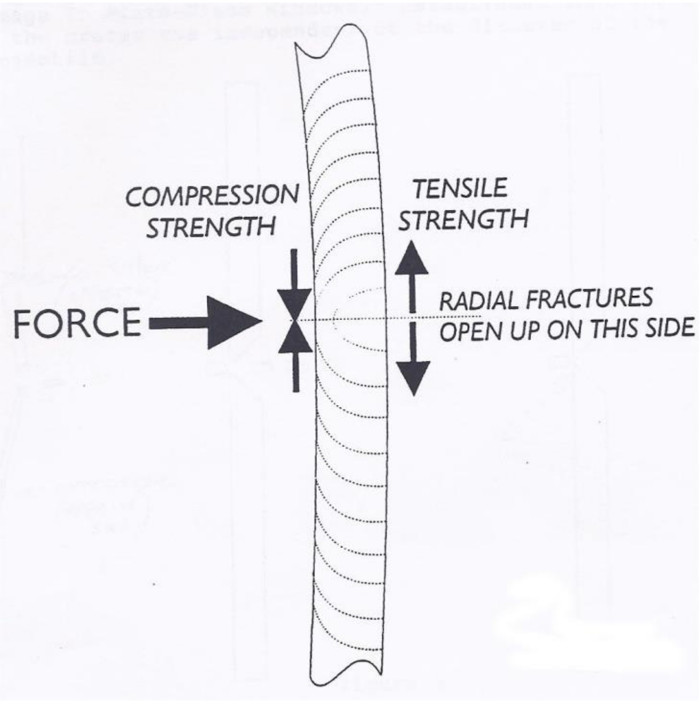
3R Rule

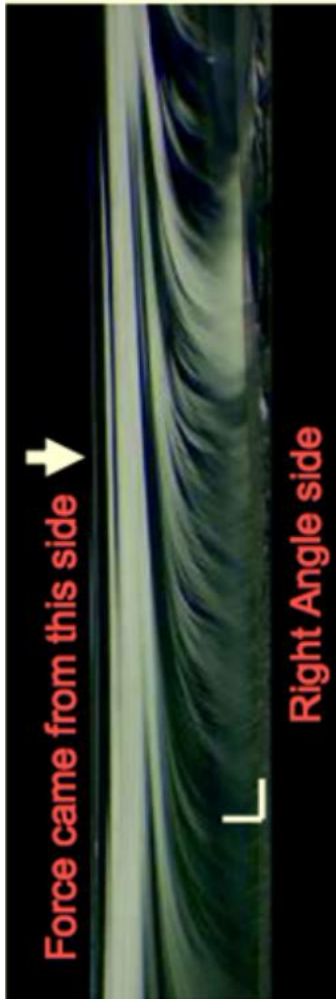
- Edges of broken pieces of glass will show rib (“stress”) marks.

- In a radial crack, the rib marks are perpendicular to unloaded side and parallel to loaded side.

  The force arrow shows the side that received the impact.

- 3R rule:
  - **Radial cracks** give rib marks that make
  - **Right angles** on the
  - **Reverse side** from where the force was applied



