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Microfibers—A Forensic Perspective

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ABSTRACT: This manuscript is a review of information relevant to the forensic scientist in the developing field of microfiber production. Manufacturing methods and applications are discussed and examples given. Two cases in which microfibers were transferred are discussed and the evidential value is assessed.

KEYWORDS: forensic science, criminalistics, microfiber, fiber production, spectrophotometry, thin layer chromatography, infrared spectroscopy

Identification and comparison of textile fibers is often important in establishing whether or not there are links between suspect and victim or suspect and scene of crime. Techniques used in the examination and comparison of these fibers include microscopy, microspectrophotometry, thin layer chromatography and infra-red spectroscopy. The application of these techniques is dependent on the nature of the sample and for this reason the forensic scientist needs to be familiar with recent developments in fiber production. The largest single area of synthetic fiber development in the last decade has been in manufacturing methods that have enabled the viable production, on a large scale, of microfibers.

'Microfiber' is a term that is generally applied to synthetic fibers with a thickness of less than 1.0 dtex (weight in decigrams of 1 km of continuous fiber) (1). This definition has yet to be agreed upon within the industry and is subject to some interpretation by the manufacturers. Microfibers of less than 0.1 dtex are further classified by some manufacturers as ultrafine fibers. For the forensic scientist, the tex system used in industry has little meaning. A more suitable measurement is the fiber diameter in microns (μm) which can be easily determined. A useful comparison of conventional and microfibers is that a thread consisting of 34 conventional fibers would be approximately the same diameter as a thread containing 238 microfibers (2).

The cross sectional shape of microfibers varies widely and this can help to identify the manufacturer. It can usually be determined from a normal slide preparation and confirmed if necessary by the examination of a mounted transverse section (3).

The first commercially available microfiber was produced in Japan in the early 1970s. There have been several paths of development since then which have resulted in the production of many types of microfiber with various applications (4). The original aim of producing an artificial silk has now become only one of a wide variety of uses.

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Methods of Microfiber Production

Microfibers are produced from most polymer types used in conventional fiber manufacture (e.g., polyamide, polyacrylonitrile, polyester, polyolefin, and cellulosic) and have been developed to produce fabrics with qualities other than those normally associated with particular materials. Three main techniques are used.

Conventional Spinning—A molten or dissolved polymer is extruded from a shaped spinneret and drawn to form fine filaments (5). Microfibers produced by this method include Tactel micro (ICI) that typically have a dtex of between 0.5 and 0.7.

Conjugate Spinning—This is usually a co-spun polyester/nylon yarn manufactured mainly by Japanese producers. The technology used in the manufacture of these biconstituent fibers has evolved from the methods used in the production of bicomponent fibers in the late 1960s. To obtain the low dtex (and hence low fiber diameter) a 'normal' diameter fiber is split into smaller components. This is possible because the fiber is made from two or more polymers that react differently to their environment. A number of similar techniques are available which rely on the properties of the specific polymers to aid the splitting process.

When the Japanese company Kanebo first began producing 'Belima,' a splittable biconstituent fiber, the cross sectional shapes were simple. Initially, it was a conjugate of four nylon wedges around a cross shaped polyester filament. The polyester was dissolved (using caustic soda) to leave four triangular nylon filaments each with a dtex of approximately a quarter of the original composite fiber. As the technology developed, the shapes have become more complex. 'Belima' has evolved into 'Belima X,' a biconstituent that can be split into 10 or more dissimilar filaments each with a dtex of less than 0.3. This irregularity means that 'Belima X' can mimic the properties of natural fibers such as silk and cotton.

'Belima X' may be blended with conventional fibers and is woven into a fabric before splitting. Rather than using caustic soda to dissolve the polyester, the conjugate fiber is exposed to a shrinking agent, thus taking advantage of the differences in shrinkage of the two components (Fig. 1). This splitting is not always complete and conjugate fibers may still be present in the finished fabric (Fig. 2).

A second type of conjugate fiber made by Kanebo, is 'Cosmo Alpha'. This is split using a chemical dissolution technique. Wedges of polyester are bonded together with a modified polyester, which is dissolved to leave nine filaments. This may also be blended with conventional fibers as in a fabric called 'Nazca'.

Kanebo also manufacture an all nylon conjugate microfiber with a similar radial cross section (6). Nylon has many advantages over

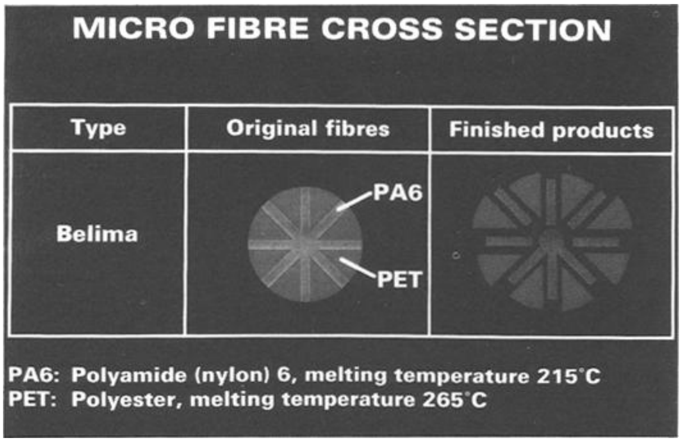

FIG. 1—*Belima X.*

polyester. It is hard-wearing but soft, is easily dyeable and comes in a variety of cross sectional shapes.

