LGC Forensics

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Bang! Goes the Airbag

Using Dust from Deployed Airbags as Trace Material in Automotive Crimes

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What's the project for?

- Traditional techniques involving hairs, fibres, blood and fingerprints are used to identify whether or not a suspect was a passenger or driver in a vehicle during a crash
- In a study in Austria[1] in 2003, 34 deployed airbags from both driver's and passenger's sides were analysed. Of these, 80% were found to have possible biological traces and of these, 60% gave DNA profiles matching the stated occupants
- The remaining 20% of cases gave no useable DNA results
- In addition, traditional techniques involving fingerprints and fibres evidence may not be relevant in a case where a suspect has legitimate, prior access to the vehicle
- **So, the next logical step is airbag debris …….**

Background 1 of 6

- Driver's side airbags
  - Mandatory from 1987 onwards (new build)
- Passenger's side airbags
  - Mandatory from 1993 onwards (new build) [2]

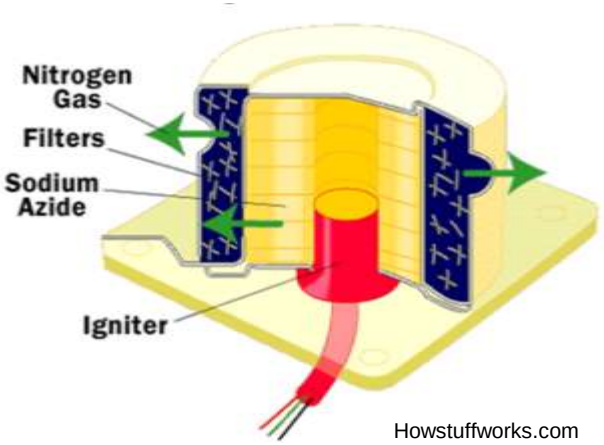
Background 2 of 6

- [6] Deployed within a 1/20th of a second
- Once activated, they deflate as the hot gas produced vents through vent holes, seams and stitching
- As hot gas is produced (600°C+), burns are often seen on skin and clothing of people in contact with the airbags during activation
- Belted occupants often make contact with front airbags with their chest, face and arms
- Unbelted occupants also make contact with their abdomen and legs as well

Background 3 of 6

- Early 1990's
  - Thick neoprene lining, packed with starch (or occasionally talc) to prevent sticking
  - During the late 1990's, driver's side airbags were produced with only small areas of neoprene, so the lubricant required diminished
- Late 1990's
  - Driver's side airbags were produced with only small areas of neoprene, so the lubricant required diminished
- Modern airbags
  - Modern driver's side airbags no longer use neoprene and so no starch lubricant is needed. These airbags use silicone as the sealant on the inside surface
  - The typical airbag system consists of crash sensors, which identify a collision and use a gas generator to inflate the airbag [3]
  - Filters are often used to reduce particle loss
- Into the future
  - Newer technologies have coated nonvented airbags which allow gas to escape by calculated airbag porosity. These may stay inflated longer for multiple collisions
  - Sodium azide was the initial choice for the solid propellant in pyrotechnic systems. Current research is identifying non-azide based propellants using alternative organic fuels with oxidizers. These formulations produce such low amounts of solid reside that a filter is not necessary.

Background 4 of 6



Howstuffworks.com

- Systems are divided into three categories [6]
  - **Pyrotechnic**
    - Includes the early sodium azide based systems, and the recent non-azide sources
    - Driver's side airbags, which relies on a precise consumption of a solid propellant which generates a predetermined volume of gas in a set time
  - **Compressed or cold gas**
    - Passenger's and curtain side airbags, with non or low venting airbags with low porosity
    - Still uses a pyrotechnic charge, but this is used to release compressed gas cylinders containing inert gasses
  - **Hybrid models**
    - Hybrid models work with both- a chemical reaction and the release of compressed gas. This combination is being used in newer vehicles for both passenger's side and side-impact airbag systems