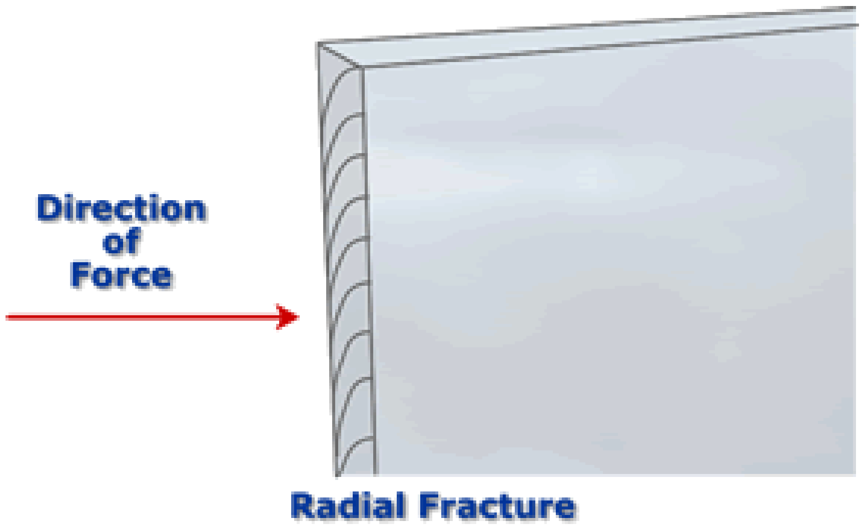


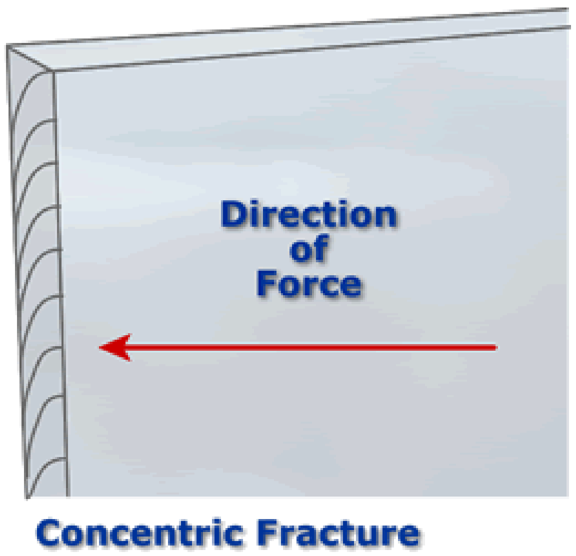
https://deathbetweenthecovers.wordpress.com/

https://slideplayer.com/slide/4888394/

Rib marks
Radial fracture vs concentric fracture

•Stress lines on the glass edge of radial cracks form a right angle on the reverse side from the force.
•Stress lines on the glass edge of concentric cracks form a right angle on the same side as the force.

