IDENTIFICATION OF GLASS FRAGMENTS BY THEIR PHYSICAL PROPERTIES FOR FORENSIC SCIENCE WORK

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Abstract: Glass, as a physical clue, is frequently encountered in various crimes. The physical properties of density and refractive index are used successfully for characterizing glass particles. The aim of this study is the identification of the glass fragments by using their physical properties and comparison of glass fragment samples to prove source correspondence. The six different types of glass; window glass, bottle glass, laboratory glassware, household cookware, tempered glass, and laminated glass were used in the experiments. Five pieces of glass fragments were selected from each type. And five more pieces of glass fragments were used to follow all experimental steps to prove the types of glass. Experimental steps chosen based on unique characteristics of the glass fragments ranging from clearly visible properties such as the fragment appearances to invisible but measurable properties like density, absorbance, and index of refraction. From the study, the measurement of the refractive index values was performed by the Digital Abbe Refractometer DR-A1. The absorbance measurement was made by USB4000 Fiber Optic Spectrometer. The density measurement was done by a simple water displacement method. The results show that combination of these methods made it possible to identify types of glass fragments.

Introduction: Glass is composed of silicon oxide mixed with various metal oxides. Most window and bottle glass are soda-lime glass, soda (Na_2CO_3) and lime (CaO) is added to sand. The wide variety of special glasses such as heat resistant glass or known as Pyrex are manufactured by adding boron oxide to the oxide mix. The safety feature glass such as tempered glass is made stronger than ordinary window glass by introducing stress through rapid heating and cooling of the glass surface.[1] Glass provides useful evidence in many forensic investigations. If glass fragments are considered to originate from the same source, they can be useful physical evidence which proves contact between the suspect and the victim. In 2000, Suzuki et al. performed the forensic discrimination of bottle glass samples from different origins by measuring refractive index and analyzing trace element by ICP-MS. They reported that comparison of trace elements in the materials is effective for discrimination, because the contents of trace elements are not strictly controlled during manufacturing processes.[2] A simple reliable technique is introduced for measuring the refractive indices of plate samples in a rather wide range of thickness by Tavassoly. This method exploits the maximum separation distance of the beams reflected from the surfaces of the plate.[3] In 2007, Newton and Buckleton used GRIM to measure the refractive index values. Data are performed that the variability of refractive index values is increased when fragment edge morphology becomes unsuitable for phase contrast microscopy.[4] The aims of this study are the identification of the glass fragments by using their physical properties and comparison of glass fragment samples to prove source correspondence. The physical properties that are density, refractive index, and absorbance were used to indicate type of glass and the data from the experiment will be used to form a data base for references. the measurement of the refractive index values was performed by the Digital Abbe Refractometer

DR-A1. The absorbance measurement was made by USB4000 Fiber Optic Spectrometer. The density measurement was done by a simple water displacement method.

Methodology: The six different types of glass; window glass, bottle glass, laboratory glassware (beaker), household cookware, tempered glass, and laminated glass were used in the experiments. Five pieces of glass fragment were selected from each type. Glass fragments were prepared by crushing a piece of glass sample for each type and collecting an appropriate size (approximately 0.5-2.0 cm in length x 1.0 cm in breadth x 1.8-4.4 cm).

Density of glass fragments measured by using a simple procedure is its mass divided by volume. Mass can be measured by digital scale and volume can be measured by volume displacement of water in a cylinder. Such a measurement was repeated 10 times for each sample, and then calculated all values of each sample to determine the average value. Density of glass fragment is determined by following relationship:

$$\text{Density of sample} = \frac{\overline{M}}{\overline{V}}$$

Refractive index measurement was performed using Digital Abbe Refractometer DR-A1. Methylene Iodine containing Sulfur Solution was used to be a contact liquid between glass fragment and prism surface in DR-A1. Reading the refractive index (RI) value was done by, while looking through the eyepiece, turning the measurement knob until the boundary line crossed the intersection point of the cross-line. The value indicated as the boundary line meeting the intersection point of the cross-line is the measurement value of RI of the sample. Such a measurement was repeated 10 times for each glass fragment sample.

Absorbance of glass fragments were measured by using USB4000 Fiber Optic Spectrometer that was connected to a computer and controlled by SpectraSuite software, and used ultraviolet (UV) LED as the light source. The UV-light transmitted through an optical fiber to the sample that was hold by placeholder. When the light interacted with the sample, another optical fiber collected and transmitted the result of the interaction to the spectrometer. The spectrometer measured the amount of light and transformed into digital information and passed the sample information to SpectraSuite. SpectraSuite compared the sample to the reference measurement and displayed processed spectral information. This experiment was done in the dark. Because UV-source was used in this experiment, so the sample information collected is set to cover wavelength 390-410 nm.