Background 5 of 6

- **How sodium azide works**
  - Inside the airbag is a gas generator containing pellets of NaN_3, KNO_3 and SiO_2. A series of three chemical reactions inside the gas generator produces nitrogen gas to fill the airbag. NaN_3 (which is highly toxic) reacts to form not just the nitrogen gas required to fill the airbag, but also sodium metal which is potentially explosive and highly reactive. The sodium metal then reacts with the KNO_3 and SiO_2 to give a final product containing an alkaline silicate, which is harmless.
- **What particles are produced?**
  - The residue of the exothermic process, the by-products of the reaction and any unconsumed reactants
  - Different elemental compositions of materials are formed as particles cool at different rates
  - When the reaction occurs, different materials may also be present amongst the starting materials which may present themselves as trace contaminants in the final produced residue.
  - Different manufacturers use different starting materials in their airbags, and the recipe is often commercially sensitive

Background 6 of 6

Previous studies

- Studies by R. Berks in 2009 [4,5] investigated the elemental composition of the resultant reside from airbag deployment using SEM/EDS analysis, using an automated GSR route
- In the findings of this study, some airbags used primers which produced particles which cannot be distinguished from particles produced from a firearm.
- Cobalt, aluminium, copper, iron, zirconium, zinc, strontium and potassium are frequently encountered, as are aluminium/silicon microfibers. Some of these microfibres also contain calcium, aluminium or tungsten, and may show heat damage, taking on the appearance of brittle, glassy spheres.
- Particles adhering to these may also indicate materials which were filtered from the gas stream. These often contain air pocket inclusions and may show remnants of ‘tails’
- **The author noted there is no such thing as a ‘unique’ airbag residue particle**

Methods and testing 1 of 3

- Vehicles in a scrap yard had airbags deployed with a 9V battery under controlled conditions
- Acetate tape lifts were left open, taped to the back of the front seats of the vehicle during deployment, and also behind the steering wheel, to catch dust particles as they were ejected
- Acetate tape lifts of the front of the airbags were taken immediately after deflation, prior to the airbag removal from the vehicle
- (SEM stubs were taken from both front seats to examine for GSR- work not yet undertaken)
- Airbags were cut from vehicle and forensically bagged for examination in the laboratory
- 2 vehicles had dummies in the seats, to search clothing for particles and also to identify if fibres transferred to the airbag on detonation. This clothing has not yet been processed

Methods and testing 2 of 3

1. Airbag deployed and half removed

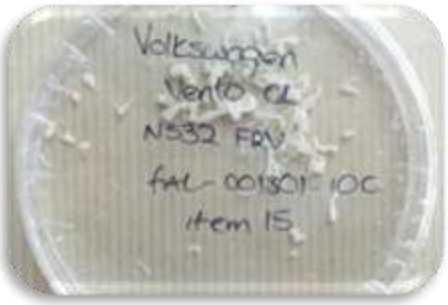
2. Open tape lift on back of steering wheel, left in-situ during deployment

3. Open tape lifts on back of driver and passenger seats, left in-situ during deployment

4. Dummies dressed in t-shirts and weighed down, left in-situ during deployment

Methods and testing 3 of 3

- Deployed airbags from the scrap yard were taken to the laboratory and dust from inside collected to Petri dishes
- In addition, several casework airbags also had their dust collected, and this was processed alongside the scrap yard airbags



- The dust particles were then investigated using low power and high power microscopy (x20-x500)
  - Microscopic light techniques used
    - White light (transmitted, reflected, polarising)
    - Fluorescent effects investigated using UV and blue light

Results 1 of 9

Table of vehicles and summary of airbags

Vehicle	Year	Source	Airbag	Size of bag (cm)	Bag shape	Lining?
Honda Civic	2009	Casework sample	Deployed Front, drivers side	unknown	round	partly, over central stitching
Ford Fiesta	2009	Casework sample	Deployed Front, drivers side	62	round	partly, over central stitching
Ford Mondeo	2003	Casework sample	Deployed Front, drivers side	60	round	no
Vauxhall Corsa	2009	Casework sample	Deployed Front, passenger side	67x57	rectangle	no
			Deployed Front, drivers side	unknown	round	partly, over central stitching
Fiat Punto	2008	Casework sample	Deployed Front, drivers side	60	round	partly, over central stitching
			Deployed Front, passenger side	74x80	rectangle	partly, over central stitching
Citroën Xsara	2001	Casework sample	Deployed Front, drivers side	56	round	no
		Casework sample	Deployed Front, passenger side	55x39	rectangle	no