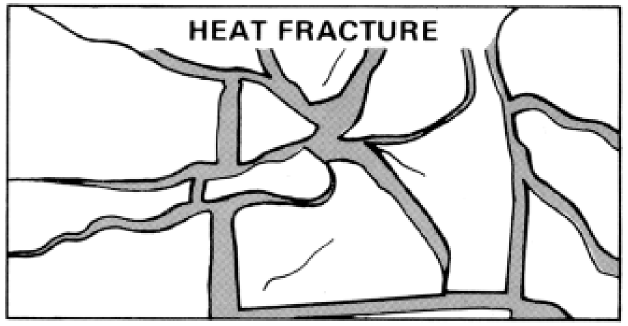




Exceptions to the Three R Rule

- Tempered glass
  "dices" without forming ridges

- Very small windows held tightly in frame
  can't bend or bulge appreciably

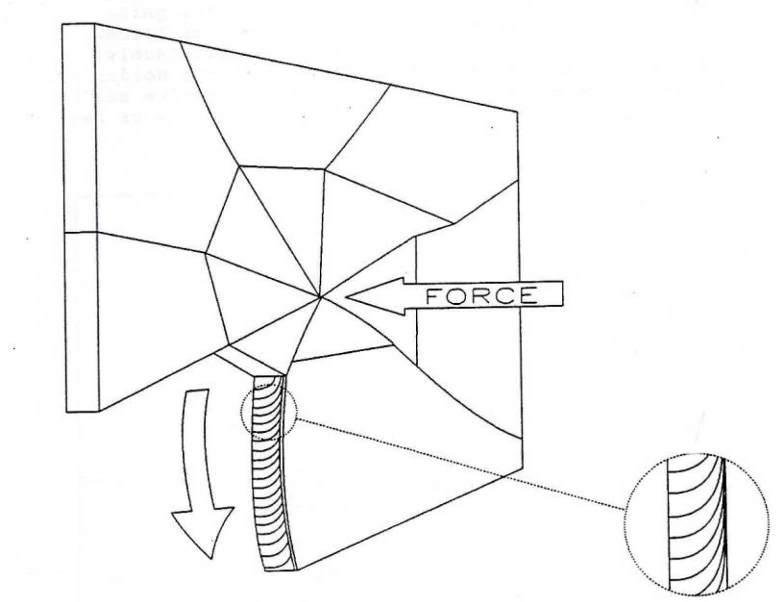


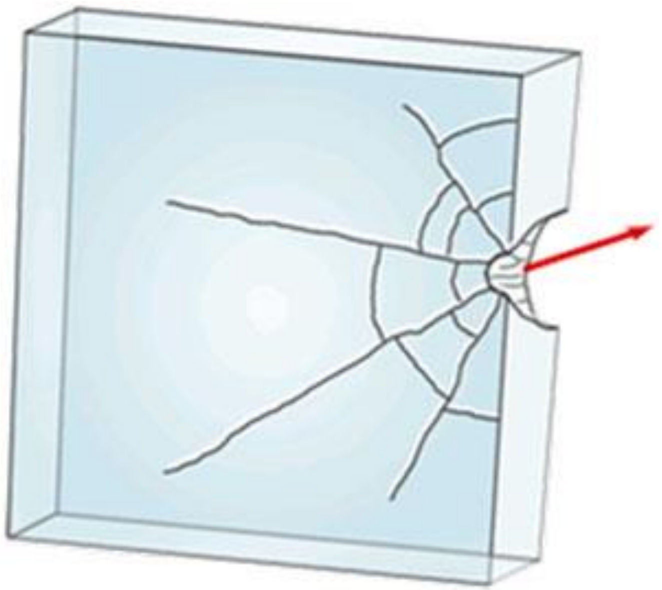
- Windows broken by heat or explosion
  no "point of impact"
  curved, smooth edges at break points

Glass Fractures by Projectiles

- Bullets are a projectile force (load) that can pass through glass.
  - Load side is the entrance side; unloaded side is the exit side.
  - Low-speed projectiles: **rib marks** may indicate where breaking force was applied
  - As the bullet's velocity increases, the central hole becomes smaller, cracking patterns become simpler, and the exit hole becomes **wider** than the entrance hole.

https://deathbetweenthecovers.wordpress.com/2013/04/04/hearts-may-be-made-of-glass-but-so-are-windows/





Path of the Bullet in the Direction of the Arrow

http://www.crimemuseum.org/crime-library/glass-analysis

Forensic Examination of Glass

- **Goals in examining glass evidence:**
  - **Determine the types of glass at the scene**
  - **Determine how the glass was fractured**
  - **Use physical characteristics to classify it**
  - **Individualize the glass to a source**

- **Compare physical and chemical characteristics:**
  - **Optical properties: color and refractive index**
  - **Non-optical properties: surface wear, striations from manufacturing, thickness, surface film or dirt, hardness, density**
  - **Chemical properties: additives or trace elements**

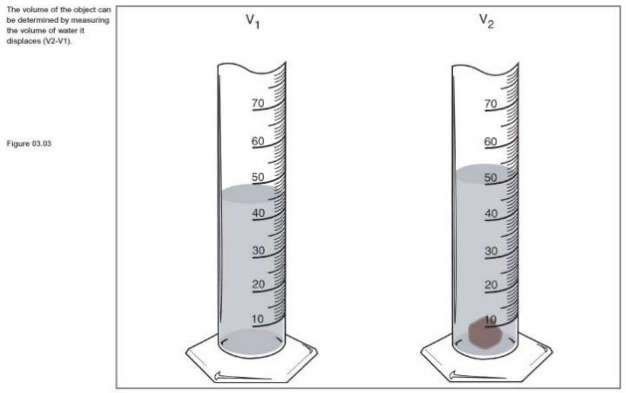
Glass type determinations

- The preliminary tests based on basic properties, such as color, thickness, and curvature, can also help to identify different samples of glass just by looking at them.
- The most important physical characteristics of glass fragments are **density** and **refractive index**.
- The chemical characteristics in terms of elemental analysis can also be conducted. Measurement of the types and quantities of these elements can help in determining whether two pieces of glass were ever part of the same object.

