Forensic Glass Analysis

Forensic Science
Glass Analysis

Students will learn:

- The difference between physical and chemical properties.
- How glass can be used as evidence.
- How individual evidence differs from class evidence.
- The nature of glass.
- How to use the properties of reflection, refraction, and refractive index to classify glass fragments.
Glass Analysis

Students will be able to:

• Make density measurements on very small particles.
• Use logic to reconstruct events.
• Use technology and mathematics to improve investigations and communications.
• Identify questions and concepts that guide scientific investigations.
Composition of Glass

• Is a hard, brittle, amorphous material
  – Amorphous because its atoms are arranged randomly
  – Due to its irregular atomic structure, it produces a variety of fracture patterns when broken
• Has numerous uses and thousands of compositions
Composition of Glass (continued)

• Made by melting the following ingredients at extremely high temperatures

  – **Sand** also known as silica or silicon dioxide (SiO₂), is the primary ingredient
  
  – **Lime or calcium oxide** (CaO) is added to prevent the glass from becoming soluble in water
  
  – **Sodium oxide** (Na₂O) is added to reduce the melting point of silica or sand
• Three categories of substances found in all glass

  – **Formers**
    • Makes up the bulk of the glass
    • Examples: *silicon dioxide* (SiO$_2$) in the form of sand, *boron trioxide* (B$_2$O$_3$), and *phosphorus pentoxide* (P$_2$O$_5$)

  – **Fluxes**
    • Change formers’ melting points
    • Examples: *sodium carbonate* (Na$_2$CO$_3$) and *potassium carbonate* (K$_2$CO$_3$)

  – **Stabilizers**
    • Strengthen the glass and make it resistant to water
    • *Calcium carbonate* (CaCO$_3$) is the most frequently used
Composition of Glass (continued)

- The raw materials for making glass are all oxides.
  - The composition of a sample can be expressed in percentage of different oxides.
  - **Example:** the approximate composition of window or bottle glass is:
    - Silica (SiO$_2$) – 73.6 %
    - Soda (Na$_2$O) – 16.0 %
    - Lime (CaO) – 5.2 %
    - Potash (K$_2$O) – 0.6 %
    - Magnesia (MgO) – 3.6 %
    - Alumina (Al$_2$O$_3$) – 1.0
Types of Glass

• **Obsidian** is a natural form of glass that is created by volcanoes

• **Soda-lime** glass
  – The most basic, common, inexpensive glass – also the easiest to make
  – Used for manufacturing windows and bottle glass
Types of Glass

• **Leaded glass**
  – Contains lead oxide which makes it denser
  – **Sparkles** as light passes through it (light waves are bent)
  – Used for manufacturing fine glassware and art glass
  – Is commonly called **crystal**
Types of Glass

- **Tempered glass**
  - Stronger than ordinary glass
  - Strengthened by introducing stress through rapid heating and cooling of its surface
  - When broken, this glass does not break into large shards, but fragments or breaks into small squares
  - Used in the side and rear windows of automobiles
Types of Glass

• **Laminated glass**
  – Constructed by bonding two ordinary sheets of glass together with a plastic film
  – Also used by automobile manufacturers
Comparing Glass

• **Investigation/Analysis includes**
  
  – Finding
  – Measuring
  – Comparing
Comparing Glass

**Individualized Characteristics**

- Only occurs if the suspect and crime scene fragments are fit together exactly, like a puzzle
- This would require matching broken edges AND irregularities and striations on the broken surfaces
- **Most glass evidence is either too fragmented or too small to permit a comparison of this type**
Comparing Glass (continued)

Class Characteristics

• (Density and Refractive Index)
  – General composition of glass is a class characteristic
  – Trace elements in glass may prove to be distinctive and measureable characteristics, but still class
  – The physical properties of density and refractive index are used most successfully for characterizing glass particles, but only as a class characteristic
Physical Characteristics

- Density—mass divided by volume
- Refractive index (RI)—the measure of light bending due to a change in velocity when traveling from one medium to another
- Fractures
- Color
- Thickness
- Fluorescence
- Markings—striations, dimples, etc
Methods of Comparison: Density and Measurements

