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Forensic Science International 141 (2004) 77–83
Forensic Science International
www.elsevier.com/locate/forsciint

Damage caused to fibres by vapour cloud explosions

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Received 17 April 2003; received in revised form 4 August 2003; accepted 4 August 2003

Abstract

Research on the very specific damage to single textile fibres caused by vapour cloud explosions is presented. Vapour cloud explosion experiments were carried out using a selection of 41 garments differing in colour, fibre composition and textile construction. Fibres subjected to a vapour cloud explosion become wider at the end, often taking the form of a ball, bulb or shovel, while the morphological structure of the remaining part of the fibre remains almost unchanged. The presented results can clearly indicate that an explosion took place at the scene of the crime. The authors would like to be able to provide investigators with specific information on how to link clothes (and thus people) to a specific type of crime.

Keywords: Textile; Fibre; Damage; Vapour cloud explosion; SEM

1. Introduction

During recent years the number of cases where vapour cloud explosions have occurred has increased. This kind of explosion takes place when a mixture of explosive gases, for example air and petrol (most frequently used by criminals), becomes ignited. The upper and the lower point of ignition limits are 0.8 and 8.0% v/v petrol in the gas phase. These explosions take place in a split second (1/700–1/800) and temperatures from 800 to 1000 °C arise [1,2].

Evidence of an explosion on a fire retardant blanket made from Nylon 6.6 material includes: ''inter-penetration'', ''explosive flash melting'', ''transient heating'' and globularising or melting of the fibre ends—these were reported in an air crash investigation [3]. Some publications describe the effect of heat and fire on fibres [4–7], but no information is available about the damage caused to single textile fibres by vapour cloud explosions.

The aim of the presented study was to ascertain whether vapour cloud explosions may cause specific damage to garments and to single textile fibres.

The changes observed in complete textiles have been published earlier [8]; the presented report has focused on single textile fibre alterations.

2. Materials and methods

A selection of 41 clothes and household garments, differing in colour, fibre composition and textile construction were used in the experiments. These textiles are very popular on the textile market.

All explosion experiments were carried out in a fire reconstruction chamber. The vapour cloud explosions were carried out as follows: 0.170 ml of petrol were poured into a metal tin (850 ml), giving a concentration of 2.9% petrol in the gas phase. Then an electrical ignition device was attached. The tin was covered with a lid for 1 min to give enough time for the petrol to evaporate. Then the lid was removed, the textile was put on the tin and fixed with an elastic band. Next, the explosive mixture was ignited electrically. Control experiments showed that operating the electrical ignition device without the presence of petrol did not affect the fibres.

The morphological structure of the fibres after their exposure to vapour cloud explosion was observed using a stereomicroscope, a brightfield microscope and a Jeol JSM

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doi:10.1016/j.forsciint.2003.08.002

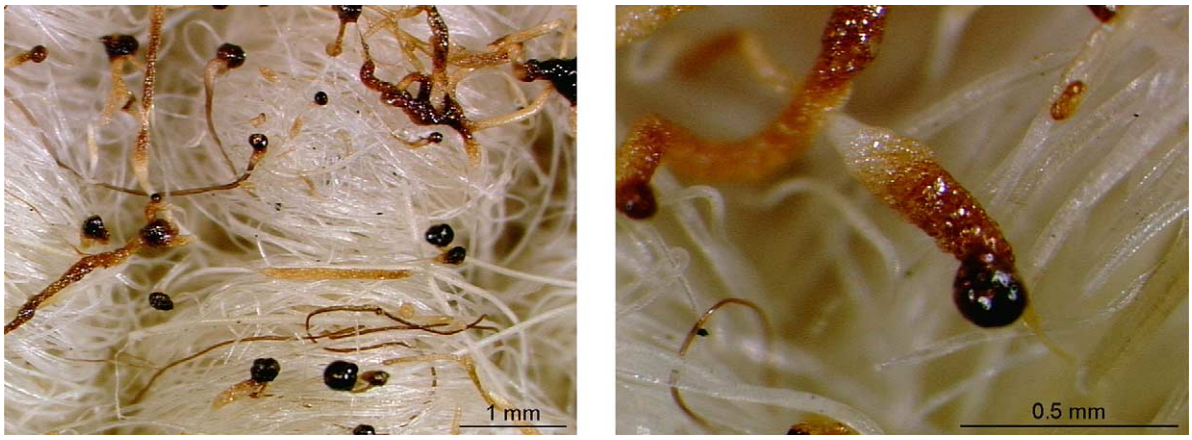

Fig. 1. Woollen carpet subjected to vapour cloud explosion.