Glass Density

- Density can be measured by:
  - directly determining mass and volume (usually by displacement)
  - comparison by flotation
  - comparison using a density gradient column

- Density gradient column method:
  - Fragments of different densities settle at different levels in the column of liquid of varying density.
  - Technique is not accurate for fragments that are cracked or contain an inclusion.



Density by the Flotation Method

- **A glass particle is immersed in a liquid. The density of the liquid is adjusted by the addition of small amounts of another liquid until the glass chip remains suspended.**

- **At this point, the glass will have the same density as the liquid medium and can be compared to other relevant pieces of glass which will remain suspended, sink, or float.**

Refractive Index By Immersion

A hot stage microscope is a key instrument in the forensic examination of glass.

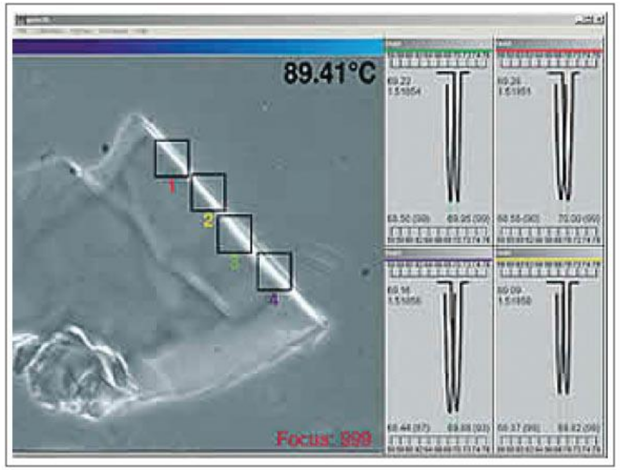
Figure 05.07

Courtesy of Foster & Freeman Ltd.

The GRIM 3 system is an automated technology for the measurement of the refractive index of glass.

Figure 05.09

Courtesy of Foster & Freeman Ltd.



