



## **Glass Analysis Test No. 17-548 Summary Report**

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This test was sent to 111 participants. Each participant received a sample set consisting of two sets of known glass fragments (Items 1 and 2) and one set of questioned glass particles (Item 3). Participants were requested to analyze and compare these and report their findings. Data were returned from 97 participants (87% response rate) and are compiled into the following tables:

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This report contains the data received from the participants in this test. Since these participants are located in many countries around the world, and it is their option how the samples are to be used (e.g., training exercise, known or blind proficiency testing, research and development of new techniques, etc.), the results compiled in the Summary Report are not intended to be an overview of the quality of work performed in the profession and cannot be interpreted as such. The Summary Comments are included for the benefit of participants to assist with maintaining or enhancing the quality of their results. These comments are not intended to reflect the general state of the art within the profession.

Participant results are reported using a randomly assigned "WebCode". This code maintains participant's anonymity, provides linking of the various report sections, and will change with every report.

# **Manufacturer's Information**

Each sample set consisted of three samples of glass fragments, two Known (Items 1 & 2) and one Questioned (Item 3). Items 1 and 3 were from the same outdoor lamp glass, while Item 2 was from a piece of replacement window glass. Examiners were instructed to examine the questioned glass particles and determine if they could have originated from the same source as either of the Known recovered glass fragments (Items 1 & 2).

## **SAMPLE PREPARATION-**

The glass was examined for defects and then broken. Differing items were processed and packaged separately from each other to prevent cross-contamination.

ITEMS 1 and 3 (ASSOCIATION): For the Known Item 1 samples, two glass fragments approximately 1/8" x 1/8" in size were selected and packaged in a glassine bag and then a pre-labeled Item 1 coin envelope. For the questioned Item 3 samples, two glass particles approximately 1/16" x 1/16" in size were selected and packaged in a glassine bag and then a pre-labeled Item 3 coin envelope. Items 1 and 3 were taken in close spatial proximity to one another and were kept together as an identification group and packaged into the sample set as described below.

ITEM 2 (ELIMINATION): For the Known Item 2 samples, two glass fragments approximately 1/8" x 1/8" in size were selected and packaged in a glassine bag and then a pre-labeled Item 2 coin envelope. Item 2 was further packaged into the sample set as described below.

SAMPLE SET ASSEMBLY: For each sample set, an Item 1 and Item 3 from the same association group were placed in a pre-labeled envelope along with an Item 2. The sample pack was sealed with invisible tape. Once verification was completed, all sample packs were further sealed with a piece of evidence tape and initialed "CTS".

The average refractive indices for the glass as reported by preliminary testing and predistribution laboratories are as follows: Item 1 RI = 1.51703, Item 2 RI = 1.51848, and Item 3 RI = 1.51705.

VERIFICATION: All three predistribution laboratories reported the expected association and elimination. The methods employed by the predistribution laboratories included Refractive Index (nD), UV fluorescence (short & long), thickness, color, XRS/XRF, and SEM/EDS.

## **Summary Comments**

This test was designed to allow participants to assess their proficiency in the examination, comparison, and interpretation of glass samples. Each sample set consisted of three samples of glass, two knowns (Items 1 and 2) and one questioned (Item 3). Items 1 and 3 were from the same outdoor lamp glass, while Item 2 was from a piece of replacement window glass. Participants were requested to determine if the set of questioned particles could have come from either of the known sources. (Refer to the Manufacturer's Information for preparation details.)

Of the 97 participants that reported results, 93 (95.9%) reported that the Item 3 glass particles could have originated from the Item 1 known glass sample and not the Item 2 known glass sample. Of the remaining participants, three reported that the Item 3 glass particles could not have originated from either the Item 1 or Item 2 known glass samples. One participant reported that the Item 3 glass particles could have originated from the Item 2 known glass sample, but not the Item 1 known glass sample.

The most commonly used methods of analysis were thickness, refractive index (nD), short UV, and color.

## Examination Results

*Could the questioned glass particles in Item 3 have originated from either the victim's outdoor lamp or home window represented by Item 1 and Item 2, respectively?*

TABLE 1

WebCode	Item 1	Item 2	WebCode	Item 1	Item 2
2474XY	Yes	No	F8DEXV	Yes	No
283U87	Yes	No	FEERNB	Yes	No
2RBVBQ	Yes	No	FNKBGU	Yes	No
2ZHRW9	Yes	No	GJ6GLU	Yes	No
3UATXN	Yes	No	GZDD6T	Yes	No
4V4W8P	Yes	No	HERY6C	Yes	No
4XQG39	Yes	No	HMKB3R	Yes	No
6H96YQ	Yes	No	HRC9C	Yes	No
6HTL68	No	No	HZRARB	Yes	No
7DGXEW	Yes	No	JJE9RF	Yes	No
7FKTXY	Yes	No	JZ77TB	Yes	No
7LMYEM	Yes	No	KB3CMA	Yes	No
7M6QQT	Yes	No	KGN8ER	Yes	No
7U682Y	Yes	No	L4V6BQ	Yes	No
7W97CR	Yes	No	LFPHHM	Yes	No
82YZMX	Yes	No	LJQL9N	Yes	No
8XFN22	No	No	LLEVKB	Yes	No
8YTEYX	Yes	No	LXB43D	Yes	No
AD3ZBM	Yes	No	M8R8MH	Yes	No
AJTAKK	Yes	No	MPVKJE	Yes	No
AKJDDR	Yes	No	MU476Q	Yes	No
AY4XWZ	Yes	No	N6KE44	Yes	No
BAKZTL	Yes	No	P6YXQL	Yes	No
BECAUY	Yes	No	P9YBEL	Yes	No
BR3YYJ	Yes	No	PBNBRA	Yes	No
BU7UHL	Yes	No	PNAQVA	Yes	No
C64UUQ	Yes	No	PXZCRL	Yes	No
CCG6LW	Yes	No	PZ2FGN	Yes	No
DFER6Y	Yes	No	QDMC6C	Yes	No
DH2KQE	Yes	No	QPEX9L	Yes	No
DL78KY	Yes	No	QXYT6	Yes	No
DT6JYN	Yes	No	R2QKXD	Yes	No
DUEQTW	Yes	No	RBCRMG	No	Yes
EBHKZV	Yes	No	T4W94H	Yes	No
EYPX3L	Yes	No	TEAR8J	Yes	No
			U8ARA3	Yes	No

TABLE 1

WebCode	Item 1	Item 2	WebCode	Item 1	Item 2
UEBPBE	Yes	No			
UEPBRG	Yes	No			
ULRG96	Yes	No			
V9VHZ	Yes	No			
VW6277	Yes	No			
WBYNAD	Yes	No			
WHZ4NE	Yes	No			
WMVU7W	Yes	No			
WWJN98	Yes	No			
WYQ6E4	Yes	No			
XEWNPZ	No	No			
XMC88E	Yes	No			
XVZ62F	Yes	No			
XZWP24	Yes	No			
Y7WNND	Yes	No			
Y8FDCY	Yes	No			
YQ8MZA	Yes	No			
YQ993G	Yes	No			
YTAHJC	Yes	No			
YTBCC4	Yes	No			
YVZHWZ	Yes	No			
Z3EN7C	Yes	No			
ZCKTXT	Yes	No			
ZFFMU9	Yes	No			
ZUXDTB	Yes	No			
ZYDLAB	Yes	No			

<b>Response Summary</b>		<b>Total Participants: 97</b>	
<i>Could the questioned glass particles in Item 3 have originated from either the victim's outdoor lamp or home window represented by Item 1 and Item 2, respectively?</i>			
		<u>Item 1</u>	<u>Item 2</u>
<b>Response</b>	Yes	93 (95.9%)	1 (1.0%)
	No	4 (4.1%)	96 (99.0%)
	Inconclusive	0 (0.0%)	0 (0.0%)

# Examination Procedures

TABLE 2

WebCode	Refractive Index				Color	Density	Thickness	Elemental		UV		
	nD	nF	nC	$\Delta$ RI				SEM/ EDS	XRS/ XRF	Long	Short	Other
2474XY	✓				✓	✓	✓		✓	✓	✓	
283U87	✓						✓			✓	✓	
2RBVBQ	✓						✓	✓				✓
2ZHRW9	✓				✓		✓			✓	✓	
3UATXN	✓				✓		✓					✓
4V4W8P	✓						✓		✓			✓
4XQG39												Inductively-Coupled- Plasma Mass Spectrometry
6H96YQ				✓			✓	✓		✓	✓	
6HTL68							✓	✓	✓			
7DGXEW	✓				✓		✓		✓	✓	✓	
7FKTXY					✓		✓	✓		✓	✓	
7LMYEM	✓				✓		✓		✓	✓	✓	PLM
7M6QQT	✓				✓		✓		✓	✓	✓	Macroscopic/ Stereomicroscopic examinations of morphology
7U682Y	✓								✓	✓	✓	color - visually and microscopically only
7W97CR	✓				✓	✓	✓	✓		✓	✓	
82YZMX												ICP-MS
8XFN22					✓		✓	✓				
8YTEYX	✓				✓		✓	✓				✓
AD3ZBM	✓				✓	✓	✓	✓		✓	✓	
AJTAKK	✓				✓		✓			✓	✓	ICP-MS
AKJDDR	✓				✓	✓	✓		✓	✓	✓	
AY4XWZ	✓				✓		✓		✓	✓	✓	
BAKZTL	✓				✓		✓		✓			✓
BECAUY	✓				✓		✓			✓	✓	
BR3YYJ	✓				✓		✓	✓				✓