In addition, five more pieces of glass fragments were used to follow the steps above. The experiment results of these five test pieces will be compared with the results of previous glass fragment samples to identify the type of glass and to prove source correspondence.

Results, Discussion and Conclusion: As mentioned previously, the physical properties of 30 glass fragment samples from five pieces of each six different types of glass were measured and recorded. The results of density measurement are displayed in Figure 1. Density values of window glasses were measured to be in the range from 2.44 to 2.89 g/cm^3, bottle glasses found in the range from 2.39 to 2.90 g/cm^3, laboratory glasses found in the range from 2.08 to 2.35 g/cm^3, cookware glasses found in the range from 2.26 to 2.45 g/cm^3, tempered glasses found in the range from 2.30 to 2.71 g/cm^3, and laminated glasses found in the range from 2.32 to 2.69 g/cm^3. The glass fragment samples are considered to be clearly indistinguishable, because the ranges of density values have overlapping part. This should be noted that the method used in this study followed a simple procedure of the water displacement. The equipment used include cylinder and syringe had rough graduation. This, therefore, gave a limited precision to the density measurement. To achieve a more precise density measurement, techniques such as floatation method and density gradient method may be used.[1]

We have plotted the distribution of the RI values of glass fragment samples. The measured RI values of glass samples included window glasses in the range from 1.5191 to 1.5224 (±0.0006), bottle glasses in the range from 1.5202 to 1.5270 (±0.002), laboratory glasses in the range from 1.4727 to 1.4795 (±0.0017), tempered glasses in the range from 1.5183 to 1.5210 (±0.0006), and laminated glasses in the range from 1.5157 to 1.5209 (±0.0009). From Figure 2., the laboratory glassware could be clearly separated from other glass's types by a specific range of RI. Also bottle glass was separable from other glass's types. This should be noted that the result for cookware glass is not in Figure 2., because the Refractometer DR-A1 cannot measure RI of cookware glass. Limitation of the Refractometer DR-A1 is on the shape of a sample. The measurable sample must be rectangular parallelepiped (approximately 20-30 mm in length x 8 mm in breadth x 3-10 in thickness) and sample's surface should be smoothed and polished. According to the reasons mentioned, the thick cookware with relatively rough surface cannot be measured by the Refractometer DR-A1.

Figure 3. shows the measured values of absorbance of glass fragment samples at wavelength 390-410 nm. The results show that, ordered from top to bottom curves, the top curve is the absorbance of laminated glass. The next curve is the absorbance of bottle glass. The next three curves are the absorbance of window glass, laboratory glass, and tempered glass, respectively, that are mixed and difficult to clearly separate. The bottom curve is the absorbance of cookware glass. So, the absorbance measurement by using USB4000 Fiber Optic Spectrometer can differentiate among bottle glass, laminated glass, and cookware glass.

The data from these experiments will be used to form a data base for references in the comparison part. Five glass fragment samples (samples A, B, C, D, and E) were used to follow the steps above. And then, the results of these samples were compared with reference data from the results of previous glass fragment samples to prove the type of glass.

