C4 Glass Measurements and Standards for Forensic Analysis

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The goals of this presentation are to describe forensic procedures and measurements related to the characterization of glass specimens for linkage to evidence or probable cause for glass failure or breakage.

This paper describes physical, optical, and chemical properties of glass; as well as analytical procedures and measurements related to the identification and/or comparison of glass specimens to be linked to evidence or to the probable cause for failure or breakage.

The measurement of physical, optical, and chemical properties of glass pieces or fragments are often used to identify the type of glass, such as ophthalmic glass, window glass, container glass, technical glass for electrical/electronic applications, bulbs, or automotive glass installed as windshields, windows or headlights. Measurements of glass properties can be used to track and identify the original producer or manufacturer, the date period of manufacture, and the intended application. For example, property measurements and/or evaluation of glass product characteristics, in addition to visual markings, can establish a link in the chain from producer, fabricator, distributor, geographical area, to the end-use or application. In auto hit-and-run cases, visual examinations and measurements of headlight fragments left at the scene of a crime, can establish a link to the manufacturer, year, and model of a vehicle. Furthermore, visual and residual stress measurements, as well as breakage patterns of glass fragments or fracture in articles, can confirm a poor annealing state, the presence of imperfections such as cords, striae, inclusions, and surface and other defects which may have caused failure. Also, residual stress analysis may point to the cause for the breakage of bottles, jars, windows, shelves and other glass products.

The most common and highly diagnostic measurements used to characterize glass, besides visual examinations, microscope evaluations and stress analysis, are measurements of the refractive index with its associated dispersion, density, and chemical analysis.

The refractive index and dispersion are highly sensitive measurements in the comparison of glass specimens, in order to determine if samples are identical or come from the same population or manufacturer. Refractive index measurements are used routinely and systematically in glass production to insure that the melting process and forming operations are kept invariable, and that the product homogeneity throughout the production development remains within strict tolerance levels. For major commercial producers, the refractive index for a specific glass composition is targeted to be a constant number, usually within 10 to 20 parts per million, and significantly more restrictive for optical glass. For window glass, the index is around 1.52 while for very dense optical glass the index reaches 2.0.

The refractive index of a transparent material, such as glass, obeys Snell's Law that is essentially the ratio of the velocity of light for a fixed wavelength in air to that in the glass medium. The refractive index varies with the wavelength of the incident light beam. For instance, in the ultraviolet end of the visible spectrum, the index is higher than in the red end. Glass manufacturers, especially for optical applications, specify the index at different wavelengths in the visual range spectrum. However, the most common specification of the index is for that determined with light emitted from a sodium lamp (yellow, D doublet). Associated with the index of refraction is the dispersion coefficient number, which is the rate of change of the index with wavelength.

The refractive index can be determined by using refractometers of various kinds or by comparing the glass immersed in fluids with specific fixed indices. Fluids with different indices can be mixed to obtain a fluid having different specific indices.

The density of a glass is another sensitive and highly diagnostic parameter in forensic studies. The density of glass is also kept as a constant number in the production process for any specific glass composition. The density of glass is specified in grams per cubic centimeter. It varies from 2.40 g/cm^3 for window or container soda lime glass, 2.2 g/cm^3 for borosilicate glass, to 4.0 g/cm^3 for lead or crystal glass. Common techniques to determine the density of glass are sink-float and buoyancy techniques. For sink-float, glass samples are immersed in a liquid having variable densities near the room temperature region (25°C). For buoyancy determinations, the Archimedes Principle is utilized.

There are several measurement methodologies related to the determination of chemical composition. Methods cover basic "wet chemistry" procedures and other sophisticated techniques, which utilize atomic and radiation physics principles, and nuclear interactions that require complex and expensive apparatus. Fortunately, a number of reference glasses having components comparable with those of the glass under test have been established. These reference materials and associated methods standard procedures are available for equipment calibrations. Similarly, for the measurement of residual stress, there are techniques that range from complex laser techniques, polarimeter examinations, and comparison to standard discs using a polariscope.

This paper will discuss the properties and characteristics of glass of interest to the forensic community. The discussion will encompass measurement practices, methods, standards, and precision and accuracy considerations to be taken into account for the measurement methodologies employed. This paper will provide insights on the needs for standards to be utilized in glass measurements and characterization.

Glass, Classification, Forensic Science

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