5800 scanning electron microscope. The samples for SEM analysis were prepared in the following way: selected fragments of fabric were fixed on SEM stubs with self-adhesive carbon tapes, then coated with carbon using a Bal-Tech SCD 050 vacuum sputtering unit and finally placed in the sample chamber of the microscope. The surfaces of the fibres were observed at magnifications of 200–500 times, using low energy secondary electron imaging (SEI).

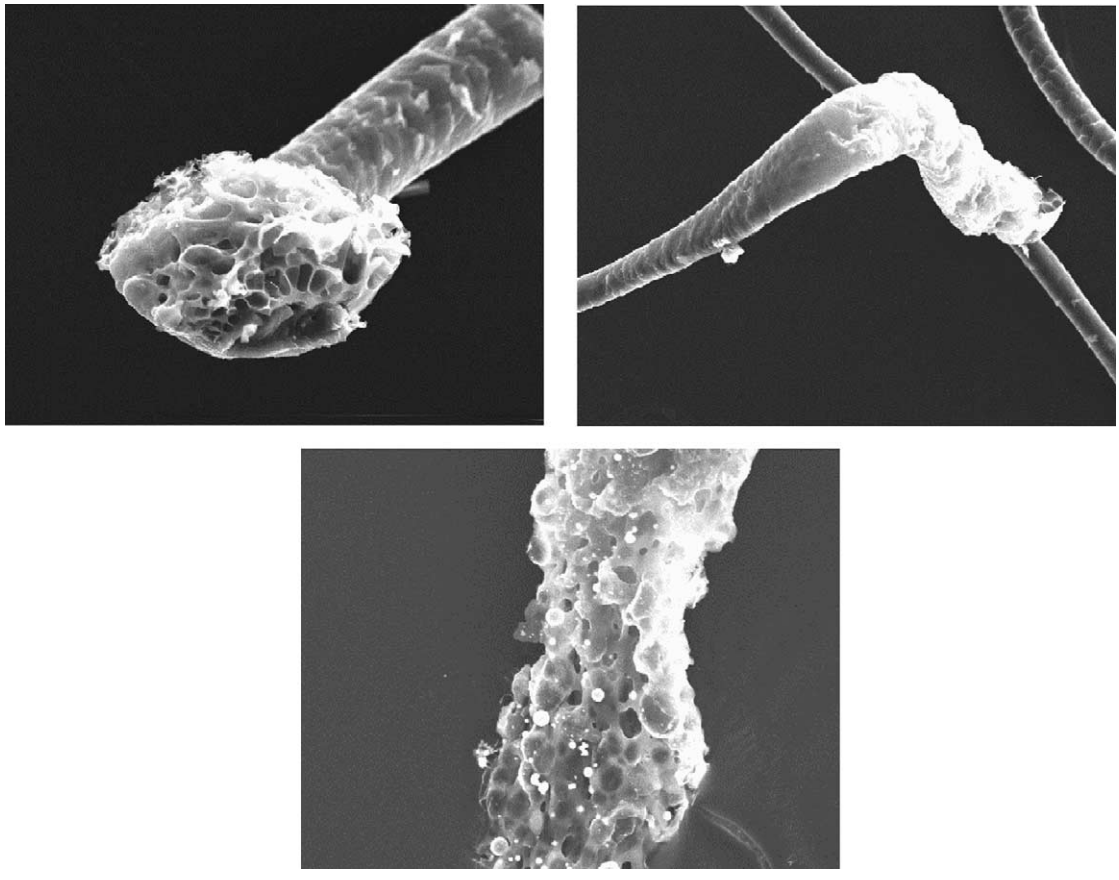

Fig. 2. Woollen fibre end alterations.