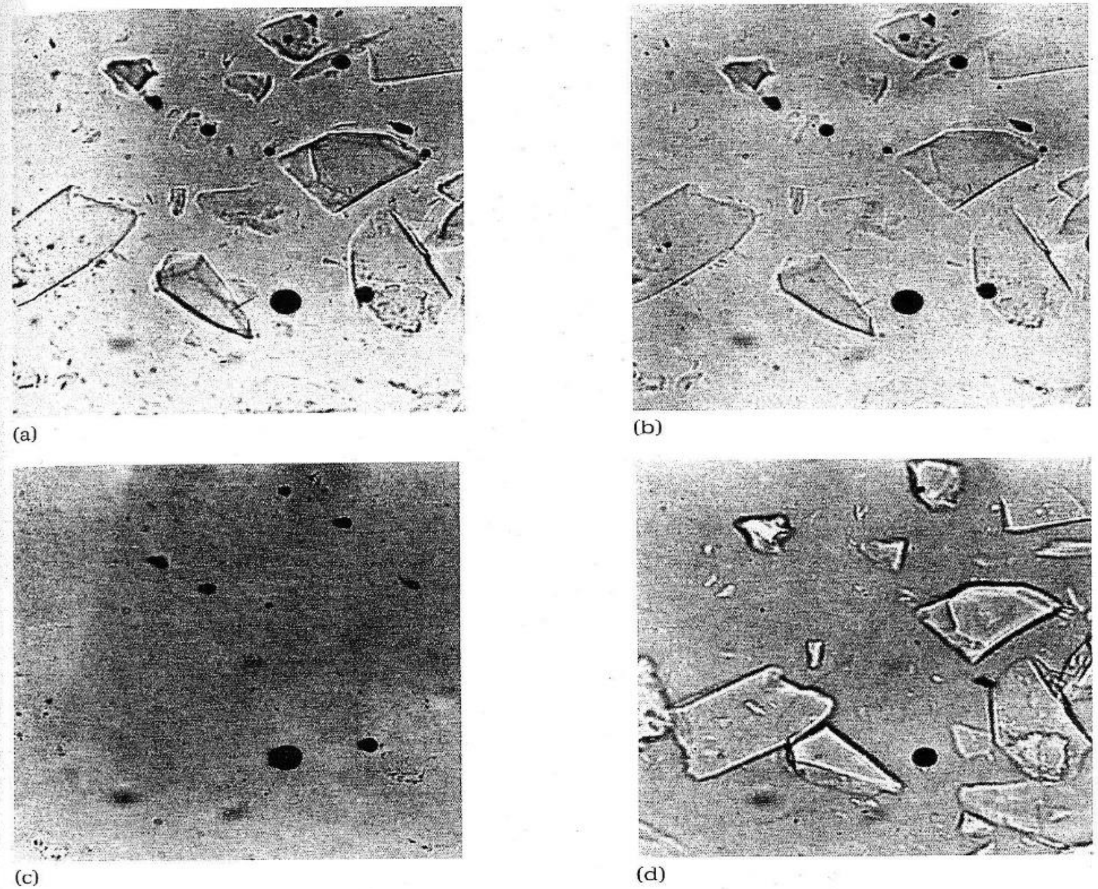
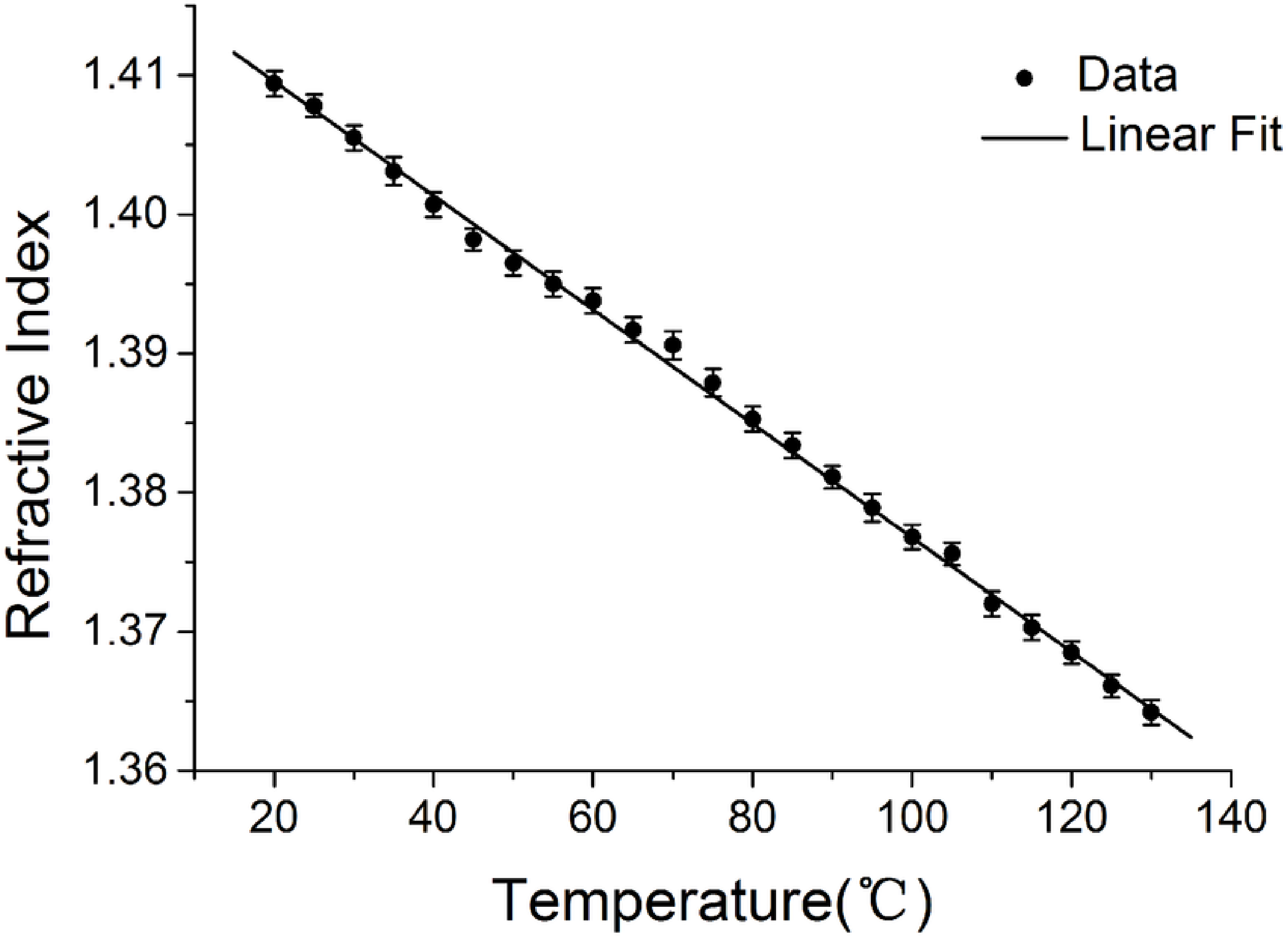