**Density comparison**

Density (D) is calculated by dividing the mass (M) of a substance by its volume (V)

\[ D = \frac{M}{V} \]
Methods of Comparison: Density

**Density comparison (continued)**

- **Step 1:** Find the sample’s mass in grams using a balance or scale
- **Step 2:** Find the sample’s volume by water displacement in a graduated cylinder
  - Record the initial volume, then add the sample
  - Record the final volume
  - Sample volume = final – initial
- Density can now be calculated from the equation in grams per milliliter

Read the bottom of the meniscus, and estimate between marks. This is 52.5 milliliters (mL)
## Density

<table>
<thead>
<tr>
<th>Type of Glass</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>window</td>
<td>2.46-2.49</td>
</tr>
<tr>
<td>headlight</td>
<td>2.47-2.63</td>
</tr>
<tr>
<td>pyrex</td>
<td>2.23-2.36</td>
</tr>
<tr>
<td>lead glass</td>
<td>2.9-5.9</td>
</tr>
<tr>
<td>porcelain</td>
<td>2.3-2.5</td>
</tr>
</tbody>
</table>
Methods of Comparison: Density and Measurements (continued)

**Flotation comparison**

- A sample of glass is dropped into and sinks to the bottom of a liquid containing an exact volume of a dense liquid, such as bromobenzene (d = 1.52 g/mL)

- A denser liquid, such as bromoform (d = 2.89 g/mL), is added one drop at a time until the piece of glass rises up from the bottom and attains neutral buoyancy

- Neutral buoyancy occurs when an object has the exact same density as the surrounding fluid, and neither sinks nor floats, but is suspended in one place beneath the surface of the fluid
Methods of Comparison: Density and Measurements (continued)

**Flotation comparison (continued)**

- The same procedure is then performed with another piece of glass, and if the volume needed to attain neutral buoyancy is the same as for the first sample, then the densities of the two samples are equal.

- The exact density of each sample can be calculated by using the following formula:

\[
d = \frac{X \times (2.89) + Y \times (1.52)}{X + Y}
\]

- X and Y refer to the volumes of the respective liquids, with the numbers in parentheses referring to the densities of each liquid.
Methods of Comparison: Refractivity

**Refractive Index**

– A measure of how much an object slows light
  • Light slows down when it passes through any medium (the denser the medium, the slower the light travels)
  • Any object that transmits light has its own refractive index

– Refractive index = velocity of light in a vacuum / velocity of light in a medium
Determination of Refractive Index

**Immersion method**—lower fragments into liquids whose refractive index is different

**Match point**—when the refractive index of the glass is equal to that of the liquid

**Becke line**—a halo-like glow that appears around an object immersed in a liquid. It disappears when the refractive index of the liquid matches the refractive index of the object (the match point).
Seen Phenomena
Refractive Index

• **Refractive index** is a distinguishable physical property of glass.
• Refractive index is a value always greater than 1.
• For example the index of refraction for water is 1.3; meaning that light travels 1.3 faster in air than water.
• It is calculated by taking the ratio between the speed of light in air to the speed of light in the medium.
Index of Refraction

\[ n_1 \sin \alpha = n_2 \sin \beta \]
Methods of Comparison: Refractivity (continued)

When light passes through media with different refractive indexes **refraction** (bending of the light) occurs

– This is why objects appear bent or distorted underwater

– Every liquid has its own refractive index

– If a piece of glass is placed in a liquid with a different refractive index an outline of the glass is clearly visible

  • **This line is known as a Becke Line**
The Becke line is a “halo” that can be seen on the inside of the glass on the left, indicating that the glass has a higher refractive index than the liquid medium. The Becke line as seen on the right is outside of the glass, indicating just the opposite.
Methods of Comparison: Refractivity (continued)

When light passes through a piece of glass placed in a liquid with the same refractive index

- The glass bends light at the same angle as the liquid
- The Becke Lines disappear
- The glass seems to disappear
# Refractive Index