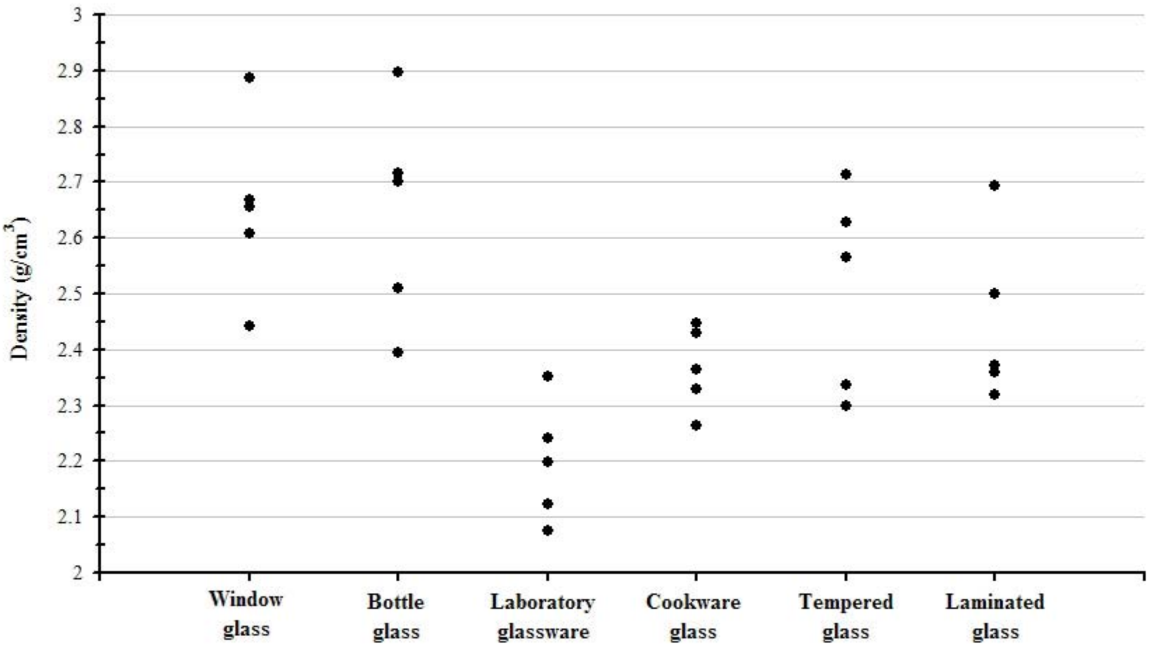

Figure 1. Plots of density results of glass fragment samples.

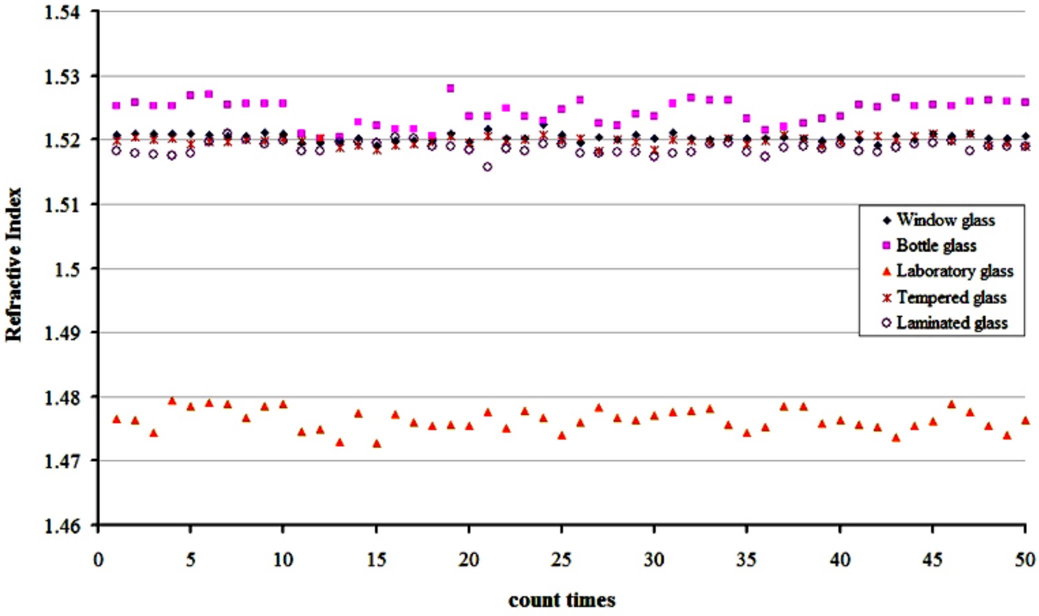

Figure 2. Plots of refractive index results of glass fragment samples by displaying RI value plotted against the count times.

