Forensic Science International 254 (2015) 26–50

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Original Research Paper

Utilization of environmentally acquired very small particles as a means of association

David A. Stoney *, Andrew M. Bowen [1], Paul L. Stoney

Stoney Forensic, Inc., 14101-G Willard Road, Chantilly, VA 20151-2934, USA

ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form 26 May 2015
Accepted 2 June 2015
Available online 28 June 2015

Keywords:
Trace evidence
Very small particles
Association
SEM analysis
EDS analysis
Carpet fibers

ABSTRACT

Very small particles (VSP) are ubiquitous in our environment and are virtually ignored by forensic science. These particles range in size from an order of magnitude smaller than conventional trace evidence, down to the molecular level. Combinations of VSP provide an extraordinary, largely untapped resource for forensic associations and source attribution. This paper describes an initial effort to exploit VSP for one specific application.

An approach was developed and tested for the SEM/EDS analysis of VSP recovered from the surfaces of carpet fibers – one of the most common types of trace evidence examined in crime laboratories. Our goal was to exploit existing computer-assisted SEM/EDS methods to test whether VSP profiles could be useful to associate shed fibers with a source carpet.

Particles were harvested by washing and filtration onto polycarbonate filters. An SEM/EDS analysis protocol currently employed for environmental particle analyses was used, resulting in individual particle characterization based on fitting to reference spectra of 28 elements. Target Particle Types were defined based on the most abundant elemental profiles and used to bin the results for each specimen, resulting in a Target Particle Type profile.

Within-carpet variability was assessed using Target Particle Type profiles from three different areas on each of nine carpets. Area profiles, defined from sets of ten fibers, were compared to profiles from individual fibers. Between-item variation was explored using a survey of an additional 12 carpets.

Hundreds to thousands of VSP were found to routinely occur on individual carpet fibers. Their quantity and character was sufficient to associate fibers with their area of origin. Within-carpet variations showed roughly even distributions for most TPTs and between-carpet variations showed wide ranges in types and quantities of VSP.

Environmentally acquired VSP showed clear potential to provide quantitative means to link carpet fibers with their area of origin. This finding is noteworthy, since such particles are acquired post-manufacture and are independent of characteristics determined by manufacture. More generally, VSP are ubiquitous, present on or in virtually any item, and there is the potential for linkages among items of any type based on adhering VSP. By way of example, the present work provides impetus for a fundamental change in the way that forensic trace evidence is conceptualized. Further fundamental research is indicated to better understand the underlying variability, usefulness and limitations of this approach.

1. Introduction

There is a fundamental limitation to the probative value of many of the most common types of trace evidence (e.g. fibers, glass, paint) because their characteristics are determined by their manufacture. As mass-produced commodities, probative value is limited to class associations. This has long been appreciated [1–4], and most recently emphasized in the summary assessments in the NRC report [5].

Furthermore, attempts to determine frequencies of occurrence for specific observed traces are problematic due to ill-defined populations, the lack of a foundation for randomness within a population, changes in manufacturing practices over time, and variations among analytical methods [2,3,6].

Despite these limitations, trace evidence interpretation has developed quantitative approaches using a Bayesian approach,

* Corresponding author. Tel.: +1 703 362 5983.
E-mail addresses: david@stoneyforensic.com (D.A. Stoney), ambowen@uspis.gov (A.M. Bowen), paul@stoneyforensic.com (P.L. Stoney).
[1] Present address: U.S. Postal Inspection Service, 22433 Randolph Drive, Dulles, VA 20104, United States.

http://dx.doi.org/10.1016/j.forsciint.2015.06.002
0379-0738/

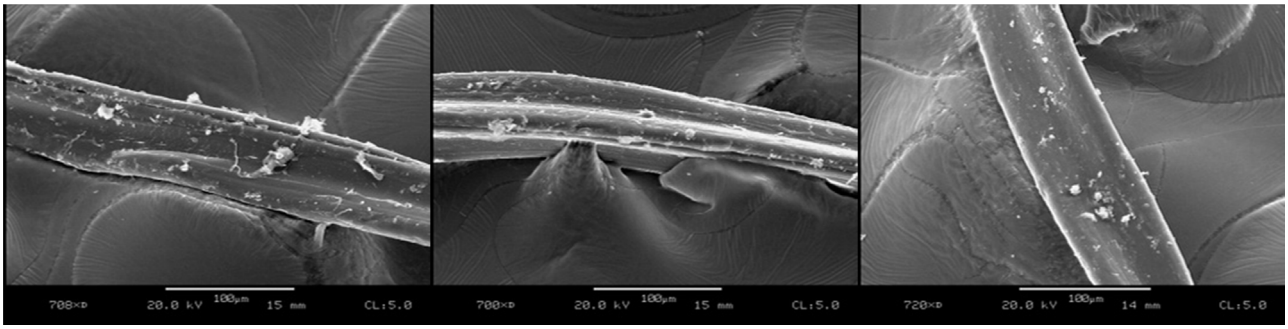

Fig. 1. Typical appearance of very small particles (VSP) on the surface of carpet fibers as seen by SEM.

incorporating expert assessments of case-specific influential factors, and drawing on aides to interpretation, which includes population surveys, industrial inquiries and tracing of manufacture. An excellent example of this approach is given (for fibers) in [7–10], and a more generalized and comprehensive approach is given in [11].