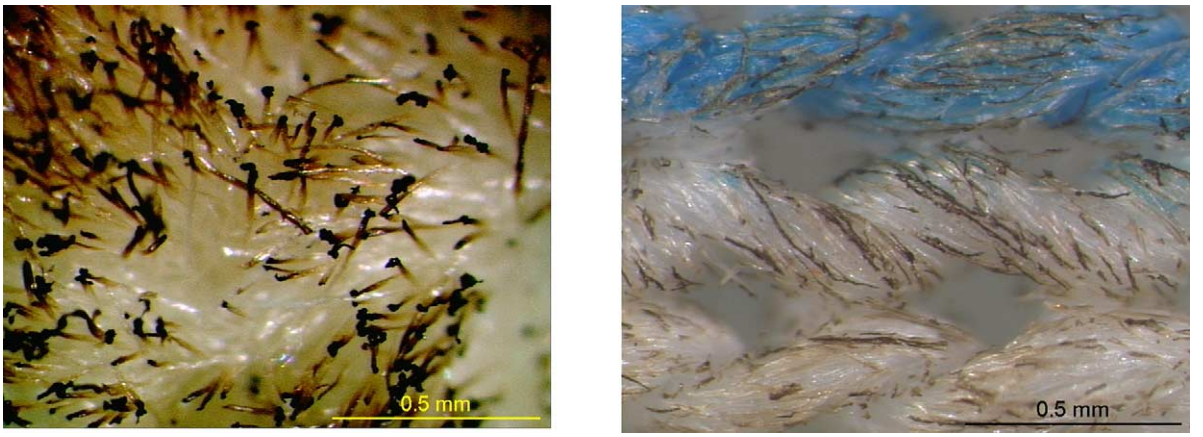

Fig. 3. Cotton T-shirt subjected to vapour cloud explosion.

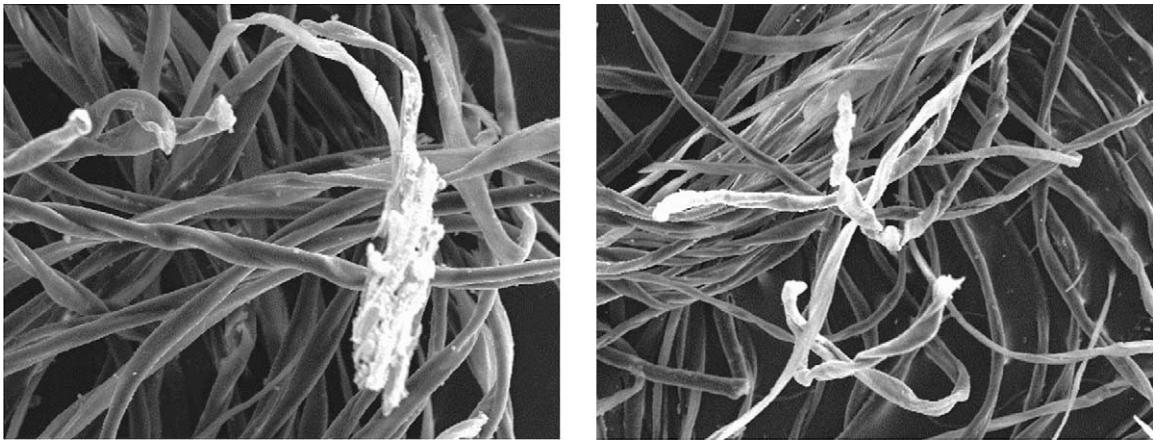

Fig. 4. Cotton fibre end alterations.

Fig. 5. Acrylic pullover subjected to vapour cloud explosion.