TABLE 2

WebCode	Refractive Index					Density	Thickness	Elemental		UV		
	nD	nF	nC	$\Delta$ RI	Color			SEM/ EDS	XRS/ XRF	Long	Short	Other
BU7UHL	✓			✓	✓		✓				✓	
C64UUQ	✓				✓		✓		✓	✓	✓	Attempted physical fit/fracture match
CCG6LW	✓			✓			✓				✓	Surface examination - interference pattern
DFER6Y	✓						✓				✓	LA-ICP-MS
DH2KQE	✓				✓	✓	✓			✓	✓	
DL78KY	✓				✓		✓		✓		✓	
DT6JYN	✓	✓	✓		✓		✓			✓	✓	
DUEQTW	✓			✓	✓		✓	✓			✓	
EBHKZV	✓											
EYPX3L	✓				✓		✓	✓				
F8DEXV	✓				✓		✓		✓	✓	✓	
FEERNB	✓				✓		✓		✓		✓	
FNKBGU	✓				✓			✓			✓	
GJ6GLU	✓						✓			✓	✓	
GZDD6T				✓	✓	✓		✓		✓	✓	
HERY6C	✓				✓		✓	✓		✓	✓	
HMKB3R	✓				✓		✓			✓	✓	
HRC9C	✓				✓		✓			✓	✓	
HZRARB	✓				✓		✓		✓	✓	✓	
JJE9RF	✓				✓		✓			✓	✓	
JZ77TB	✓				✓		✓	✓			✓	
KB3CMA	✓				✓	✓	✓			✓	✓	Temper
KG8ER	✓				✓		✓	✓	✓	✓	✓	Laser-ICP-MS
L4V6BQ				✓	✓		✓			✓	✓	
LFPHHM	✓				✓		✓	✓		✓	✓	LA-ICP-MS
LJQL9N	✓				✓		✓		✓		✓	
LLEVKB	✓	✓	✓		✓		✓	✓		✓	✓	
LXB43D	✓			✓	✓		✓				✓	Interferometry

TABLE 2

WebCode	Refractive Index					Density	Thickness	Elemental		UV		
	nD	nF	nC	$\Delta$ RI	Color			SEM/ EDS	XRS/ XRF	Long	Short	Other
M8R8MH				✓	✓		✓		✓			LIBS
MPVKJE	✓				✓				✓	✓	✓	
MU476Q	✓				✓		✓	✓		✓	✓	Polarized Light Microscopy.
N6KE44	✓				✓		✓		✓		✓	
P6YXQL				✓	✓		✓		✓			
P9YBEL												LA-ICP-MS
PBNBRA	✓				✓		✓	✓	✓	✓	✓	
PNAQVA	✓				✓		✓				✓	LIBS
PXZCRL	✓				✓		✓				✓	LA-ICP-MS
PZ2FGN					✓	✓			✓			LIBS
QDMC6C	✓	✓	✓		✓		✓			✓	✓	
QPEX9L	✓				✓		✓			✓	✓	ICP-OES
QXYT6												LA-ICP-MS
R2QKXD	✓			✓	✓		✓		✓	✓	✓	Microscopic exam (stereoscopic and PLM)
RBCRMG												Raman Spectroscopy
T4W94H	✓				✓		✓		✓	✓	✓	
TEAR8J	✓						✓	✓		✓	✓	
U8ARA3	✓						✓		✓		✓	
UEBPBE	✓						✓	✓				
UEPBRG							✓	✓				
ULRG96	✓				✓			✓				
V9VHZ				✓	✓		✓	✓		✓	✓	
VW6277	✓				✓		✓		✓	✓	✓	
WBYNAD	✓				✓				✓	✓	✓	
WHZ4NE	✓			✓	✓		✓		✓		✓	
WMVU7W	✓				✓		✓		✓	✓	✓	
WWJN98												LASER ABLATION ICP-MS
WYQ6E4	✓			✓	✓		✓			✓	✓	LA-ICP-MS



TABLE 2

WebCode	Refractive Index				Color	Density	Thickness	Elemental		UV		
	nD	nF	nC	$\Delta$ RI				SEM/ EDS	XRS/ XRF	Long	Short	Other
XEWNPZ	✓				✓		✓				✓	
XMC88E	✓											
XVZ62F	✓	✓			✓		✓		✓		✓	
XZWP24	✓	✓	✓		✓	✓	✓			✓	✓	
Y7WNND	✓				✓		✓				✓	ICP-OES
Y8FDCY	✓				✓		✓			✓	✓	LIBS
YQ8MZA	✓											
YQ993G	✓				✓		✓	✓	✓	✓	✓	
YTAHJC												LA-ICPMS
YTBC4	✓	✓	✓		✓	✓	✓			✓	✓	
YVZHWZ	✓				✓		✓			✓	✓	LIBS and LA-ICP-MS
Z3EN7C	✓	✓	✓		✓	✓	✓				✓	
ZCKTXT	✓				✓				✓	✓	✓	
ZFFMU9					✓		✓	✓	✓	✓	✓	
ZUXDTB	✓				✓		✓		✓	✓	✓	
ZYDLAB	✓						✓		✓			

### Response Summary

Participants	Refractive Index				Color	Density	Thickness	Elemental		UV	
	nD	nF	nC	$\Delta$ RI				SEM/ EDS	XRS/ XRF	Long	Short
97	78	7	6	13	73	11	79	27	36	52	77
Percent	80%	7%	6%	13%	75%	11%	81%	28%	37%	54%	79%

# Conclusions

TABLE 3

WebCode	Conclusions
2474XY	The glass in Item 3 was identical to the glass in Item 1 in optical, physical, and elemental properties. This means that the glass recovered from the suspect's jacket could have originated from the victim's outdoor lamp. The glass in Item 3 was different from the glass in Item 2. This means that the glass recovered from the suspect's jacket did not originate from the victim's home window.
283U87	1). The particles of questioned glass recovered from the suspect's jacket (Item 3) could not be excluded as having come from the victim's outdoor lamp (Item 1). Therefore, these glass particles came from either the victim's outdoor lamp or from another source or sources of broken, greenish, tempered glass indistinguishable from item 1 in thickness, color and refractive index. 2). The recovered fragments from suspect's jacket (Item 3) were found to be distinguishable from the known glass from taken from the victim's home window (Item 2). This negative comparison indicates a different origin between both items.
2RBVBQ	Item 1 comprised clear glass with parallel sides. The thickness of the glass was 2.25 mm. The average refractive index of the glass was 1.5169. The gross elemental composition of the glass included the elements silicon, sodium, calcium, magnesium and aluminium. Item 2 comprised clear glass with parallel sides. The thickness of the glass was 2.23 mm. The average refractive index of the glass was 1.5184. Item 3 comprised clear glass with parallel sides. The thickness of the glass was 2.25 mm. The average refractive index of the glass was 1.5169. The gross elemental composition of the glass included the elements silicon, sodium, calcium, magnesium and aluminium. Item 3 corresponded in thickness, average refractive index and gross elemental composition with item 1. The results support the proposition that item 3 originated from item 1. Item 3 differed in thickness and refractive index from item 2. The results do not support the proposition that item 3 originated from item 2.
2ZHRW9	The glass from questioned "item 3" was found to be consistent with the known glass "item 1". Therefore, the glass from the "item 3" could have come from the same source as the glass from "item 1". The glass from questioned "item 3" was found to be inconsistent with the known glass "item 2". Therefore, the glass from the "item 3" could not have come from the same source as the glass from "item 2".
3UATXN	In my opinion the findings provide strong support for the proposition that the clothing believed to belong to the suspect was close (within 1-2m) to the glass from the lamp (Item 1) when it broke, rather than the proposition that it was not close to the glass when it was broken. It is also my opinion that there is no evidence of an association between the clothing of the suspect and the broken window (Item 2).
4V4W8P	Glass fragments in item 3 could have come from the same source (outdoor lamp) as those in item 1, or from another broken glass object with similar measured properties. The window, as represented by the glass fragments in item 2, could not have been the source of the glass fragments in item 3.
4XQG39	The chemical composition of ITEM 3 is indistinguishable from the chemical composition of ITEM 1, and therefore could have the same origin. The chemical composition of ITEM 3 is distinguishable from the chemical composition of ITEM 2, and therefore could not have the same origin.
6H96YQ	1. Item 2 and item 3 glass samples could be distinguished from each other based upon differences in physical properties and refractive index. 2. Item 1 glass samples were consistent with item 3 glass samples in physical properties, refractive index and elemental composition.

