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Glass fragments from portable electronic devices: Implications for forensic examinations

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ABSTRACT

Personal electronic devices (PEDs) are now widespread in the community. Many such devices have glass display screens that, despite being a relatively strong and specialised material, are vulnerable to breakage. Unlike other glass objects that are usually thrown away when they break, PEDs can still function with a broken or cracked screen and it is not uncommon for their owners to keep using them in this condition. Broken PED screens, therefore, might represent a new and significant source of glass fragments that are present on the clothing and belongings of the general public and individuals suspected of offences involving the breaking of glass. The forensic implications of this new source of glass fragments in the community were investigated. PED glass is easily recognised using scanning electron microscopy-energy dispersive X-ray analysis and refractive index measurement and is easily distinguished from domestic and automotive soda-lime glass using these methods; as a consequence there should be no confusion of soda-lime glass fragments and PED glass fragments in forensic glass casework. In cases where the objective is to compare recovered glass fragments to a putative PED source, comparison using refractive index measurement and elemental analysis achieves good discrimination between sources.

1. Introduction

There is a continuous rising demand for portable personal electronic devices (PEDs), such as smartphones, notebooks, and tablets. In 2014 there were 6.9 billion mobile telephone subscriptions worldwide [1]. PEDs combine the functionality of several previously separate, hand–held devices such as telephones, music players and cameras. The current generation of PEDs utilises features such as touchscreens to increase the functionality of the devices. Due to the portability and high usage rates of PEDs, there is a requirement that they are durable and can withstand accidents. Glass display screens are used in the manufacture of many PEDs, but despite being a relatively strong material, they are vulnerable to breakage. Unlike other glass objects that are usually discarded or replaced when they break, PEDs can still function with a broken or cracked screen and it is not uncommon for their owners to keep using them in this condition. The motivation for the research presented in this article is that broken PED screens might represent a new and significant source of glass fragments on the clothing and belongings of individuals in the community, both those involved in crime and those with no involvement in crime, which could have implications for forensic examination of glass evidence.

Glass fragments can be important associative evidence in crimes involving the breaking of glass, for example assaults, break and enter and vehicle hit and run offences. The use of a Bayesian statistical model can be used to assist in interpreting any glass evidence located and provide the forensic scientist with a likelihood ratio of the probability of two competing propositions. The propositions are the Prosecution Hypothesis (H1), that the suspect was involved in the crime and that is how the glass evidence was present, versus the Defence Hypothesis (H2), that the suspect was not involved in the crime and the glass evidence located was from an unknown source that is there by chance [2].

Therefore, key issues for evaluation of the evidence are whether the glass fragments associated with the suspect can be distinguished from the putative source glass and, if they cannot, whether broken glass of that type is common or rare in the community, for example on the clothing of random individuals in the community (i.e., "random man") or on the clothing of suspects of crimes that do not involve breaking of glass. Also of key relevance are the rates at which glass particles are found on individuals at random, the

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number of groups of different glass types found on these individuals and the number of particles present in each group.

PED glass is typically toughened glass and whilst the most common method for toughening soda-lime glass is through thermal tempering [3], the original equipment manufacture (OEM) glass used on PEDs is a surface-treated alkali–aluminosilicate glass [4]. These glasses have different proportions of the major elements compared to soda-lime glass, most notably having low calcium and high aluminium concentrations. The surface treatment for alkali–aluminosilicate glass involves placing it in a heated (~400 °C) potassium nitrate bath. This draws sodium ions out of the top layer of the glass, replaces them with larger potassium ions, and creates a compressed layer in the top 80–100 μm of the sheet. The newest versions of this glass use surface enrichment of potassium and silver ions to impart both toughness and antimicrobial properties [5]. The dominant product in the toughened glass market is Corning's Gorilla™ Glass, present in over 3 billion PEDs worldwide. Its only competitor is Asahi Glass Company's Dragontrail™ Glass, which has now been incorporated into devices by at least 37 brands [6]. However this glass is favoured by independent manufacturers and not used by the major international brands.

It is worth noting the uses of chemically toughened glass beyond PEDs appear to be on the increase. Dragontrail X™ was used in 2014 in roofing for glass benches at the FIFA World Cup in Brazil [6]. Corning has also made significant headway in regards to transferring their glass technology to the automotive industry, with at least one manufacturer planning to use Gorilla Glass™ windshields in their 2015 vehicles [7].