<table>
<thead>
<tr>
<th>Liquid</th>
<th>RI</th>
<th>Glass</th>
<th>RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.333</td>
<td>Vitreous silica</td>
<td>1.458</td>
</tr>
<tr>
<td>Olive oil</td>
<td>1.467</td>
<td>Headlight</td>
<td>1.47-1.49</td>
</tr>
<tr>
<td>Glycerin</td>
<td>1.473</td>
<td>Window</td>
<td>1.51-1.52</td>
</tr>
<tr>
<td>Castor oil</td>
<td>1.82</td>
<td>Bottle</td>
<td>1.51-1.52</td>
</tr>
<tr>
<td>Clove oil</td>
<td>1.543</td>
<td>Optical</td>
<td>1.52-1.53</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>1.560</td>
<td>Quartz</td>
<td>1.544-1.553</td>
</tr>
<tr>
<td>Bromoform</td>
<td>1.597</td>
<td>Lead</td>
<td>1.56-1.61</td>
</tr>
<tr>
<td>Cinnamon oil</td>
<td>1.619</td>
<td>Diamond</td>
<td>2.419</td>
</tr>
</tbody>
</table>
Glass Fracture Patterns

Glass has a certain degree of elasticity

– It breaks when its elastic limit is exceeded
– The elasticity produces fractures when it is penetrated by a projectile (i.e. a bullet)
Types of fractures

- **Radial**
  - Produced first
  - Form on the side of the glass opposite to where the impact originated
  - Look like spider webs that spread outward from the impact hole
  - Always terminate into an existing fracture
Radial Fractures
Glass Fracture Patterns (continued)

Types of fractures (continued)

- **Concentric**
  - Form **second**
  - **Encircle the bullet hole**
  - Start on the same side as that of the destructive force
Concentric Fractures
Glass Fracture Patterns (continued)

- **Conchoidal Lines**
  
  - Amorphous solids do *not* break along any natural plane of separation as a crystalline solid would.
  
  - The side of broken glass will show curved, rippling conchoidal lines that can be used to determine direction of impact.

  - 4 R Rule: “On **Radial** cracks, **Ridges** make **Right** angles to the **Rear**.”

This is opposite for sides of concentric fractures!
Glass Fracture Patterns (continued)

Determining the sequence of multiple bullet holes

• The radial fractures from the second bullet hole always terminate into the fractures from the first bullet hole, and so forth
Glass Fracture Patterns (continued)

**Determining bullet path direction**

- Compare the size of the entrance hole to the size of the exit hole
- **Exit holes are larger.** More fragmented glass is knocked out of the surface where the bullet is leaving because glass is elastic and bows outward when struck
Glass Fracture Patterns (continued)

Determining bullet path direction

- **Entrance holes**
  - The bullet makes a very small hole when it enters
  - The glass blows back in the direction of the impact because of its elasticity
  - The glass snaps back violently after being stressed and can blow shattered glass back several meters
  - *Most of the shattered glass lands on the impacted side of the glass, instead of by the exit hole*

Shot fired into Obama campaign office in Denver, CO (Oct. 2012)
Source: telegraph.co.uk
Collecting Glass as Evidence

• Avoid the loss or contamination of any evidence samples
• Identify and photograph all glass samples before moving them
• Collect the largest fragments
• Identify the outside and inside surfaces of any glass
• Indicate the relative position of multiple window panes in a diagram
Collecting Glass as Evidence (continued)

• Note any other trace evidence found on or embedded in the glass, such as skin, hair, blood, or fibers.

• Package all of the collected materials properly in order to maintain the chain of custody.

• Separate the glass by physical properties, such as size, color, and texture.
Collecting Glass as Evidence (continued)

• Catalog the samples and keep them separated in order to avoid contamination between two different sources.

• Separate the glass fragments from any other trace evidence (e.g., hair, blood, fibers) once in the lab.

• Examine any clothing (or other objects that may have been used to break the glass) related to the crime scene for glass fragments and other trace evidence.
Resources

• Texas Education Agency, Forensic Certification Training, Sam Houston State University
• Forensic Science: Fundamentals & Investigation (1st Edition), Anthony Bertino
• Forensic Science: From the Crime Scene to the Crime Lab (1st Edition), Richard Saferstein
• ChemMatters, “More Than Meets The Eye” Brian Rohrig
• The Science Spot – Forensic Science
  – http://www.sciencespot.net/Pages/classforsci.html
• Investigator/Officer’s Personal Experience
• Corning Museum of Glass site
  – http://www.cmog.org/default.asp
• Federal Bureau of Investigation: Laboratory Services
  – Forensic Glass Comparison: Background Information Used in Data Interpretation
  – Introduction to Forensic Glass Examination
  – Glass Density Determination