TABLE 3

WebCode	Conclusions
6HTL68	Sample item #3 shows differences in elemental analysis which indicates that the item #3 doesn't originate from either item #1 nor item #2
7DGXEW	<p>CONCLUSIONS: Two glass fragments recovered from the suspect's jacket (Item 3) either originated from the victim's outdoor lamp (Item 1) or another source of broken glass possessing the same distinct physical, optical, and chemical characteristics. These two glass fragments recovered from the suspect's jacket (Item 3) did not originate from the victim's home window (Item 2). RESULTS: Two full thickness questioned glass fragments from the suspect's jacket (Item 3) were examined for the purpose of determining whether or not there is any glass present like the known glass standards from the victim's outdoor lamp (Item 1) and/or the victim's home window (Item 2). The known glass standard from the victim's outdoor lamp (Item 1) is colorless, non-tempered, non-float glass. The known glass standard from the victim's home window (Item 2) is colorless, non-tempered, float, sheet glass. Examination and comparison of the questioned glass fragments recovered from the suspect's jacket (Item 3) with the known glass standard from the victim's outdoor lamp (Item 1) reveals they are alike with respect to physical, optical, and chemical characteristics. It is therefore concluded that these questioned glass fragments recovered from the suspect's jacket (Item 3) either originated from the lamp (Item 1) or another source of broken glass possessing the same distinct physical, optical, and chemical characteristics. Examination and comparison of the questioned glass fragments recovered from the suspect's jacket (Item 3) with the known glass standard from the victim's home window (Item 2) reveals they are dissimilar with respect to ultraviolet fluorescence and chemical characteristics. It is therefore concluded that these questioned glass fragments recovered from the suspect's jacket (Item 3) did not originate from the window (Item 2).</p> <p>METHODS OF ANALYSIS: Examinations were performed visually, by stereo microscopy, polarized light microscopy, ultraviolet fluorescence, micrometry, refractive index determination, and x-ray fluorescence spectroscopy.</p>
7FKTX	The color and thickness of all three items are similar, however, items 1 and 3 are more similar than item 2. This is also true of the brilliance (visual estimation of refractive index) of items 1 and 3 relative to item 2. Compositionally, especially in terms of minor components Ca, and Mg, and Al, item 3 looks the same as item 1. Item 2 is compositionally different. So item 1 could be the source of item 3; item 2 could not.
7LMYEM	Analysis showed the known glass taken from the victim's outdoor lamp (item #1) and the broken glass recovered from the suspect's jacket (item #3) were consistent in physical properties, refractive index, and elemental composition. These fragments could have shared a common origin. No association was found between the known glass taken from the victim's home window (item #2) and the broken glass recovered from the suspect's jacket (item #3).
7M6QQT	Item 1 consists of two colorless glass fragments that exhibit characteristics consistent with non-tempered non-float glass. Item 2 consists of two colorless glass fragments that exhibit characteristics consistent with non-tempered float glass. The glasses in both Items 1 and 2 have their full thicknesses and were used as standards for comparison to the glass in Item 3. The Item 3 glass consists of two colorless glass fragments that have their full thickness and exhibit characteristics consistent with non-tempered non-float glass. While the glasses in Items 2 and 3 could not be discriminated by examinations of their color or thickness, significant differences between them were observed with respect to their fluorescence under ultraviolet lamps as well as their chemical compositions. Therefore, the glass from the subject's jacket could not have originated from the victim's broken home window represented by Item 2. Macroscopic, microscopic and instrumental examinations and comparisons of Items 1 and 3 revealed that they are like one another with respect to their color, thickness, refractive index values and chemical characteristics. It is therefore concluded that the glass fragments found in the subject's

TABLE 3

WebCode	Conclusions
	jacket originated either from the victim's broken outdoor lamp or from another source of broken non-tempered non-float glass having these same characteristics.
7U682Y	Questioned glass fragments QA and QB were submitted to the [Laboratory] for glass analysis and comparison to the known glass fragments K1A, K1B, K2A, and K2B. All six fragments were visually and microscopically (stereomicroscope and Polarized Light microscope) examined, probed for hardness, and subjected to solubility testing in water. The six fragments were found to be hard, isotropic, insoluble in water, and all exhibited conchoidal fractures, which are class characteristics of glass. K1A, K2A, K2B, QA, and QB were instrumentally analyzed by X-Ray Fluorescence Spectrometry (XRF) and Glass Refractive Index Measurement System (GRIM). Visual and microscopic examination and instrumental analysis (XRF and GRIM) of questioned glass fragments QA and QB and comparison to the known glass fragment K1A disclosed that they are consistent and no discriminating differences were observed with respect to color, appearance, response to UV light, elemental composition and refractive index. Therefore, it is the opinion of the undersigned that the questioned glass fragments QA and QB could have originated from the same source as represented by the known glass K1A or from another source exhibiting all of the same analyzed characteristics. Visual and microscopic examination and instrumental analysis (XRF and GRIM) of questioned glass fragments QA and QB and comparison to the known glass fragments K2A and K2B disclosed that they are different with respect to their elemental composition and refractive index. Therefore, it is the opinion of the undersigned that the questioned glass fragments QA and QB could not have originated from the same source as represented by the known glass fragments K2A and K2B. Fragment K1B was not instrumentally analyzed and no further conclusions can be reached about K1B at this time. Examination of Laboratory items #1, 2, and 3 did not disclose the presence of any trace evidence.
7W97CR	Based on the particles examined, the glass from Item #3 was consistent with Item #1 glass in the physical properties examined, refractive index, and inorganic composition. It was concluded that these particles could have originated from the same source or another source of broken glass with the same properties. Glass from Item #3 could not be associated with Item #2 glass due to differences in refractive index.
82YZMX	Item 1 is not distinguishable from Item 3 based on comparison of 42 elements using 4x standard deviation criteria and therefore could have originated from the same source. Item 2 is distinguishable from Item 3 by 33 of the 42 elements using 4x standard deviation criteria based on the following elements: Li, Be, Al, Ti, V, Mn, Fe, Ga, Rb, Sr, Y, Nb, Cs, Ba,La,Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta, Pb, Th, & U. Therefore, Item 2 could not have originated from the same source as Item 3.
8XFN22	On the basis of the work carried out, it was considered that the fragments comprising Item 3 did not match either the Item 1 fragments or Item 2 fragments.
8YTEYX	INTERPRETATIONS AND OPINIONS: Examination and comparison of Items 1 and 3 revealed glass that was similar in all measured physical, optical and elemental properties. They could have come from the same source or any other source with the same properties. Examination and comparison of Items 2 and 3 revealed glass that was dissimilar in all measured physical and optical properties. They could not have come from the same source
AD3ZBM	Based on the particles examined, the glass from Item #3 was consistent with Item #1 glass in the physical properties examined, refractive index, and inorganic composition. It was concluded that these particles could have originated from the same source or another source of broken glass with the same properties. Glass from Item #3 could not be associated with Item #2 glass due to differences in their Refractive Index.

TABLE 3

WebCode	Conclusions
AJTAKK	Microscopic and instrumental examination and comparison of Item 3 to Item 1 revealed them to be the same with respect to physical and optical properties and elemental composition. Therefore, Item 3 came from the source represented by Item 1 or another source with the same physical and optical properties and elemental composition. Microscopic examination and comparison of Item 3 to Item 2 revealed them to be inconsistent with respect to optical properties. Therefore, Item 3 could not have come from the source represented by Item 2.
AKJDDR	The glass in Item 3 was identical to the glass in Item 1 in physical, optical, and elemental properties. This means the glass recovered from the suspect's jacket could have come from the victim's outdoor lamp. The glass in Item 3 was different from the glass in Item 2. This means the glass recovered from the suspect's jacket did not come from the victim's home window.
AY4XWZ	Based on our examination regarding the RI the incriminated glass particles of Item 3 could have originated from the material of comparison of Item 1. Item 2 could be excluded as being the source of origin of Item 3.
BAKZTL	Questioned glass particles (Item 3) and known glass (Item 1) were compared using physical characteristics, refractive index measurements, and elemental analysis by X-Ray Fluorescence (XRF). The tested questioned glass fragments were similar in color, thickness, refractive index, and elemental composition to the known glass. The source of the known glass (Item 1) is a possible source of the tested questioned glass fragments (Level 3 - Association). Because similar glass has been manufactured that would be indistinguishable from the submitted evidence, an individual source cannot be determined. Questioned glass particles (Item 3) and known glass (Item 2) were compared using physical characteristics and elemental analysis by X-Ray Fluorescence (XRF). The tested questioned glass fragments differed in color, UV fluorescence, and elemental composition from the known glass. The questioned glass and the known glass (Item 2) do not share a common origin (Elimination).
BECAUY	The two control glasses were examined when their physical characteristics were noted. The two fragments of glass recovered from the suspect's jacket were examined when they were found to be similar in colour and refractive index to the control glass from the lamp, and therefore they could have had a common origin. The two fragments of glass recovered from the suspect's jacket were examined when they were found to be different in refractive index from the control glass from the window.
BR3YYJ	The glass from item 1 and the glass from item 3 were visually, microscopically and instrumentally (refractive index and elemental composition) consistent. This indicates that the glass from item 1 and the glass from item 3 could share a common origin. The glass from item 2 and the glass from item 3 were visually and instrumentally (refractive index) inconsistent. This indicates that the glass from item 2 and the glass from item 3 do not share a common origin.
BU7UHL	Particles of questioned glass recovered from the suspect's jacket (Item 3) could have a common origin with glass fragments of known glass taken from the victim's outdoor lamp (Item 1). Particles of questioned glass (Item 3) are different from glass fragments of known glass taken from the victim's home window (Item 2).
C64UUQ	1. Comparative examinations of the glass fragments in Exhibit 1 (known glass from the victim's outdoor lamp) with the glass fragments in Exhibit 3 (questioned glass recovered from the suspect's jacket) disclosed them to be consistent in their physical characteristics, elemental compositions, and refractive indices. As a result of these findings, the fragments in Exhibit 3 could have originated from the same source as the fragments in Exhibit 1 or another source with the same characteristics. 2. It should be noted that a glass association is not a means of positive identification and the number of possible sources for a specific glass is unknown. 3. Comparative examinations of the glass fragments in Exhibit 2 (known glass from the victim's