This paper presents an investigation of whether the presence of broken PED glass in the community could raise any issues with regards to evaluation of evidence in typical forensic glass casework, given that data upon which evaluations are based were gathered in the days before PEDs were available. Further, there is scope for glass from PEDs to be useful associative evidence in cases, for example if a device is damaged during an assault and glass fragments from it transfer to the assailant. In such a case a major consideration is whether the glass associated with the suspect could have come from the PED involved, another PED, or even a completely different glass object. First, we present analytical data gathered from broken screens from a number of mobile telephones available on the Australian market using refractive index (RI) measurement and scanning electron microscopy with energy dispersive X-ray spectrometry (SEM–EDS), both of which are techniques commonly used in forensic laboratories for examination of glass evidence. Those data indicate that glass from PEDs is easily distinguished from common soda-lime glass. Second we show that refractive index measurement and elemental composition can be used to distinguish between PED glasses from different sources. Finally, we show that the characteristic elemental distribution within pieces of PED glass can be detected using laser ablation inductively coupled plasma mass spectrometry (LA-ICPMS) and SEM–EDS.

2. Materials and methods

Sixty-one screens from PEDs were obtained either from a local PED repair company (Alltech Mobile Phone Repairs, Adelaide, South Australia) or through private donations. These devices were identified by make and model, given unique labels (e.g., "Samsung Galaxy S3 (2)" indicates the 2nd Samsung Galaxy S3 device screen collected, and "Blackberry Bold" indicates the screen from the only Blackberry Bold collected) and separately packaged until required for analysis. The outer glass layer for each device was separated from any lower glass or electronic layers and then washed in acetone. Two types of samples for analysis were collected. Larger fragments, which included both of the surfaces of the sheet, were prepared by applying medium force to the screen with the edge of a hammer. Smaller fragments, obtained from just the touch surface of the screen, were prepared by cross-hatching approximately 1 cm^2 of the surface with a diamond tipped scriber (Proscitech Pty Ltd, Thuringowa, Queensland, Australia). A significant number of fragments were then analysed using glass refractive index measurement and X-ray fluorescence in order to determine whether the PED screens could be discriminated from the general population of glass in the community and from each other. A smaller number of samples were also examined using SEM–EDS and LA-ICPMS in order to determine whether the surface treatment of glass screens could be detected using methods typically available to forensic laboratories. The devices used in this study and the tests carried out are listed in Table 1; not all testing methods were carried out on all samples in this exploratory study.

Glass refractive index (RI) measurement was carried out using a Foster and Freeman GRIM 3™ equipped with a Mettler hot stage model FP82HT, a Leica DMLB2 phase contrast stereomicroscope, and a Sodium D line filter. A mixture of Locke Scientific Silicon oil "C" and Locke Scientific Silicon oil "B" (49.997% and 50.003%, *w*/*w*, respectively) was prepared. The mixed oil was calibrated to R^2 better than 0.9999 using the following Locke Scientific Reference Glasses for RI Determination in Forensic Science: B9 (n = 1.51034), B10 (n = 1.50911), B11 (n = 1.50508), B12 (n = 1.50187) and C1 (n = 1.48652). Glass B11 was used as a daily standard to monitor inter-day variation in RI measurements. The stage was cleaned before the start of each analysis, using a Kim™ wipe moistened with ethanol. Two types of refractive index measurements were carried out. Surface fragments from 13 devices, prepared using the

Table 1
Sources of glass and test carried out in this study.

Type of PED	Total	GRIM		SEM–EDS line/map	XRF	LA-ICPMS
		interior	surface			
Apple						
iPods	2	2	0	1	1	0
iPads	1	1	0	0	1	0
iPhone 5	22	6	3	1	22	1
iPhone 4	14	5	3	2	13	0
iPhone 3	3	3	1	0	3	1
Samsung	7	6	4	1	6	0
HTC	4	4	0	0	4	0
Nokia	2	2	0	0	2	0
LG	2	2	0	0	2	0
Sony	1	1	1	1	1	1
Motorola	1	1	0	0	0	0
Blackberry	1	1	1	0	1	0
Galaxy Nexus	1	1	0	0	1	0
Total	61	35	13	6	57	3