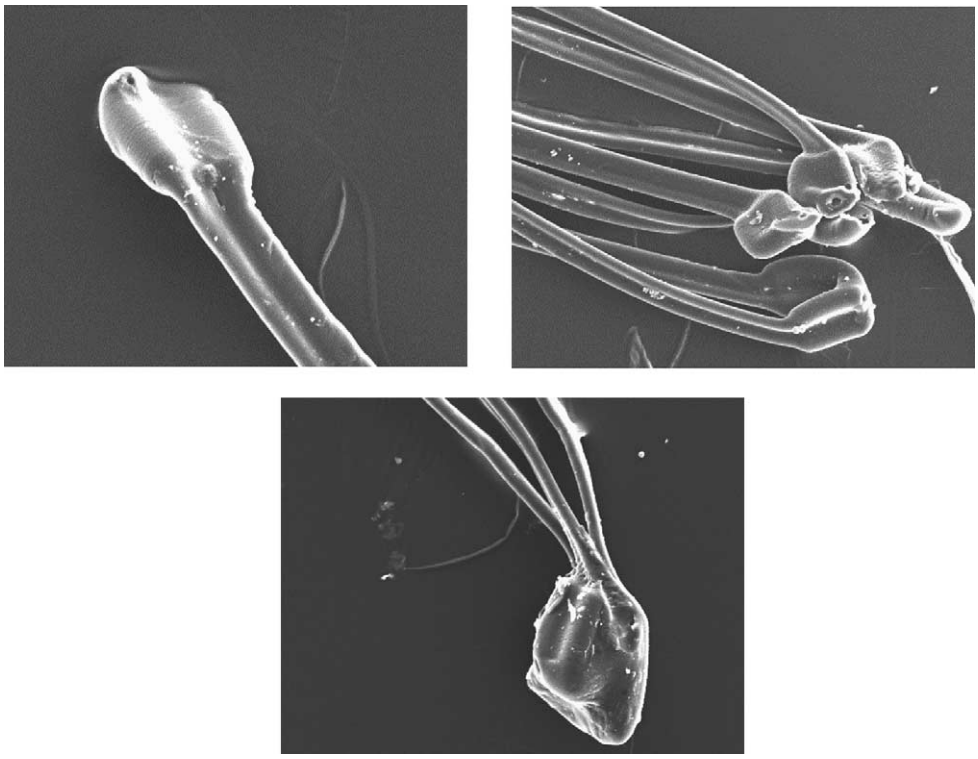

Fig. 6. Acrylic fibre end alterations.

3. Results and discussion

Selected results of the effects of experimental vapour cloud explosions on single fibres are shown in Figs. 1–10. Fibres exposed to a vapour cloud explosion become wider at the end, often taking the form of a ball, bulb or shovel, while the morphological structure of the remaining part of the fibre remains almost unchanged. Altered fibre ends of this type can be the result of extremely short exposure to a very high temperature and air pressure.

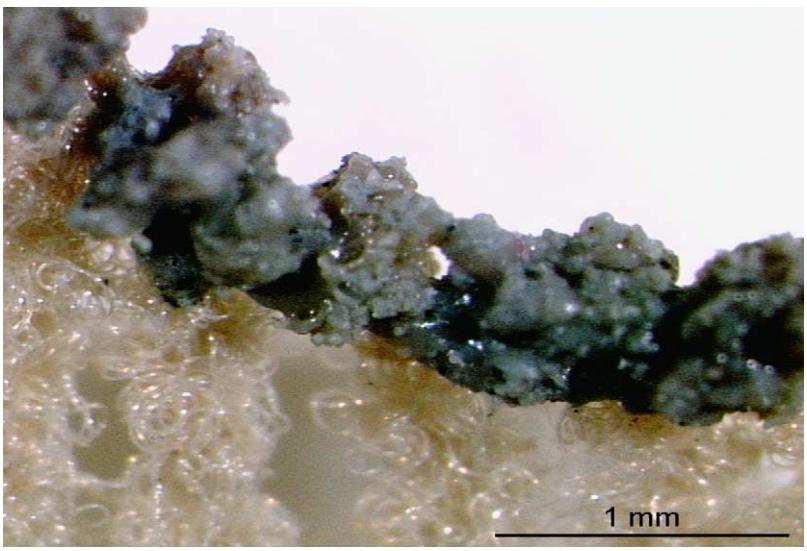

Fig. 7. Polyamide tights subjected to vapour cloud explosion.