Results 2 of 9

Table of vehicles and summary of airbags

Vehicle	Year	Source	Airbag	Size of bag (cm)	Bag shape	Lining?
Vauxhall Cavalier	1992	Scrap yard sample	Deployed with 9v battery Front, drivers side	70	round	partly, over central stitching
Vauxhall Astra Estate	1994	Scrap yard sample	Deployed with 9v battery Front, drivers side	71	round	partly, over central stitching
Ford Fiesta	1994	Scrap yard sample	Undeployed Front, passenger side	63	round	yes
Volkswagon Vento CL	1995	Scrap yard sample	Deployed with 9v battery Front, drivers side	58	round	none
Ford Mondeo	1996	Scrap yard sample	Deployed with 9v battery Front, drivers side	64	round	none
Fiat Coupe	1996	Scrap yard sample	Deployed with 9v battery Front, drivers side	61	round	none
Volkswagon Polo	1996	Scrap yard sample	Deployed with 9v battery Front, drivers side	53	round	none
Toyota Celica	1996	Scrap yard sample	Deployed with 9v battery Front, drivers side	60	round	none
Rover 623 GSI	1996	Scrap yard sample	Deployed with 9v battery Front, passenger side	72x76	rectangle	none
Rover 623 GSI	1996	Scrap yard sample	Deployed with 9v battery Front, drivers side	65	round	partly, over central stitching
Rover 200	1997	Scrap yard sample	Deployed with 9v battery Front, drivers side	53	round	none
Audi A4	1997	Scrap yard sample	Deployed with 9v battery Front, drivers side	70	round	none
Peugot 306	1999	Scrap yard sample	Deployed with 9v battery Front, drivers side	57	round	none
Renault laguna	2000	Scrap yard sample	Deployed with 9v battery Front, drivers side	64	round	none
Citroen Saxo	2002	Scrap yard sample	Drivers Side airbag was already deployed (Airbag cut from vehicle at scrap yard)	56	round	none

Results 3 of 9

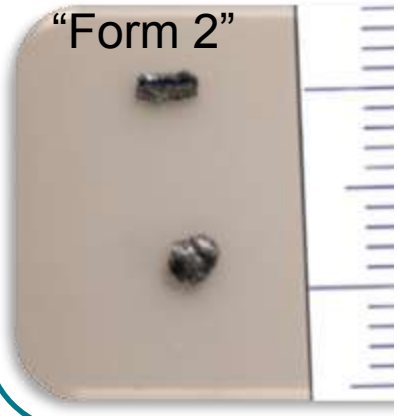
Dust found

- In total, 50 different “Forms” were identified based on morphological and microscopic appearance
- Sizes investigated ranged from about 40µm (smallest particle to manipulate with tweezers) up to 600µm
- Virtually none of the dust found exhibited birefringence when viewed under cross polars
- Many of the same forms cropped up in many different airbag dust, but in each and every airbag, the forms seen and their ratios varied
- ‘Worms’ which were glass-like forms were seen from almost every airbag. Many of these were coloured- red, green, blue, pink, black, and there seems a good correlation between the colour of the stitching on the airbag and the worm colours
- Initial, preliminary results indicate that the dust reaching the passenger seat during detonation of a driver’s airbag is approximately half the amount which reaches the driver’s seat
- The presence of a lining on the airbag- although debris was reduced, at least 1/2 teaspoon of debris was recovered from each airbag

Results 4 of 9

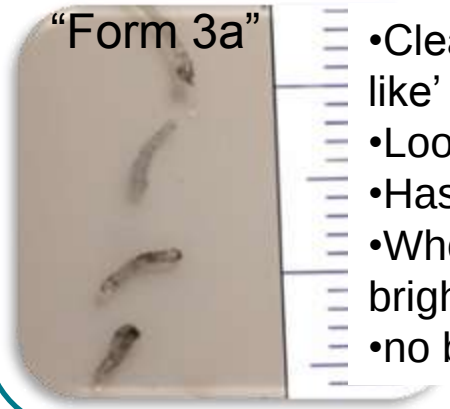
Most common particles found

Appeared in 48% of airbag samples (11/23)