TABLE 3

WebCode	Conclusions
	home window) with the glass fragments in Exhibit 3 (questioned glass recovered from the suspect's jacket) disclosed them to be inconsistent in their optical properties and elemental composition. As a result of these findings, the fragments in Exhibit 3 could not have originated from the same source as the fragments in Exhibit 2.
CCG6LW	I have considered the proposition that the two particles of glass recovered from the suspect's jacket item 3 could have originated from glass from the victim's outdoor lamp as represented by the submitted control item 1; the results of this examination provide support for this proposition. The two particles of glass item 3 did not originate from the glass from the victim's home window as represented by the submitted control item 2.
DFER6Y	<p>The evidence was examined from 6/7/17-6/21/17 via automated glass refractive index measurement (GRIM2) and laser ablation - inductively coupled plasma mass spectrometry (ICP-MS). The questioned glass from Item 3 was consistent in thickness, fluorescence, refractive index and trace elemental composition with the known glass from Item #1 and could have originated from this source (Level II association). The questioned glass from Item 3 was inconsistent in thickness, fluorescence, refractive index and trace elemental composition with the known glass from Item #2 and did not originate from this source (Elimination). Terminology Key for Associative Evidence: The following descriptions are meant to provide context to the levels of opinions reached in this report. Every level of conclusion may not be applicable in every case nor for every material type. Level I Association: A physical match; items physically fit back to one another, indicating that the items were once from the same source. Level II Association: An association in which items are consistent in observed and measured physical properties and/or chemical composition and share atypical characteristic(s) that would not be expected to be readily available in the population of this evidence type. Level III Association: An association in which items are consistent in observed and measured physical properties and/or chemical composition and, therefore, could have originated from the same source. Because other items have been manufactured that would also be indistinguishable from the submitted evidence, an individual source cannot be determined. Level IV Association: An association in which items are consistent in observed and measured physical properties and/or chemical composition and, therefore, could have originated from the same source. As compared to a Level III association, items categorized within a Level IV share characteristics that are more common amongst these kinds of manufactured products. Alternatively, an association between items would be categorized as a Level IV if a limited analysis was performed due to characteristics or size of the specimen(s). Level V Association: An association in which items are consistent in some, but not all, physical properties and/or chemical composition. Some minor variation(s) exists between the known and questioned items and could be due to factors such as sample heterogeneity, contamination of the sample(s), or having a sample of insufficient size to adequately assess homogeneity of the entity from which it was derived. Inconclusive: No conclusion could be reached regarding an association/elimination between the items. Elimination: The items were dissimilar in physical properties and/or chemical composition, indicating that they did not originate from the same source.</p>
DH2KQE	Items 1, 2 and 3 were examined visually, using stereomicroscopy, and a digital caliper. Items 1 and 3 were further examined with a density comparison technique and the Glass Refractive Index Measurement system (GRIM3). The Item 3 glass fragments were consistent with the Item 1 glass in color, thickness, temper float properties, density and refractive index. It was concluded that these particles could have originated from the broken glass source represented by Item 1 or another source of broken glass with the same properties. The Item 3 glass fragments could not be associated with the Item 2 glass due to differences in float properties.
DL78KY	The color, physical, and elemental characteristics of Item# 3.1 and 3.2 were consistent with the

TABLE 3

WebCode	Conclusions
	color, physical, and elemental characteristics of Item #1. This is a Type III Association. Differences were found in the color, physical, and elemental characteristics of Item# 3.1, 3.2 and Item #2. Therefore, these two items do not share a common source. This is an Elimination.
DT6JYN	Two particles of glass were found in Item 3 (from suspect's jacket) that corresponded in general appearance (colorless), thickness, fluorescence and refractive index (GRIM – 656 nm, 589 nm and 488 nm) to the known glass from Item 1 (victim's outdoor lamp). Therefore, the unknown glass in Item 3 cannot be eliminated as having a common source with the glass from the Item 1 lamp glass (Type IV Association). It should be noted that the [Laboratory] currently does not have the instrumentation that would provide for additional discrimination which would allow for a higher association. The unknown glass in Item 3 was different in fluorescence and refractive index (GRIM – 589 nm) to the known glass from Item 2 (victim's home window). Therefore, the unknown glass in Item 3 did not come from the same source of glass as the Item 2 window glass (Elimination). KEY for instrument acronyms: GRIM – Glass Refractive Index Measurement. Interpretation: The following descriptions are meant to provide context to the opinions reached in this report. Every type of conclusion may not be applicable in every case or for every material type. Type I Association: Identification: An association in which items share individual characteristics and/or physically fit together that demonstrate the items were once from the same source. Type II Association: Association with distinct characteristics: An association in which items correspond in all measured physical properties, chemical composition and/or microscopic characteristics and share distinctive characteristic(s) that would not be expected to be found in the population of this evidence type. The distinctive characteristics were not sufficient for a Type I Association. Type III Association: Association with conventional characteristics: An association in which items correspond in all measured physical properties, chemical composition and/or microscopic characteristics and could have originated from the same source. Because it is possible for another sample to be indistinguishable from the submitted evidence, an individual source cannot be determined. Type IV Association: Association with limitations: An association in which items could not be differentiated based on observed and/or measured properties and/or chemical composition. As compared to the categories above, this type of association has decreased evidential value as a result of items that are more commonly encountered in the relevant population, the inability to perform a complete analysis, limited information, or minor variations observed in the data. Inconclusive: No conclusion could be reached regarding an association or an elimination between the items. Dissimilar: The items were dissimilar in physical properties and/or chemical composition, indicating that the items may not have originated from the same source. However, these dissimilarities were insufficient for a definitive Elimination. Elimination: Items exhibit dissimilarities in one or more of the following: physical properties, chemical composition or microscopic characteristics and, therefore, conclusively did not originate from the same source.
DUEQTW	In my opinion my findings provide moderately strong support for the proposition that the two glass fragments taken from the jacket, represented by item 3, originated from the broken lamp at the premises in question, represented by item 1.
EBHKZV	The questioned glass recovered from the suspect's jacket, item 3 could have originated from the known glass taken from the victim's outdoor lamp, item 1. Item 3 could not have originated from the victim's home window, item 2.
EYPX3L	The known glass sample in Item 1 taken from the victim's outdoor lamp comprised two pieces of transparent and colourless glass fragments, which were found to agree in colour, thickness, refractive index* and elemental composition with each other. Furthermore, these two pieces of glass fragments could be physically fitted together, with matching their characteristic contours at the broken edges, to form a single piece of glass fragment. The known glass sample in Item 2



TABLE 3

WebCode	Conclusions
	taken from the victim's home window comprised two pieces of transparent and colourless glass fragments, which were found to agree in colour, thickness, refractive index* and elemental composition with each other. Furthermore, the known glass sample in Items 1 & 2 were found to agree in colour and elemental composition, but differ in refractive index* with each other. The questioned glass sample in Item 3 recovered from the suspect's jacket comprised two pieces of transparent and colourless glass fragments. These recovered glass fragments were found to agree in colour, thickness, refractive index* and elemental composition with the known glass sample Item 1, suggesting that they could have come from the same source. *Refractive index is a physical property of glass, which is a measurement of the degree of refraction of light after passing through the glass and can vary from glass to glass.
F8DEXV	The glass recovered from the suspect's jacket Item3, was indistinguishable in physical properties, refractive index and elemental composition to the glass taken from victim's outdoor lamp Item1, therefore, The glass recovered from the suspect's jacket Item3, could have originated from the glass taken from victim's outdoor lamp Item1 or from another source of glass produced by the same manufacturer exhibiting the same physical and chemical properties. The glass recovered from the suspect's jacket Item3, could not have originated from the glass taken from victim's home window Item2.
FEERNB	The findings provide moderately strong support for the proposition that the glass from the suspect's jacket originated from the broken lamp. The glass from the suspect's jacket can be excluded as having originated from the broken window based on differences in physical and chemical properties.
FNKBGU	In my opinion, the findings provide moderately strong support for the view that the glass fragments recovered from the suspect's jacket have originated from the broken outdoor lamp at the victim's house, rather than originating from a different, random source of glass.
GJ6GLU	Item 1 is consistent with Item 3. Item 2 is not consistent with Item 3.
GZDD6T	The analysis revealed that the measured physical and chemical properties of Item #1 and Item #3 are indistinguishable. The measured physical and chemical properties of Item #2 and Item #3 are dissimilar. The glass from Item #1 cannot be eliminated as the source of glass for Item #3. The glass from Item #2 cannot be the source of glass for Item #3.
HERY6C	The glass in Item 1 was visually, microscopically and instrumentally (refractive index and elemental composition) consistent with the glass in Item 3. This indicates that the glass in Items 1 and 3 could share a common origin. The glass in Item 2 was instrumentally (refractive index) different from the glass in Item 3. This indicates that the glass in Items 2 and 3 do not share a common origin.
HMKB3R	Item 3 differs in color, thickness, UV fluorescence behavior and in the refractive index from Item 2 (glass from the home window). Item 3 cannot be distinguished from Item 1 by looking at color, thickness, UV fluorescence and refractive index. The questioned glass particles in Item 3 may have originated from the victim's outdoor lamp (Item1).
HRCD9C	The glass from the suspect's jacket (Item 3) could have originated from the same source as the glass standard from the victim's outdoor lamp (Item 1) or from another source of glass with indistinguishable color, refractive index, fluorescence, and thickness. The glass from the suspect's jacket (Item 3) could not have originated from the same source as the glass standard from the victim's window (Item 2).
HZRXRB	Two glass fragments were recovered from the suspect's jacket (Item 3). One glass fragment recovered from the suspect's jacket (Item 3A) is similar in visual color, type of glass, thickness, UV fluorescence, refractive index, and trace elemental composition to the known glass from the



