Forensic Glass Analysis

Forensic Science
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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 (SiO$_2$), is the primary ingredient
  – **Lime or calcium oxide** (CaO) is added to prevent the glass from becoming soluble in water
  – **Sodium oxide** (Na$_2$O) 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* \((\text{SiO}_2)\) in the form of sand, boron trioxide \((\text{B}_2\text{O}_3)\), and phosphorus pentoxide \((\text{P}_2\text{O}_5)\)
  
  – **Fluxes**
    • Change formers’ melting points
    • Examples: *sodium carbonate* \((\text{Na}_2\text{CO}_3)\) and potassium carbonate \((\text{K}_2\text{CO}_3)\)
  
  – **Stabilizers**
    • Strengthen the glass and make it resistant to water
    • *Calcium carbonate* \((\text{CaCO}_3)\) is the most frequently used
• 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

[Image of tempered glass]
Types of Glass

• **Laminated glass**
  – Constructed by bonding two ordinary sheets of glass together with a plastic film
  – Also used by automobile manufactures
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
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
Methods of Comparison: Density and Measurements

Density comparison

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

\[ D = \frac{M}{V} \]
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).
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
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
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
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)
Glass Fracture Patterns (continued)

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
• **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.””

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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
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 http://www.fbi.gov/about-us/lab/forensic-science-communications/fsc/april2009/review