- Flat grey/silver particles
- Glittery appearance
- Very smooth shiny metallic surface
- Has slightly jagged edges
- Size range 80µm - 600µm

Appeared in 26% of airbag samples (6/23)



- Clear, some grey ‘worm like’ shapes
- Looks like glass
- Has internal air bubbles
- Whole particle fluoresces bright blue under UV
- no birefringence seen

- Smooth, has internal air bubbles
- Has crumbly and brittle texture

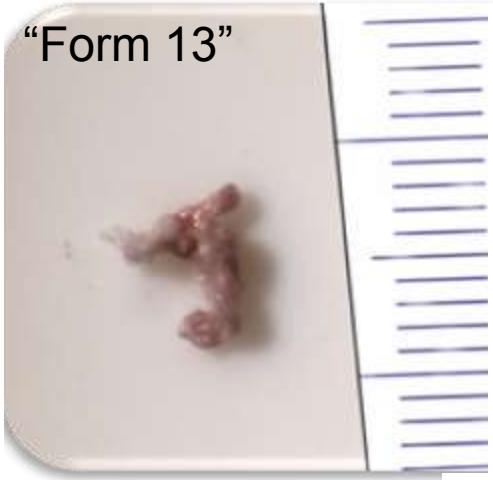
* Scale shown is 0.1mm

Results 5 of 9

Most common particles found

Appeared in 22% of airbag samples (5/23)

- •White/ opaque
- •Uneven texture
- •Looks like glass
- •Has internal air bubbles
- •Particle fluoresces bright blue under UV light



- •Very uneven shape
- •Red, crystalline texture
- •Has internal air bubbles
- •Does not fluoresce

- •Has a gold/rusty colour
- •Glitter effect on surface
- •Looks like metal
- •Does not fluoresce

- •Uneven shape
- •Pink, shiny appearance
- •Looks like glass
- •Some areas fluoresce bright blue under UV, bright green under blue light

Results 6 of 9

Most common particles found

Appeared in 17% of deployed airbags (4/23)

“Form 1A”

- Smooth spherical particles
- Dark grey in colour

“Form 1”

- Clear spherical particles
- Some tear-drop shaped
- Some with ‘tails’
- Has internal air bubbles
- Does not fluoresce

“Form 4”

- Dark grey/black powder like clumps
- Breaks very easily difficult to pick up and move
- Has internal air bubbles
- Does not fluoresce

Results 7 of 9

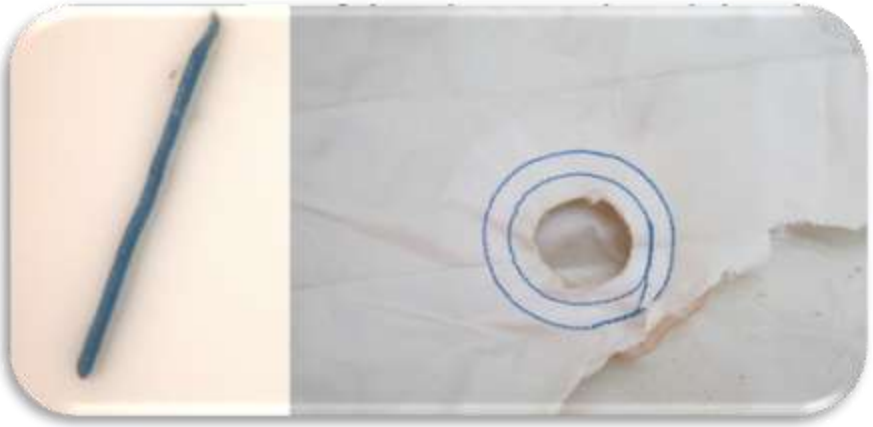
Coloured worms and correlation with colours of stitching on the airbag