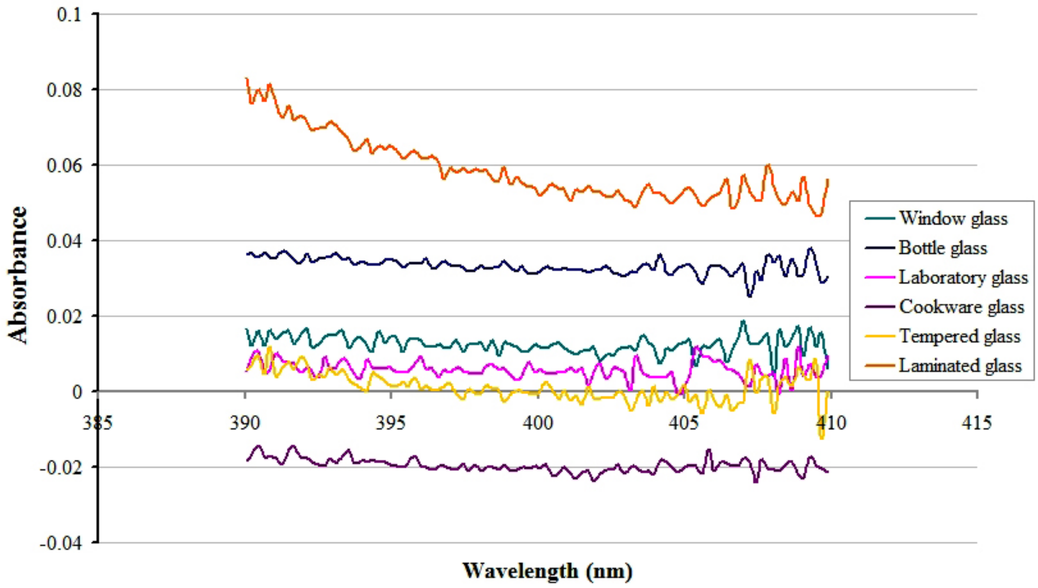

Figure 3. Absorbance results of glass fragment samples at wavelength 390-410 nm.

Figure 4. shows the density of five samples comparing with the references. Horizontal line represents the density of the samples. Density value of sample A is 2.30 g/cm^3, density value of sample B is 2.81 g/cm^3, density value of sample C is 2.49 g/cm^3, density value of sample D is 2.62 g/cm^3, and density value of sample E is 2.50 g/cm^3. From these results, we can conclude that sample A can be laboratory glass, cookware glass, or tempered glass. Sample B can be either window glass or bottle glass. Samples C, D, and E can be window glass, bottle glass, tempered glass, or laminated glass. With so many possibilities of glass

types for a piece of unknown glass fragment, only the density value cannot be used as a sole factor to distinguish glass types. Such RI measurement was repeated 10 times for each sample, and then calculated all values of each sample to determine the average. The results of RI values (mean ± SD) are as follows; RI value of sample A is 1.4776 (±0.0007), RI value of sample B is 1.5196 (±0.0006), RI value of sample C is 1.5202 (±0.0006), RI value of sample D is 1.5191 (±0.0005), RI value of sample E is 1.5237 (±0.0008). Figure 5. shows plots of the results of RI measurements for five glass samples by displaying RI value plotted against the count times. When comparing with reference data and Figure 2., it shows that sample A can be laboratory glass and sample E can be bottle glass. But samples B, C, and D cannot clearly be separated. Graphs of absorbance values of all five samples at wavelength 390-410 nm are displayed in Figure 6. When comparing with Figure 3., it shows that sample B can be window glass, sample D can be laminated glass, and sample E can be bottle glass. But sample A and C can be either laboratory glass or tempered glass.

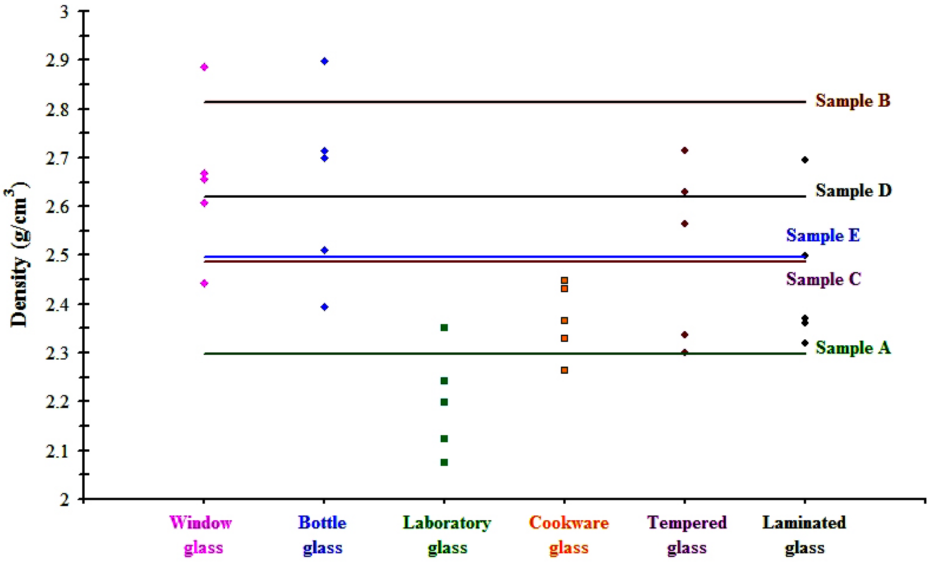

Figure 4. The results of density of five samples when compare with the references.