TABLE 3

WebCode	Conclusions
	victim's outdoor lamp (Item 1). It is our opinion that this glass fragment from the suspect's jacket could have come from the victim's outdoor lamp. The other glass fragment recovered from the suspect's jacket (Item 3B) exhibits slight difference in trace elemental composition from the known glass from the victim's outdoor lamp (Item 1). We are unable to determine if this difference is because this fragment from the jacket did not come from the lamp or because of other factors affecting the analysis. Both glass fragments recovered from the suspect's jacket (Items 3A and 3B) are different than the known glass from the victim's home window (Item 2). It is our opinion that neither fragment from the suspect's jacket came from the victim's home window.
JJE9RF	I formed the opinion based on the techniques used, that the glass fragments recovered from the suspect's jacket (item 3) had the same refractive index as the control glass collected from the victim's outdoor lamp (item 1) and could have come from it. I also formed the opinion based on the techniques used, that the glass fragments recovered from the suspect's jacket (item 3) had a different refractive index to the control glass collected from the victim's home window(item 2) and could not have come from it.
JZ77TB	Item 1 - A colorless glass standard was analyzed for comparison to Item 3. Item 2 - A colorless glass standard was analyzed for comparison to Item 3. Item 3 - In the sample analyzed, two small pieces of colorless glass were found. The unknown glass (Item 3) and the standard glass (Item 2) are not the same in physical and chemical characteristics. The unknown glass (Item 3) could not have originated from the standard (Item 2). The unknown glass (Item 3) either originated from the standard glass (Item 1) or another source of broken glass possessing the same distinct physical and chemical characteristics.
KB3CMA	Items 1, 2, and 3 were examined visually and using a digital caliper and the Glass Refractive Index Measurement system (GRIM3). Items 1 and 3 were further examined using a density comparison technique. The Item 1 and 2 glass samples could be distinguished from each other based upon differences in float properties and color. The Item 3 glass fragments were consistent with the Item 1 glass in float properties, thickness, density, and refractive index. It was concluded that these fragments could have originated from the broken glass source represented by Item 1 or another source of broken glass with the same properties. The Item 3 fragments could not be associated with the Item 2 glass due to differences in float properties.
KGN8ER	According to the results of above mentioned examination and analysis procedures [Table 2 - Examination Procedures], the questioned glass particles in Item 3 could have originated from the victim's outdoor lamp represented by Item 1, could not have originated from the victim's home window represented by Item 2.
L4V6BQ	The two particles of questioned glass recovered from the suspect's jacket (Item 3), the two fragments of known glass taken from the victim's outdoor lamp (Item 1) and the two fragments of known glass taken from the victim's home window (Item 2) were examined visually using stereomicroscopy, a digital caliper and ultraviolet light. These Items 1, 2 and 3 were further examined using the Glass Refractive Index Measurement system (GRIM 3). Based on the fragments examined, the Item 1 glass fragments were consistent with the Item 3 glass in color, thickness and refractive index. It was concluded that these Item 1 fragments could have originated from the glass source represented by Item 3. The Item 2 glass fragments were found to be different from Item 3 glass due to differences in refractive index.
LFPHHM	The questioned glass fragments from Item 3 and the control glass fragments from Item 1 were found to have no significant difference in terms of colour, fluorescence, thickness, refractive index and trace elemental composition. Hence, the questioned glass fragments from Item 3 were very likely to have originated from the same source as control glass fragments from Item

TABLE 3

WebCode	Conclusions
	1; other sources of glass with similar characteristics are limited. The questioned glass fragments from Item 3 were found to be different from the control glass fragments from Item 2 in terms of refractive index and trace elemental composition. Hence, the questioned glass fragments from Item 3 did not originate from the same source as the control glass fragments from Item 2.
LJQL9N	It was determined utilizing visual examination and measurement, Glass Refractive Index Measurement System (GRIM3), and X-Ray Fluorescence Spectroscopy that the glass samples from item 1 and item 3 exhibit consistent color, thickness, refractive index and elemental composition. Therefore, based on those characteristics the known sample from item 1 cannot be eliminated as being the source of the questioned glass from item 3. It was determined utilizing visual examination and measurement, and X-Ray Fluorescence Spectroscopy that the glass samples from item 2 and item 3 exhibit dissimilar refractive index. Therefore, based on that characteristic the known sample from item 2 can be eliminated as being the source of the questioned glass from item 3.
LLEVKB	The glass in Item 3 either originated from the same glass source represented by the glass in Item 1, or from another broken glass source with similar properties. The glass in Item 3 did not originate from the same glass source represented by the glass in Item 2.
LXB43D	The two fragments of glass recovered from the suspect's jacket (item 3) had the same refractive index, colour, thickness and were the same type of glass as the sample of glass from the broken lamp (item 1). The samples of glass were annealed which indicated that the samples have originated from a source of non-toughened glass. Therefore, these fragments of glass could have come from the broken lamp. However other sources of glass are possible. The two fragments of glass recovered from the suspect's jacket had a different refractive index and were a different type of glass to the sample of glass from the broken window (item 2). Therefore they could not have come from the broken window. In my opinion, the glass evidence very strongly supports the suggestion that the jacket was close to the breaking glass objects.
M8R8MH	Item 1 and Item 3 showed significantly similar relative abundances for Ca, Al, K, Ti, and Fe, whereas Item 2 showed different relative abundances for Ca, Al, K, Ti, and Fe. Statistical analysis by PCA results for LIBS and XRF showed that Item 1 and Item 3 were grouped together. In addition, refractive index of Item 1 and 3 were similar, but Item 2 has significantly different refractive index. Therefore, it was concluded that Item 1 and Item 3 could have originated from a same source.
MPVKJE	The glass pieces from Items 1 and 3 are similar to each other in physical characteristics, elemental composition and refractive indices. The glass from Item 3 could have originated from the same source as the submitted standard (Item 1) or from a different source of broken glass with the same physical characteristics, elemental composition and refractive index. The glass from Item 3 was found to have a different elemental composition and refractive index in comparison to the standard (Item 2.) The glass from Items 2 and 3 could not have come from the same source. Chemical analyses performed include X-Ray Fluorescence Spectroscopy and Refractive Index. Samples collected and analyzed during the examination of the items in this case (ex. pillboxes and glass slides) have been returned to and retained with the original item.
MU476Q	Item #1 (MU476Q.1A) - It was concluded that these glass fragments could have been originated from the broken glass source represented by Item #3 (MU476Q.1C). Item #2 (MU476Q.1B) - The item #3 (MU476Q.1C) particles could not have been associated with the Item #2 (MU476Q.1B) glass due to differences in the physical properties and/or refractive index.
N6KE44	Based on RI, using the t-Test, elemental composition and visual observations the recovered glass from Item 1.3 (Two particles of questioned glass recovered from suspect's jacket) could