Figure 4–12 **Determination of the refractive index of glass. (a) Glass particles are immersed in a liquid of a much higher refractive index at a temperature of 77°C. (b) At 87°C the liquid still has a higher refractive index than the glass. (c) The refractive index of the liquid is closest to that of the glass at 97°C, as shown by the disappearance of the glass and the Becke lines. (d) At the higher temperature of 117°C, the liquid has a much lower index than the glass, and the glass is plainly visible.** *Courtesy Walter C. McCrone*

The refractive index of silicon oil vs temperature



Article *in* PLoS ONE 11(3):e0151454 · March 2016
DOI: 10.1371/journal.pone.0151454

Table 2.3 Physical Properties of Glass

Type	Softening Point[1] (°C)	Density (g/mL)	Refractive Index[2]
Alkali barium	646	2.64	1.511
Alkali barium (optical)	647	2.60	1.512
Alkali barium borosilicate	712	2.27	1.484
Alkali borosilicate	718	2.29	1.486
Alkali strontium	688	2.26	1.519
Alkali zinc borosilicate	720	2.57	1.523
Borosilicate	720	2.28	1.490
Baria alumina borosilicate	844	2.76	1.530
Barium-alumina borosilicate	847	2.96	1.545
Borosilicate	821	2.23	1.473
Lanthanum barium	759	3.98	1.678
Lead borosilicate	447	5.46	1.860
Lead zinc borosilicate	370	3.80	—
Lithia potash borosilicate	—	2.13	1.469
Potash borosilicate	820	2.16	1.465
Potash soda lead	630	3.05	1.560
96% Silica	1530	2.18	1.458
96% Silica (porous)	1530	1.50	—
Silica (99.9% fused)	1585	2.20	1.459
Soda borosilicate	808	2.27	1.476
Soda alumina borosilicate	705	2.17	1.468
Soda-lime	696	2.47	1.510

[1]The softening point is the temperature at which heated glass starts to deform under its own weight.
[2]The refractive index of all samples is measured at a wavelength of 589.3 nm.

Table 2-3
Investigating Chemistry, First Edition