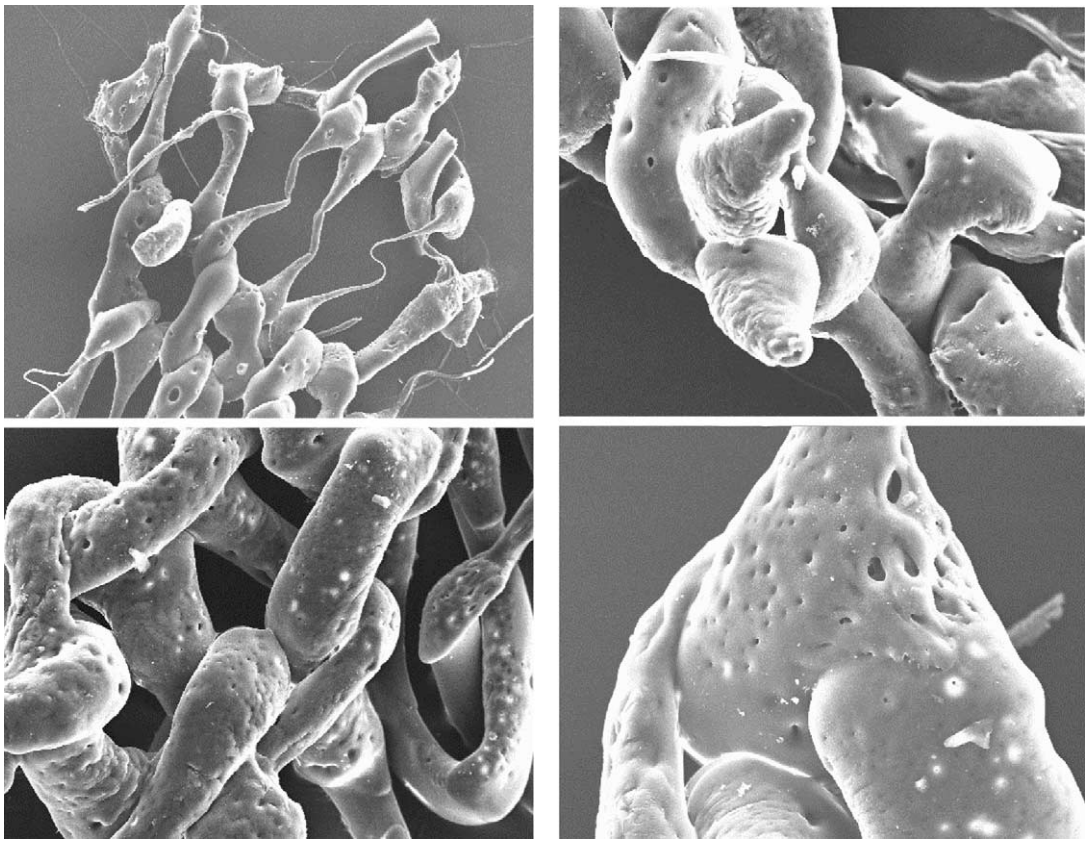

Fig. 8. Polyamide fibre alterations.

Figs. 1–2 present wool fibre ends. The woollen carpet alterations (Fig. 1) are similar to those of other woollen textiles: the fibre ends formed bulbs which were brown to black in colour, whilst many of the wool fibres inside the garment were not affected. In SEM images (Fig. 2) one can observe many holes in the fibre endings as a result of gas escape during the process of wool degradation. The basal part of the degraded wool fibre stayed almost unchanged.

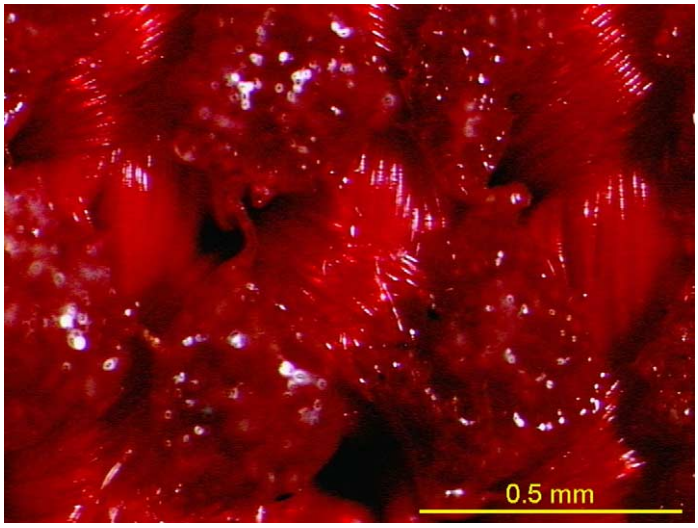

Fig. 9. Polyester textile subjected to vapour cloud explosion.