Nonetheless, absent multiple transfers and exceptional circumstances [12,13], probative value is often called into question and remains limited by the possibility, or the suggestion of the possibility, that the evidence came from an alternative mass-produced item.

Multiple-transfer cases shatter this limitation. Generally speaking, these are cases where a set of different trace evidence materials, found on a suspect, correspond to sources at a crime scene, and/or the reverse: where a set of trace evidence materials, found at the crime scene, correspond to suspect-related sources. When the possibilities of correlation can be discounted, the probative value can become extraordinarily high, even when probabilities for the occurrence of individual trace types are modest, or subject to inherent imprecision in their estimates. The co-occurrence of multiple events of modest frequency is the foundation for all highly probative types of physical evidence, including DNA and fingerprint associations, and is an inherent aspect of some types of trace evidence, including the comparison of multi-layered structural paints and comparisons of complex soil specimens.

This research is part of new approach to trace-evidence analysis, systematically addressing the fundamental limitations affecting the strength and measurement of probative value, by exploiting the very small particles (VSP) that are present on virtually every material object [6].

Four founding principles guide this effort:

1. Mixtures of particles have a great potential to provide enhanced probative value via their joint occurrence, with individual particle types occurring at modest, estimable frequencies with testable correlations.
2. Particles are always present in mixtures.
3. Consideration of VSP increases the number of particles and the complexity of their mixture.
4. VSP occurring on the surfaces of evidence can be recovered, identified, and quantified leading to independent testing of the hypotheses of common origin.

The first principle has already been discussed, with specific reference to DNA, fingerprints and multiple-transfer evidence as precedence.

Given the value of mixtures, the second principle guides us to broaden our perspective and recognize that mixtures are always there. The traditional focus of forensic particle trace evidence work is on one of a small set of particle types, such as fibers, glass, paint, or hair. Target particles such as these are defined by casework circumstances, and corresponding particles are sought as evidence of transfer and contact [7]. The significance of these particles is that (1) their transfer can be reasonably predicted, based on a hypothesis of contact and (2) they can be efficiently detected among the mixtures of particles that are always present. Other co-occurring particles, smaller, or without a discrete crime scene or suspect source, are largely ignored as "noise."

The third principle guides us to focus on smaller particles. As we consider them, we have more particles, and the mixture becomes more complex. There is a nearly ten-thousand-fold dimensional gap between conventional trace evidence types and those routinely recovered and analyzed by conventional DNA analysis. The biggest of these are those seen by higher power light microscopy and by electron microscopy. These are the respirable or near-respirable dusts, which are traditionally ignored in forensic investigations, with the notable exception of gunshot residue (GSR).

The fourth principle states that we can recover, identify, quantify and make practical use of VSP that adhere to other types of evidence. These VSP will "ride piggy-back" on virtually any item, including conventional trace evidence. They occur in complex mixtures and include a extraordinary variety of particles that are acquired when manufactured materials are exposed to alternative environments. These particles reflect cumulative exposures and conditions; they will be highly characteristic of the local environment [14] and their presence, identity and relative quantities provide an untapped source of individuality for conventional trace evidence. There is tremendous potential here: every trace evidence case can potentially become a multiple-transfer case, with the adhering fine particles providing an independent quantitative means to test hypotheses of common origin. Consider: if *these* carpet fibers came from *that* carpet, then the multivariate occurrence of a quantitative profile of fine particles, present on *that* carpet, ought to be present, subject to statistical sampling, on *these* fibers.[2]

To unlock this potential, research is required that (1) determines which VSP have useful forensic performance characteristics, (2) develops suitable methods for detection and measurement, and (3) provides data on variation and occurrence that enables reliable statistical interpretation.

The research described here develops and tests this approach using the SEM/EDS analysis of populations of VSP occurring on the surface of carpet fibers (see Fig. 1). Carpets are common in indoor domestic and many commercial environments, and they are ubiquitous in automobiles. Carpet fibers are easily shed, easily transferred, easily recognized on careful examination, and easily recovered. The transfer and persistence of fibers have received the

[2] Traces, as remnants, can only be imperfect proxies for their source. As a result, correspondence will necessarily be incomplete and subject to variations based on contingencies of separation and transfer (or, in the statistical sense, sampling).