Forensic Glass Analysis

Forensic Science
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Composition of Glass

• Is a hard, brittle, amorphous material
  – Called an amorphous solid because its atoms are arranged in a random fashion
  – 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
    • The primary ingredient
    • Also known as silica or silicon dioxide (SiO₂)
  – 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
Composition of Glass (continued)

• Three categories of substances found in all glass
  – Formers
    • Makes up the bulk of the glass
    • Examples: silicon dioxide (SiO₂) in the form of sand, boron trioxide (B₂O₃), and phosphorus pentoxide (P₂O₅)
  – Fluxes
    • Change the temperature at which the formers melt during the manufacturing of glass
    • Examples: sodium carbonate (Na₂CO₃) and potassium carbonate (K₂CO₃)
  – Stabilizers
    • Strengthen the glass and make it resistant to water
    • Calcium carbonate (CaCO₃) is the most frequently used
Composition of Glass (continued)

• The raw materials for making glass are all oxides
  – The composition of any sample can be given in terms of the percent of each oxide used to make it
  – 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
  – 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 (continued)

• 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 (continued)

• Tempered glass
  – Stronger than ordinary glass
  – Strengthened by introducing stress through rapid heating and cooling of its surface
  – When broken, this glass does not shatter, but fragments or breaks into small squares
  – Used in the side and rear windows of automobiles
Types of Glass (continued)

• 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 (continued)

• Individual Characteristics
  – Only occurs when the suspect and crime scene fragments are assembled and physically fitted together
  – Comparisons of this type require piecing together irregular edges of broken glass as well as matching all irregularities and striations on the broken surfaces
  – Most glass evidence is either too fragmentary or minute to permit a comparison of this type
Comparing Glass (continued)

• Class Characteristics (Density and Refractive Index)
  – The general composition of glass is relatively uniform and offers no individualization
  – Trace elements in glass may prove to be distinctive and measurable characteristics
  – The physical properties of density and refractive index are used most successfully for characterizing glass particles, but only as a class characteristic
  – This data (density and refractivity) gives analysts the opportunity to compare and exclude different sources of data
Methods of Comparison: Density and Measurements

• Density comparison
  – A method of matching glass fragments
  – Density (D) is calculated by dividing the mass (M) of a substance by its volume (V)
    • \( D = \frac{M}{V} \)
Methods of Comparison: Density and Measurements (continued)

• Density comparison (continued)
  – Example
    • A solid is weighed on a balance against known standard gram weights to determine its mass
    • The solid’s volume is then determined from the volume of water it displaces
    • Measured by filling a cylinder with a known volume of water (v1), adding the object, and measuring the new water level (v2)
    • The difference (v2 – v1) in milliliters is equal to the volume of the solid
    • Density can now be calculated from the equation in grams per milliliter
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 ($d = 1.52 \text{ g/mL}$)
  – A denser liquid, such as bromoform ($d = 2.89 \text{ g/mL}$), 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
  – A ratio of the velocity of light in a vacuum to the velocity of light in a particular medium (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 the 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 Line disappears
  - 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
    • Always 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
Glass Fracture Patterns (continued)

- Types of fractures (continued)
  - Concentric
    - Form next
    - Encircle the bullet hole
    - Always start on the same side as that of the destructive force
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
  – The radial fractures from a third bullet terminate into the radial fractures from the second bullet, and so forth

• Determining the first shooter
  – Examine the termination lines of the radial fractures from each bullet hole
  – Compare the size of the exit and entrance holes of each bullet
Glass Fracture Patterns (continued)

• Determining the direction from which a bullet was fired
  – Compare the size of the entrance hole to the size of the exit hole

  • Exit holes
    – Always larger, regardless of the type of material that was shot
    – A larger piece of 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 the direction from which a bullet was fired
  – Compare the size of the entrance hole to the size of the exit hole (continued)
    • Entrance holes
      – The bullet makes a very small hole when it enters
      – The glass always 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
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](http://www.sciencespot.net/Pages/classforsci.html)
- Investigator/Officer’s Personal Experience
- Corning Museum of Glass site
  - [http://www.cmog.org/default.asp](http://www.cmog.org/default.asp)
- Federal Bureau of Investigation: Laboratory Services