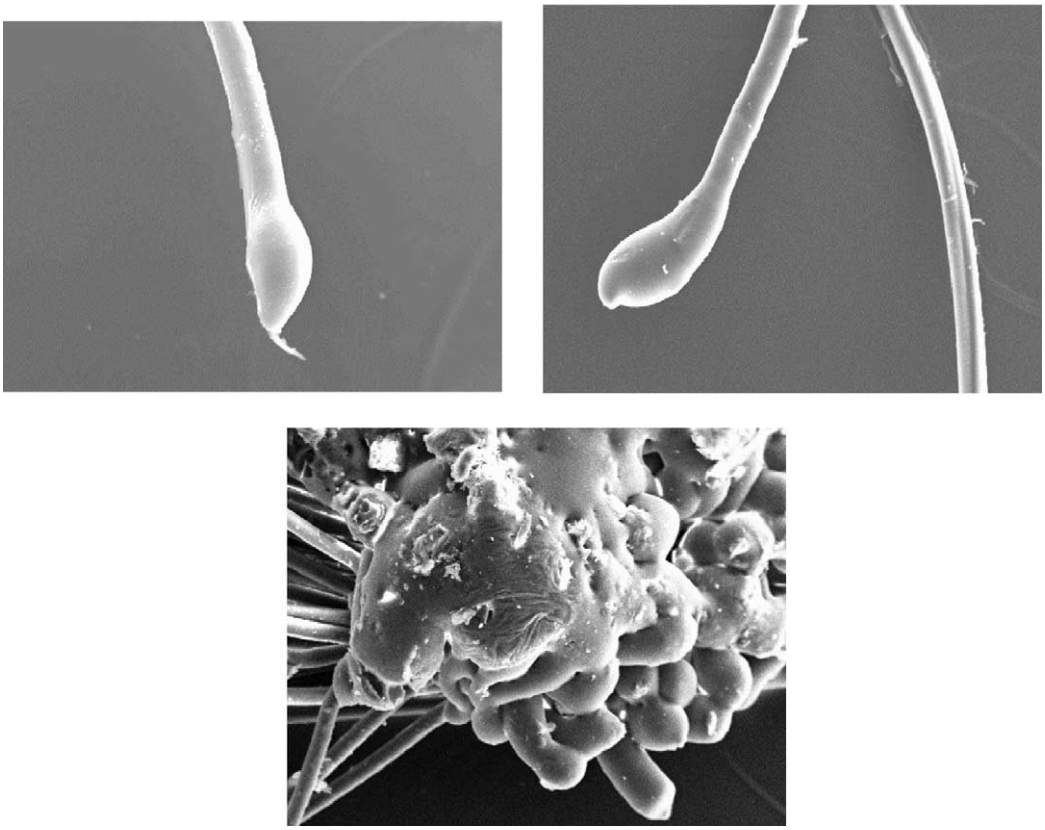

Fig. 10. Polyester fibre alterations.

Figs. 3–4 present cotton fibres penetrated by the heat wave. The heat wave going through the cotton T-shirt affected single fibres: they became brown to black and tended to char (Figs. 3 and 4).

Fig. 5 shows the effect of an explosion on a sweater made of acrylic fibres. After the explosion wave has penetrated, the homogenous textile surface with lots of projecting single fibres changed dramatically: as a result of the melting process, not one single projecting acrylic fibre can be seen. As observed in the SEM picture (Fig. 6), the single fibre ends have a shovel form, tending to be regular for single fibres, but more irregular when several fibres are involved. In the case of a conglomerate of many acrylic fibres, these characteristic end forms can not always be seen.

A strong melting effect is seen for polyamide fibres in tights (Fig. 7). After a vapour cloud explosion, fibres showed a lot of holes along the whole length (Fig. 8) as a result of the escape of internal gas bubbles. Fibre narrowings can also be seen and rare discernible single fibre ends can also have a shovel form.

Polyester fibre ends of a skirt and blouse textiles are shown in Figs. 9–10. After the vapour cloud explosion, the irregular oval shape of single polyester fibres can be observed (Fig. 10).

4. Conclusions

Vapour cloud explosions cause very specific damage to textiles and single fibres. Because the heat wave goes through the textile very quickly, many fibres of the yarns remain unaffected. Affected single natural fibres became burned, showing brown to black ends (mainly cotton and wool). Synthetic fibres (acrylics, polyamide, polyester) melted and formed conglomerates and their fibre ends formed the shape of a ball, bulb or shovel.

Such observations clearly indicate that a vapour cloud explosion took place at the scene of the crime.

The presented research results may be helpful in providing a link between suspects and the scene of the crime, and may therefore offer the possibility of solving a particular crime.

Acknowledgements

Authors would like to thanks to Deutsches Zentrum Für Luft- und Raumfahrt e.V. (German Aerospace Center DLR) and Polish Committee of Scientific Research (KBN) and Polish Ministry of Justice for their financial supports and the possibility of the realisation of the project.

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