TABLE 3

WebCode	Conclusions
	not be distinguished from the control glass contained within Item 1.1 (Two fragments of known glass taken from victim's outdoor lamp). Therefore, the recovered glass from Item 1.3 could have come from the same source as Item 1.1. However, other sources with similar RI, elemental composition and physical properties cannot be excluded. Based on elemental composition and visual observation the recovered glass from Item 1.3 (Two particles of questioned glass recovered from suspect's jacket) could be distinguished from the control glass contained within Item 1.2. Therefore, the recovered glass from this group could not have come from the same source as Item 1.2.
P6YXQL	The physical properties of the Item#1 and #3 (thickness, color, and refractive index) so as the trace elemental concentrations are identical. Item#2 shows differences in refractive index and in trace elemental concentrations, but has the same color and thickness as Item#1 and #3. Item#3 could originate from Item#1, but not from Item#2.
P9YBEL	1.1 The chemical composition of the glass fragments of "Item 1" is consistent with the chemical composition of the glass fragments of "Item 3", therefore the glass fragments of "Item 3" could have originated from "Item 1". 1.2 The chemical composition of the glass fragments of "Item 2" is different from the chemical composition of the glass fragments of "Item 3". Therefore "Item 2" could be excluded as a possible source of the glass fragments of "Item 3"
PBNBRA	CONCLUSIONS: Two glass fragments recovered from the suspect's jacket (Item 3) either originated from the victim's outdoor lamp (Item 1) or another source of broken glass possessing the same distinct physical, optical, and chemical characteristics. These two glass fragments (Item 3) did not originate from the victim's home window (Item 2). RESULTS: Questioned glass identified as from the suspect's jacket (Item 3) was examined for the purpose of determining whether or not there is any glass present like the known glass standards from the victim's outdoor lamp (Item 1) or the victim's home window (Item 2). The known glass standard from the victim's outdoor lamp (Item 1) is colorless, non-tempered, non-float glass. The known glass standard from the victim's home window (Item 2) is colorless, non-tempered, float, sheet glass. Examination of the questioned glass identified as from the suspect's jacket (Item 3) revealed two full thickness glass fragments. Examination and comparison of these two questioned glass fragments with the known glass standard from the victim's outdoor lamp (Item 1) reveals they are alike with respect to physical, optical, and chemical characteristics. It is therefore concluded that these two questioned glass fragments either originated from the outdoor lamp or another source of broken glass possessing the same distinct physical, optical, and chemical characteristics. Examination and comparison of the two questioned glass fragments identified as from the suspect's jacket (Item 3) with the known glass standard from the victim's home window (Item 2) reveals they are dissimilar with respect to fluorescence. It is therefore concluded that these two questioned glass fragments did not originate from the window. METHODS OF ANALYSIS: Examinations were performed visually, by stereo microscopy, polarized light microscopy, ultraviolet fluorescence, micrometry, refractive index determination, scanning electron microscopy/energy dispersive x-ray spectroscopy, and x-ray fluorescence spectroscopy.
PNAQVA	The glass fragments in Item 3 were found to be distinguishable from the reference glass in Item 2 based on refractive index. The glass fragments in Item 3 were found to be indistinguishable from the reference glass in Item 1 in macroscopic properties, refractive index, and elemental composition. The glass fragments in Item 3 could have originated from the lamp (Item 1) or another glass with the same macroscopic properties, refractive index, and elemental composition. The glass fragments in Item 3 could not have originated from the window (Item 2).
PXZCRL	The two particles recovered from the suspect's jacket (item 3) are indistinguishable to the

TABLE 3

WebCode	Conclusions
	victim's outdoor lamp (item 1) in glass refractive index, elemental concentrations, color, and thickness. This result strongly suggest the opinion that these glass particles may originate from this outdoor lamp. The two particles from item 3 are different in glass refractive index, elemental concentrations, color, and thickness to the the glass from victim's home window (item 2). Therefore these particles could not have originated from this window.
PZ2FGN	Based on the color of the glass splinters as well as the obtained density values and the chemical composition measured with XRF and LIBS, item 3 originates from item 1.
QDMC6C	The glass in Item 3 is similar in thickness and refractive index to the glass in Item 1; therefore, these glass fragments could have originated from the same source. The Double Variation Method with Monochrometer was used to determine the glass refractive index of both the questioned glass and glass standard. More sensitive testing that could potentially yield more discriminating results is available at another commercial laboratory. The glass in Item 3 is dissimilar in refractive index and in observed fluorescence under ultraviolet light to the glass in Item 2; therefore, these glass fragments did not originate from the same source.
QPEX9L	Glass recovered from the debris from the suspect's jacket (Item 3) is indistinguishable in the physical properties, refractive index, and elemental composition observed and/or measured from the glass from the victim's outdoor lamp as represented by Item 1. Therefore, the glass recovered from the debris from the suspect's jacket (Item 3) either originated from the victim's outdoor lamp (Item 1) or from another source(s) of broken glass indistinguishable in all of the measured or observed physical properties, refractive index, and elemental composition. Glass recovered from the debris from the suspect's jacket (Item 3) is different than the glass from the window of the victim's house as represented by Item 2. Therefore, the window of the victim's house as represented by Item 2 is eliminated as a possible source of the glass recovered from the debris from the suspect's jacket (Item 3).
QXYT6	The two particles of questioned glass, recovered from the suspect's jacket (Item 3) are similar in elemental composition compared with the known glass (Item 1). These results are much more likely if the questioned particles (item 3) have originated from the glass taken from the victim's outdoor lamp, represented by the particles from (Item 1), than if they have originated from a random other glass object. The two particles of questioned glass, recovered from the suspect's jacket (Item 3) differ in elemental composition from the known glass (Item 2). Therefore these particles (Item 3) could not have originated from the victim's home window, represented by the particles from (Item 2).
R2QKXD	a. Examination of lab item #3(Q1&Q2)and comparison to lab item #1(K1&K2)disclosed they are consistent with no discriminating differences observed with respect to color, appearance, thickness, response to UV light, elemental composition and refractive index. b. Examination of lab item #3(Q1&Q2)and comparison to lab item #2(K3&K4)disclosed that they are different with respect to color, appearance, thickness, response to UV light and elemental composition. It is the opinion of the undersigned that lab item #3(Q1&Q2)could have originated from the same source as lab item #1(K1&K2)or another source exhibiting all of the same analyzed characteristics. It is also the opinion of the undersigned that lab item #3(Q1&Q2)could not have originated from the source represented by lab item #2(K3&K4).
RBCRMG	Item 3 could be originated or related to Item 2, but maybe not item 1.
T4W94H	The particles of questioned glass (Item3) recovered from the suspect's jacket are consistent with the fragments of known glass taken from the victim's outdoor lamp (Item1) in color, thickness, UV fluorescence, refractive index, elemental composition and Raman spectrum. Therefore, Item3 could have originated from the victim's outdoor lamp. On the other hand, Item3 are different from the fragments of known glass taken from the victim's home window (Item2) in

TABLE 3

WebCode	Conclusions
	color, thickness, UV fluorescence, refractive index and Raman spectrum. Therefore, Item3 could not have originated from the victim's home window.
TEAR8J	The glass recovered from the suspect's jacket (Item 3) is consistent in physical, optical, and elemental properties as the glass recovered from the victim's outdoor lamp (Item 1). Therefore, the glass recovered from the suspect's jacket (Item 3) and the glass recovered from the victim's outdoor lamp (Item 1) could share a common origin. The glass recovered from the suspect's jacket (Item 3) is not consistent in optical properties as the glass recovered from the victim's home window (Item 2). Therefore, the glass recovered from the suspect's jacket (Item 3) could not share a common origin with the glass recovered from victim's home window (Item 2).
U8ARA3	The known glass in Item 1, identified as recovered from an outdoor lamp, and the questioned glass from the suspect's jacket (Item 3) exhibited similarities in elemental composition and optical properties (refractive index). These glass samples could have originated from a common source. The known glass in Item 2, identified as recovered from a window, and the questioned glass from the suspect's jacket (Item 3) exhibited dissimilarities in elemental composition and optical properties (refractive index). These glass samples did not originate from a common source.
UEBPBE	Item 3 is different from the glass in Item 2 by refractive index. As such Item 3 could not have originated from the broken window at the victim's home as represented by the glass in Item 2. In my opinion, the glass in Item 3 was indistinguishable from the glass in Item 1 by the properties tested. In my opinion, the findings in this case provide strong support for the view that Item 3 has originated from the outdoor lamp at the victim's address.
UEPBRG	The evidence (elemental composition of glass samples as well as the thickness measurements) provides support for the proposition that glass fragments recovered from suspect's jacket (Item 3) could have originated from the victim's outdoor lamp (Item 1) whereas glass fragments recovered from suspect's jacket (Item 3) have not originated from the victim's home window (Item 2).
ULRG96	The refractive index of the glass fragments from the suspect's jacket (item 3) was found to be different to the victim's window glass (item 2). Therefore the glass from the jacket could not have originated from the victim's window. In relation to colour, refractive index and elemental composition, the glass from the suspect's jacket (item 3) was found to be indistinguishable from the glass from the victim's outdoor lamp (item 1). Therefore these glass items may share a common origin.
V9VHZ	The questioned glass in Item 3 is consistent with the known glass in item 1 on the basis of refractive index and elemental composition. Therefore, the questioned glass in item 3 could have originated from the known glass in Item 1. The questioned glass in item 3 is not consistent with the known glass in item 2 on the basis of refractive index and elemental composition. Therefore, the questioned glass in item 3 could not have originated from the known glass in item 2.
VW6277	1. Comparative examinations of Exhibit 1 (known glass taken from the victim's outdoor lamp) with Exhibit 3 (questioned glass recovered from the suspect's jacket) disclosed them to be consistent in physical characteristics, refractive indices, and elemental compositions. Therefore, Exhibit 3 could have originated from Exhibit 1, or another source with the same characteristics. 2. Comparative examinations of Exhibit 2 (known glass taken from the victim's home window) with Exhibit 3 disclosed them to be inconsistent in physical and elemental characteristics. Therefore, Exhibit 3 could not have originated from Exhibit 2. 3. It should be noted a glass association is not a means of positive identification and the number of possible sources for a specific glass is unknown.