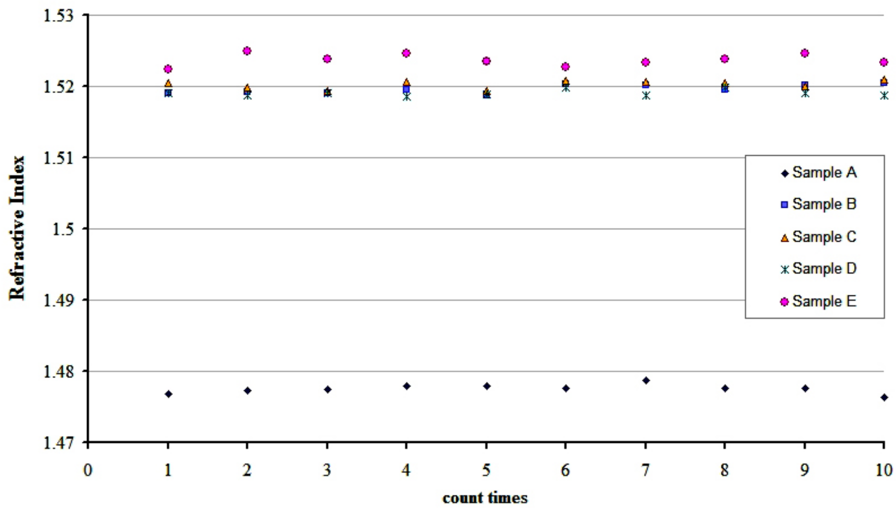

Figure 5. Plots of the results of RI measurements for five glass samples by displaying RI value plotted against the count times.

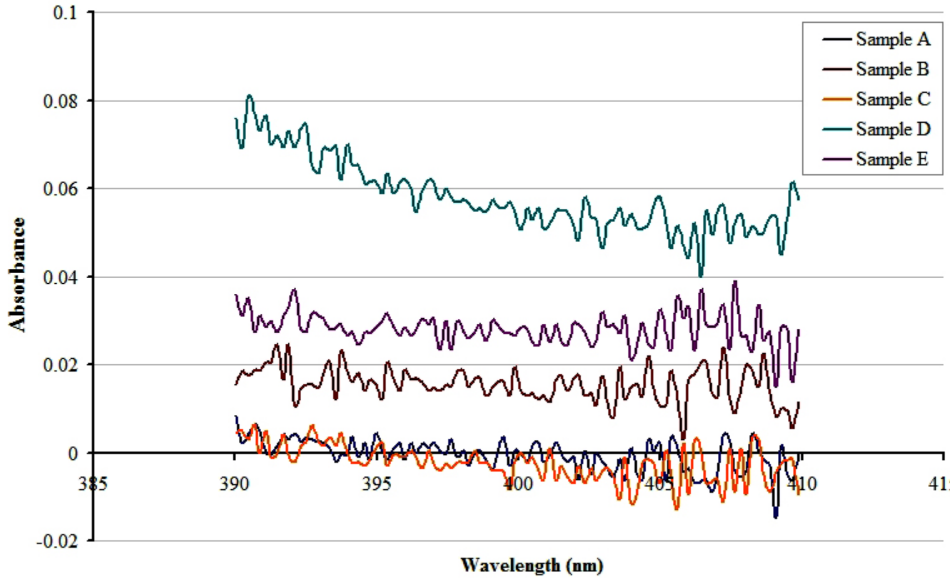

Figure 6. Absorbance values of five samples at wavelength 390-410 nm.

As the results above, we can indicate that sample A is laboratory glass, sample B is window glass, sample C is tempered glass, sample D is laminated glass, and sample E is bottle glass.

The methods of physical properties as mentioned above do not damage the sample and the execution of one method to a sample do not interfere other, so the sequential use of the method is unnecessary. From this study, RI values can separate laboratory glass and bottle glass from other glass's types, but the measurement needs skills to perform. Density measurement is easily performed, but the glass fragments cannot clearly discriminate. Identification of the glass's type by absorbance measurement can be observed from the graphs in which bottle glass, laminated glass, and cookware glass can be differentiated. However, the installation of the equipment is quite complicated. In all, choosing only one method cannot completely separate types of glass. The results of experiment have been shown that combination of these methods made it possible to identify types of glass fragment.

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