Volkswagen Vento
Red stitching red worms

Volkswagen Vento
Green stitching green worms

Results 8 of 9

Coloured worms and correlation with colours of stitching on the airbag

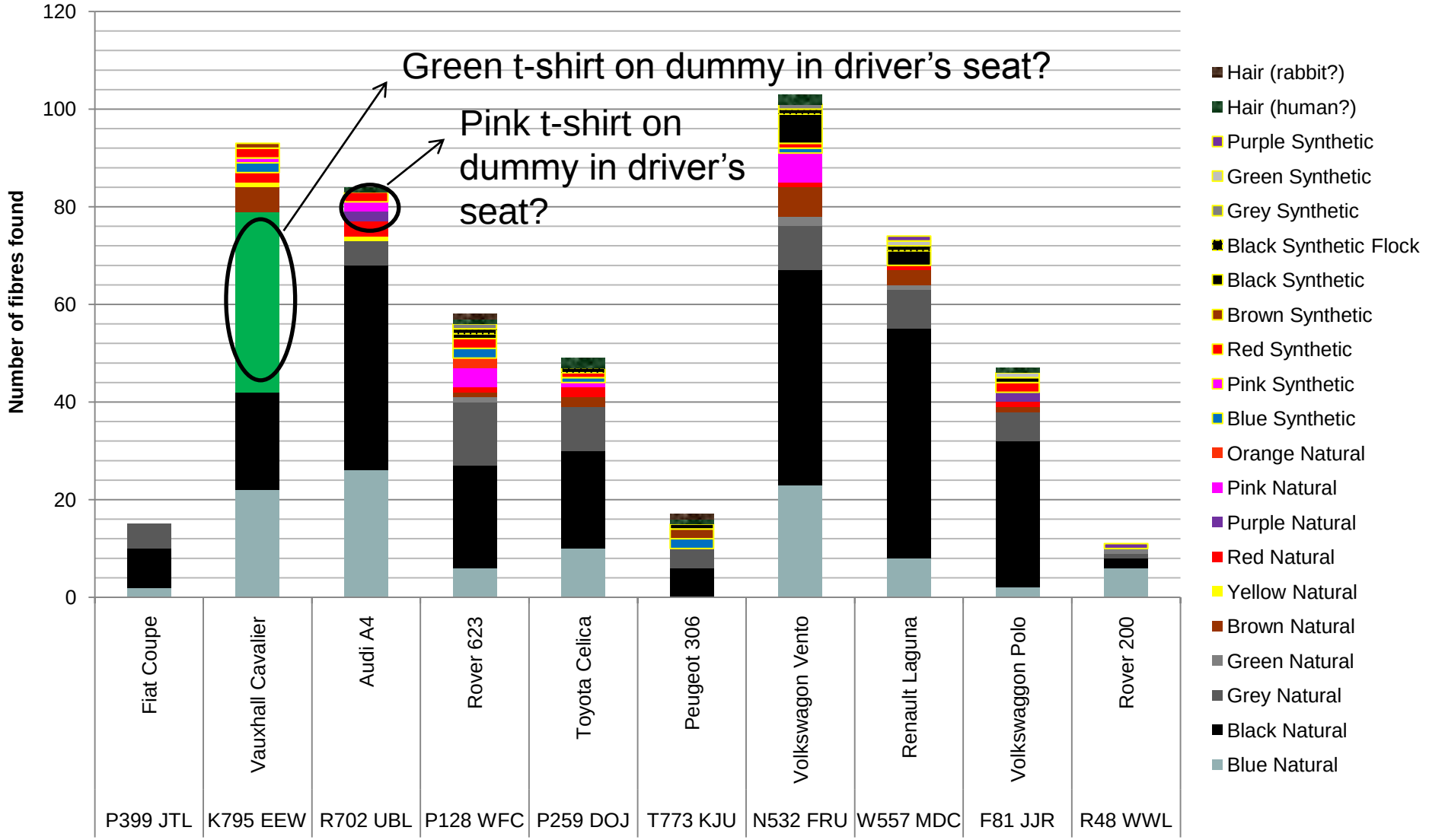


Toyota Celica
blue stitching blue worms

Vauxhall Cavalier
Orange stitching orange worms

Results 9 of 9

Fibres recovered from the surface of the deployed airbag before removal



Conclusions 1 of 1

- In every case, dust was produced from deploying an airbag (the only airbag recovered which had not deployed did not have any debris)
- The dust produced was varied and distinctive, and was searchable, recoverable and comparable with low and high power microscopy
- The colour of the stitching on the airbag is important, as potential sublimation of the dye in the stitching (?) may occur into forms created
- Each detonation may be viewed as an individual exothermic reaction, and consequently the forms and their ratios produced may be viewed as potentially discriminatory
- Forms would best be recovered from clothing by shaking the item- from looking at the tapes it is virtually impossible to remove the forms from adhesive without distorting the morphology
- A significant number of fibres were recovered from the surfaces of the recently deployed airbags- although most were ‘background’ grey, black and blue, care should be taken when placing significance onto the finding of matching fibres
- If a passenger and a driver’s airbag have deployed, the dust produced from each may have similar forms. As dust was found to be distributed around the front of the vehicle, it would not be possible to differentiate where a person was sitting in the vehicle by the finding of dust on clothing alone.
- The distinctive forms show signs of heating and melting, with little birefringence- typically what would be expected when material heats and cools rapidly without crystallisation being able to occur

Case study 1 of 2

Case circumstances

Victims' car was stolen, a 2009 blue Honda Civic. The stolen vehicle was sighted by police being driven in a suspicious manner, they chased it and temporarily lost sight of it. During this time, the vehicle was found to have crashed into a garden wall. Witnesses saw a single person in a dark top decamp and run away. The impact had caused the drivers airbag to deploy. Police stopped a male matching the witnesses' description and his black hooded top was seized. He claimed legitimate access to the vehicle a few days prior. The airbag from the vehicle was submitted, examined for DNA and the results showed a complex mixture. The top was therefore examined for airbag particle analysis.