TABLE 3

WebCode	Conclusions
WBYNAD	The two particles of questioned glass recovered from the suspect's jacket (item 3) can come from the two fragments of known glass taken from the victim's outdoor lamp (item 1) or from another glass material with the same characteristics. The two particles of questioned glass recovered from the suspect's jacket (item 3) are different from the two fragments of known glass taken from the victim's home window (item 2) ; they don't come from the same origin.
WHZ4NE	The known glass samples from the lamp (item 1) and from the window (item 2) could be well distinguished by the manufacturing process (float / non float), by the refractive index and by the elemental composition. The two glass particles from the suspect's jacket (item 3) matched the known glass sample from the lamp (item 1) with respect to colour, thickness, refractive index before and after an annealing procedure and chemical composition. Hence there is serious evidence that these two particles come from the broken outdoor lamp at the scene of crime. Due to the mass product character of glass products a different source cannot be excluded with certainty. Among a casework database, which consists of more than 3400 control glass items, there was no item, which matched the glass particles from the suspect with respect to thickness and refractive index.
WMVU7W	Glass recovered from the suspect's jacket (item 3) is similar in color, florescence, and refractive index to the known glass from the victim's outdoor lamp (item 1). Please note that elemental analysis was not performed on this sample. It is our opinion that the glass from the suspect's jacket and the glass from the victim's outdoor lamp could have come from the same source. The Glass recovered from the suspect's jacket (item 3) is dissimilar to the glass from the victim's home window (item 2). It is our opinion that the glass from the suspect's jacket and the glass form the victim's home window do not share a common source.
WWJN98	Based on tri-draw and 100% graph, item 1 is indistinguishable from item 3 and Item 2 is distinguishable from item 3. Therefore item 1 and item 3 could have the same origin.
WYQ6E4	Glass fragments (item 3) from the suspect's jacket could not be excluded as having come from the victim's outdoor lamp (item 1). As such, item 3 came from either the outdoor lamp (item 1) or another source of broken clear, colourless, non-tempered, non-float glass, indistinguishable from item 1 with respect to thickness, refractive index and elemental composition. Glass fragments (item 3) from the suspect's jacket were excluded as having come from the victim's home window (item 2).
XEWNPZ	The results of the examination extremely strongly support that the analyzed glass particles in Item 3 do not originate from the broken lamp as represented by Item 1 (Level -4). The analyzed glass particles in Item 3 do not originate from the broken window as represented by Item 2.
XMC88E	THE FRAGMENTS OF QUESTIONED GLASS TAKEN FROM THE SUSPECT'S JACKET "ITEM 3" AND PARTICLES OF KNOWN GLASS TAKEN FROM THE VICTIM'S OUTDOOR LAMP "ITEM 1" EXHIBIT THE SAME RESULTS IN ALL INVESTIGATED PHYSICAL PROPIERTIES. BOTH OF THEM ARE SIGNIFICANTLY DIFFERENT FROM "ITEM 2".
XVZ62F	1. The two particles of questioned glass recovered from the suspect's jacket (item 3) and the two fragments of known glass taken from the victim's outdoor lamps (item 1) matched in all properties investigated. Accordingly, the glass from the victim's outdoor lamps (item 1) could be a possible source of the glass recovered from the suspect's jacket (item 3). 2. The two particles of questioned glass recovered from the suspect's jacket (item 3) and the two fragments of known glass taken from the victim's home window (item 2) did not confirm in RI, in UV-fluorescence and in the chemical composition. These two glass particles recovered from the suspect's jacket (item 3) did not originate from the victim's home window (item 2).
XZWP24	The glass in Items 1 & 3 could have originated from the same source. The glass in Item 3 did



TABLE 3

WebCode	Conclusions
	not originate from the same source as the glass standard in Item 2.
Y7WNND	Glass recovered from the debris from the suspect's jacket (Item 3) is indistinguishable in the observed and measured physical properties, refractive indices, and elemental concentrations from the glass sample from glass from the victim's outdoor lamp (Item 1). Therefore, the glass recovered from the debris from the suspect's jacket (Item 3) either originated from the victim's outdoor lamp as represented by Item 1, or from another source of broken glass indistinguishable in all the observed and measured physical properties, refractive indices, and elemental composition. Glass recovered from the debris from the suspect's jacket (Item 3) is different in thickness and refractive index than the glass sample from the victim's home window (Item 2). Accordingly, the victim's home window as represented by Item 2 is eliminated as a possible source of the glass recovered from the debris from the suspect's jacket (Item 3).
Y8FDCY	The glass of item 3 was found to have a different refractive index than the glass of item 2. The glass from the suspect's jacket (item 3) could not have originated from the victim's window (item 2). The glass of items 1 and 3 were found to be indistinguishable based on macroscopic properties, refractive index, and elemental composition. The glass from the suspect's jacket (item 3) could have originated from the victim's lamp (item 1) or another source of glass with the same macroscopic properties, refractive index, and elemental composition.
YQ8MZA	The questioned glass particles in Item 3 recovered from the suspect's jacket could have originated from the known glass fragments from the victim's outdoor lamp (Item 1). The questioned glass particles in Item 3 did not originate from the known glass fragments from the victim's home window (Item 2).
YQ993G	The questioned glass particles recovered from the suspect's jacket (Item 3) could have originated from the victim's outdoor lamp (Item 1) because of similarities in refractive index, thickness of particles and elemental composition. Refractive index, thickness of particles and elemental composition of Item 2 were different from those of Item 3.
YTAHJC	Item 3 could have originated from the victim's outdoor lamp (Item 1) because the elemental composition of Item 3 and 1 are indistinguishable. Item 3 and 2 were distinguishable since their elemental composition differed.
YTBCC4	The glass in Exhibit 3 could have originated from the same source as the glass in Exhibit 1. The glass in Exhibit 3 did not originate from the same source as the glass in Exhibit 2.
YVZHWZ	The glass, Item 001-3, recovered from the suspect's jacket, was indistinguishable in physical properties, refractive index, and elemental composition from the glass, Item 001-1, taken from the victim's outdoor lamp. Therefore, the glass recovered from the suspect's jacket could have originated from the victim's outdoor lamp or from another source of glass produced by the same glass manufacturer exhibiting the same physical and chemical properties. The glass, Item 001-3, recovered from the suspect jacket had a different refractive index than the glass, Item 001-2, recovered from the victim's home window; therefore, it did not come from this window.
Z3EN7C	The glass in Item 3 is similar in color, type, UV fluorescence, thickness, density and refractive index to the glass in Item 1. The glass in Item 3 could have originated from the same source as the glass in Item 1.
ZCKTXT	The glass fragments from Item 3 are similar in all examined characteristics to the glass fragments from Item 1; therefore, the glass from the suspect's jacket could have originated from the victim's outdoor lamp or another source of glass of similar manufacture. The glass fragments from Item 3 are dissimilar to the glass fragments from Item 2; therefore, the glass from the suspect's jacket could not have originated from the victim's home window.

TABLE 3

WebCode	Conclusions
ZFFMU9	<p>On analysis, I found: i)The particles of questioned glass recovered from the suspect's jacket (Item 3)and the fragments of known glass taken from the victim's outdoor lamp (Item 1) to be similar. ii)The particles of questioned glass recovered from the suspect's jacket (Item 3)to be different with the fragments of known glass taken from the victim's home window (Item 2). Therefore, I am of opinion that: i) The questioned glass (Item 3) and the known glass (Item 1) could have originated from the same source. ii)The questioned glass (Item 3) did not originated from the same source as the known glass (Item 2).</p>
ZUXDTB	<p>1. Examination for Characteristics of Glass: a. Laboratory items 1 through 3 were tested using a probe, placed in a beaker of water and examined visually and microscopically with the aid of a polarized light microscope. i. Laboratory items 1 through 3 were found to be hard, isotropic, insoluble in water, and exhibited conchoidal fractures, which are characteristics of glass. ii. Laboratory items 1 through 3 were observed to have two parallel original surfaces. iii. Laboratory item 2 was observed to have "hackle" marks near one surface and displayed fluorescence on one surface when exposed to short wave UV light. 2. Comparison: a. Examination of Laboratory item 3a and comparison to Laboratory item 1a disclosed that they are consistent and no discriminating differences were observed with respect to color, appearance, thickness, response to UV light, elemental composition, and refractive index. b. Examination of Laboratory item 3a and comparison to 2a and 2b disclosed that they are different with respect to their thickness, response to UV light and elemental composition. Examination of Laboratory item 3b and comparison to 2a and 2b disclosed that they are different with respect to their thickness and response to UV light. INTERPRETATION OF RESULTS: 1. It is the opinion of the undersigned that Laboratory item 3a could have originated from the same source as Laboratory item 1a or another source exhibiting all of the same analyzed characteristics. 2. It is the opinion of the undersigned that Laboratory item 3 could not have originated from the source represented by Laboratory item 2. 3. The additional particles comprising Laboratory items 1 and 3 (1b and 3b) were not instrumentally analyzed. No further conclusions can be reached regarding Laboratory item 1b.</p>
ZYDLAB	<p>Glass collected from the jacket belonging to the suspect is probably of the same type as the glass from ITEM 1. Glass collected from the jacket belonging to the suspect is not of the same type as glass from ITEM 2</p>



# Additional Comments

TABLE 4

WebCode	Additional Comments
283U87	The refractive index was measured with a Glass Refractive Index Measurement 3 (GRIM3, Foster and Freeman) system.
3UATXN	My conclusions are based on the results of my laboratory examination and the information made available to me at this time. If any aspects of the case should change then I am prepared to review my conclusion in light of such changes.
4V4W8P	In an actual case, more fragments from the known sources would be desirable. Also, it would be useful to have more information about the design of the outdoor lamp, so I would know whether the thickness of the fragments is significant or not.
6H96YQ	results (measurements done): 1. Thickness (average): item 1: 2.255mm, item 2: 2.230mm, item 3: 2.255mm. 2. UV fluorescence: item 1: long-no, short-small, non-float glass. item 2: long-small, short-one side high, one side small, float glass. item 3: long-no, short-small, non-float glass. 3. Refractive index (average): item 1: 1.5187, item 2: 1.5192, item 3: 1.5185. 4. Elemental analysis (SEM-EDS): item 1: Si, O, Na, Mg, Ca, Al, small traces of Fe. item 2: Si, O, Na, Mg, Ca, Al. item 3: Si, O, Na, Mg, Ca, Al, small traces of Fe.
AY4XWZ	Our elemental analysis supported the RI results.
BECAUY	A technical introduction would be included in the report to explain Refractive Index. Differences were noted in the colour of the float surface between item 1 and item 2 under UV fluorescence. Items 1 and 3 were noted to be similar to each other under UV fluorescence.
DUEQTW	It is uncommon to recover cubes of glass with full thickness from an item of clothing unless it was recovered from a pocket. With glass found in pockets it is not possible to address when it was acquired so is considered less evidentially significant than glass recovered from the surface of an item. Usually numerous cubes/pieces of glass are received in the laboratory as a control sample from the broken window/object in question. This allows a better assessment of the variation of the refractive window across the window/object.
FNKBGU	The findings have been evaluated at "Source level" on the basis of the information provided and fragments of the size provided in "Item 3" are more likely to have been recovered from pockets or some other enclosed space, where they could have been for some time. An "Activity level" evaluation of the findings would have been performed if the fragments had been stated to have come from the surface of the jacket and additional incident information was provided to enable a glass transfer / persistence assessment to be performed at the outset of the case.
GJ6GLU	For a conclusive match between Items 1 and 3 elemental analysis must be performed on both samples. This lab cannot perform this analysis at the moment.
HMKB3R	Both glasses (Item 3 and Item 1) show a broad variance in their refractive indices.
LFPHHM	Refractive index (3SD range): Item 1: 1.5169 – 1.5173; Item 2: 1.5185 – 1.5186; Item 3: 1.5170 – 1.5172. Comparison of trace elemental compositions: The match criterion for LA-ICP-MS analysis was set at 4SD range (minimum 3% RSD) around control sample. The elements compared are: Li7, Na23, Mg24, Al27, K39, Ca42, Ti49, Mn55, Fe57, Rb85, Sr88, Zr90, Ba137, La139, Ce140, Nd146, Hf178, Pb208. Comparing Item 2 and Item 3, the concentrations of the following elements are different: Li7, Al27, K39, Ca42, Ti49, Mn55, Fe57, Rb85, Sr88, Zr90, Ba137, La139, Ce140, Nd146, Hf178, Pb208.
QPEX9L	Additional sections on methods used, interpretation of results, limitations of the examinations, and disposition of the evidence are also included in the report, but are not submitted for this test.
UEPBRG	The answer is based on results of likelihood ration calculations.

TABLE 4

WebCode	Additional Comments
WHZ4NE	The following match criteria were applied: Refractive index: Ten measurements were made at each sample. Then a Student-t-test was conducted where p-values above 1 percent would be assessed as a match. Elemental composition: Ten measurements were made at the original surface of each sample. Semiquantitative analysis was performed for elemental ratios Ca/Mg, Ca/K, Ca/Ti and Ca/Fe calculated from the net intensities. A match was stated if the mean of the questioned sample matched the mean of the known sample plus/minus the threefold standard deviation of the known sample.
WYQ6E4	Of the 2319 samples of broken glass collected from casework and survey samples examined at this Laboratory for which refractive index, thermal history, thickness, and float data are available, 1 (0.05%) was non-tempered, non-float glass, indistinguishable in refractive index and thickness from item 1. A study performed at this Laboratory examining 150 casework samples of architectural and vehicle float glass by LA-ICP-MS resulted in 11,175 pair-wise comparisons. Of these pairs, 6 (0.06%) were indistinguishable in elemental composition, using the 22 elements examined in this case. It should be noted that 4 of these 6 pairs were differentiated by refractive index, and the remaining 2 pairs were differentiated by thickness.
XZWP24	Items 1 & 3 are similar in color, glass type, UV fluorescence, density and refractive index. Items 2 & 3 are dissimilar in UV fluorescence, density and refractive index.
Y7WNND	Reports also contain sections on Methods, Interpretation and Limitations.

# Appendix: Data Sheet

Collaborative Testing Services - Forensic Testing Program

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## Test No. 17-548: Glass Analysis

DATA MUST BE RECEIVED BY July 31, 2017 TO BE INCLUDED IN THE REPORT

Participant Code:

WebCode:

### Accreditation Release Statement

CTS submits external proficiency test data directly to ASCLD/LAB, ANAB, and A2LA. Please select one of the following statements to ensure your data is handled appropriately.

This participant's data is intended for submission to ASCLD/LAB, ANAB, and/or A2LA. (Accreditation Release section on the last page must be completed and submitted.)

This participant's data is NOT intended for submission to ASCLD/LAB, ANAB or A2LA.

### Scenario:

Police are investigating the homicide of a man in his home. The police believe that the suspect may have broken an outdoor lamp, then broken into the home through a window. Known samples were taken from the glass remaining in the lamp and the window. The same day, police apprehended a suspect and conducted a search. Particles of glass were found in the suspect's jacket. Investigators are requesting that you examine and compare the glass particles recovered from the jacket with the fragments recovered from the victim's outdoor lamp and home window.

### Please Note:

-Samples contained within each individual Item are from a single source.

-CTS will not reproduce Interpretation Scales, Scale of Conclusions or Terminology Keys in the final report, please do not submit with the participant's data sheet.

### Items Submitted (Sample Pack GL):

Item 1: Two fragments of known glass taken from the victim's outdoor lamp.

Item 2: Two fragments of known glass taken from the victim's home window.

Item 3: Two particles of questioned glass recovered from the suspect's jacket.

### 1.) Could the questioned glass particles in Item 3 have originated from either the victim's outdoor lamp or home window represented by Item 1 and Item 2, respectively?

Item 1 (Known glass from outdoor lamp)

Item 3: Yes  No  Inc

Item 2 (Known glass from home window)

Item 3: Yes  No  Inc

Please return all pages of this data sheet.

Page 1 of 3

Participant Code:

WebCode:

**2.) Indicate the procedures used to examine the submitted items:**

Refractive Index:

nD

nC

nF

Δ RI

UV Fluorescence:

Long

Short

Color

Thickness

Density

Elemental Analysis:

SEM/EDS

XRS/XRF

Other (specify): \_\_\_\_\_

**3.) What would be the wording of the Conclusions in your report?**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**4.) Additional Comments**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

<p><b>Return Instructions:</b> Data must be received via online data entry, fax (please include a cover sheet), or mail by <i>July 31, 2017</i> to be included in the report. Emailed data sheets are not accepted.</p> <p>QUESTIONS?</p> <p>TEL: +1-571-434-1925 (8 am - 4:30 pm EST)</p> <p>EMAIL: <a href="mailto:forensics@cts-interlab.com">forensics@cts-interlab.com</a> <a href="http://www.ctsforensics.com">www.ctsforensics.com</a></p>	<p>Participant Code:</p> <p>ONLINE DATA ENTRY: <a href="http://www.cts-portal.com">www.cts-portal.com</a></p> <p>FAX: +1-571-434-1937</p> <p>MAIL: Collaborative Testing Services, Inc. P.O. Box 650820 Sterling, VA 20165-0820 USA</p>
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**Please return all pages of this data sheet.**

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## Collaborative Testing Services ~ Forensic Testing Program

**RELEASE OF DATA TO ACCREDITATION BODIES**

The following Accreditation Releases will apply only to:

Participant Code:

WebCode:

for Test No. **17-548: Glass Analysis**

This release page must be completed and received by **July 31, 2017** to have this participant's submitted data included in the reports forwarded to the respective Accreditation Bodies.

Have the laboratory's designated individual complete the following steps **only if your laboratory is accredited in this testing/calibration discipline** by one or more of the following Accreditation Bodies.

**Step 1: Provide the applicable Accreditation Certificate Number(s) for your laboratory**

ASCLD/LAB Certificate No. \_\_\_\_\_

ANAB Certificate No. \_\_\_\_\_

A2LA Certificate No. \_\_\_\_\_

**Step 2: Complete the Laboratory Identifying Information in its entirety**

Signature and Title \_\_\_\_\_

Laboratory Name \_\_\_\_\_

Location (City/State) \_\_\_\_\_

**Accreditation Release****Return Instructions**

*Please submit the completed Accreditation Release at the same time as your full data sheet. See Data Sheet Return Instructions on the previous page.*

*Questions? Contact us 8 am-4:30 pm EST*  
Telephone: +1-571-434-1925  
email: forensics@cts-interlab.com

**Please return all pages of this data sheet.**

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