Item was a round, pink airbag with a red, stitched circle to the front. On the rear was a rough cut hole and the airbag was unlined. The material of the airbag was of a smooth, tight knit construction. There was some scorching seen on the inside, and a substantial quantity of debris was seen on the outside surface and also in the interior of the airbag.

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The debris was grey in colour, ranging in size from 0.3mm to less than 0.1mm. The debris was very distinctive, found to be soft when squashed, and fairly shiny in appearance. Some debris was almost transparent, and was seen in three different morphological types; thick amorphous flakes, round balls and elongated 'worm' shapes.

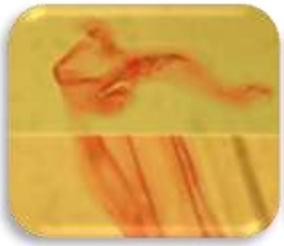
It was found that the centre stitching was colourless, but coated in a layer of pink/red material. This pink/red plastic coating was deemed to be suitable as a target on clothing, as it was found to flake.

Case study 2 of 2




•The jacket was of a standard sweatshirt type material, and was labelled as being 100% cotton
•Possible scorch marks were seen on the right cuff
•Four sections of white gelatine lift were placed on the surface, one on each cuff and two down the middle section of the garment. These gelatine lifts were pressed onto the surface with a fair amount of force. The gelatine lifts then had the original acetate sheets returned over them.
•When the item was turned over, a single gelatine lift was placed in the centre back of the jacket, and pressed down on with equivalent force as the front ones. This gelatine lift was also stored with the original acetate sheet being placed back onto it.
•The item was then shaken and debris collected to a Petri dish.

Tested fragments from the jacket were optically indistinguishable from airbag particles (x500 by bright field, dark field, polarising transmitted light and for their fluorescent properties.
EDX analysis found that four of the five tested particles from the jacket were chemically similar to the particles from the airbag



One particle of pink/red thin plastic, recovered from the jacket and compared x500 (left- white light, middle- blue ‘light’, right- UV ‘light’) to the airbag stitching & found to match.

Acknowledgements

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