These are just three examples of conjugate microfibers. There are others which use alternative splitting techniques (e.g., mechanical distortion) and have more specific applications, some of which will be discussed later.

Island-in-Sea Configuration—A non-homogeneous polymer mixture is spun into fine yarn (2). The yarn is woven or knitted before the sea component is dissolved leaving fine non-continuous filaments. In our experience this is the least common type and little information is available (5).

Applications

The two microfibers discussed at length previously (Belima X and Cosmo Alpha from Kanebo) are mainly used in the clothing industry for lightweight garments where a good drape is necessary. Since its launch in 1977, 'Belima' has been used in many different fabrics, and provides a good example of evolution within the microfiber industry. The first named fabric produced was 'Belleseime,' a man-made suede. This had many advantages over natural suede as it was washable and its softer handle enabled it to be used in a wide variety of items. 1982 saw the production of 'Belseta,' a water resistant and breathable fabric used in jackets and coats which therefore requires no further treatment or coating. Fabric similar to this is now being used in the manufacture of shoes. 'Belseta CX,' a cotton type material, was launched in 1983. It was quickly followed by the revolutionary 'Belseta PS,' a peach-skin fabric with a fine nap which started a trend for this type of soft to the touch but practical material. 'Beldano' was produced in 1991 as a soft suede-like fabric and in 1993 a fabric with fibers of different diameters was manufactured.

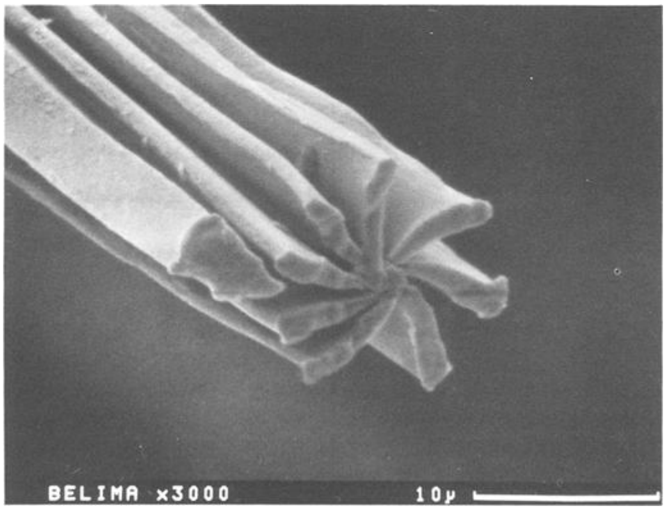

FIG. 2—*Micrograph showing incomplete splitting of microfibers.*

A second Japanese producer, Teijin, has combined a radial conjugate fiber with a hollow spun fiber in its 'Hilake Ellettes' fabric. This is a densely woven material with 1424 filaments in one warp/weft unit (5). This tight weave means that the fabric has a good drape and is water and windproof. As no additional treatment or coating is necessary these properties are retained after washing. The material has specialist uses both as a high density fabric for outer clothing and in fashion garments.

The three main uses for microfibers are as artificial silks, artificial suedes, and high density material in a whole range of garments from underwear and hosiery to coats and all-weather wear. Other more obscure uses include filters and artificial arteries (4).

Microfibers in Forensic Science

The impact of microfibers on forensic science depends entirely on whether or not they shed from the surface of garments and how well they are retained after transfer. Microfibers are often blended with conventional fibers and even if no microfibers are shed, the conventional fibers may still transfer. Preliminary work done by Kolar (7) suggests that microfiber fabrics are indeed a good source of transferred fibers.

At the MPFSL the most common type of microfiber encountered is the peach skin type fabric which is most often seen in jackets and coats. In our experience this microfiber sheds in very small fragments (less than 1-mm lengths) which can be retained by recipient surfaces.

Microfibers retrieved on 'Sellotape' (7) from the surface of a garment are very small and are usually lightly dyed. They are therefore very difficult to locate on tapings. With patience, and a higher magnification than normal (i.e., greater than ×15) this task is possible. Use of this labor intensive technique is justified, as the comparative rarity of these fibers at the present time gives microfibers high evidential value. Once removed from the tapings, the microfibers are compared with a control sample using visible and UV comparison microscopy (8). In order to give a preliminary indication of the fiber type the birefringence (9) of the control sample and recovered fibers is measured. The small diameter of microfibers makes accurate measurement difficult and often they can be estimated as having a birefringence value of 0.05 which is close to that of silk. Such samples may also have the appearance of silk when viewed as a normal slide preparation. Definitive identification of the polymer can be achieved by fourier transform infra-red (FTIR) spectroscopy (8).

In this laboratory the instrumental and chromatographic analysis is performed on a proportion of the fibers that match after comparison microscopy. Microspectrophotometry is usually carried out on approximately a third of the matching recovered fibers and the control sample. To obtain reliable, reproducible spectra the measuring aperture of the instrument needs to be smaller than the diameter of the fiber. This can be achieved by either having a measuring slit with an adjustable area, or using a fixed slit with a higher power objective. As stated earlier, FTIR is used for polymer identification. One fiber from the control sample and one recovered fiber from each recipient item are tested using a Nicolet 510 bench instrument connected to a Spectra-tech IR plan microscope. The microscope attachment is essential for the FTIR analysis of conventional fibers, but microfibers additionally require the use of a compression cell with diamond windows which eases sample preparation and presentation. In our experience single microfibers are too small for thin layer chromatography (TLC), however, large samples can be compared using existing techniques.

Casework Examples

A security truck containing three million pounds sterling was stopped by three men, one of whom produced a gun, threatening the driver. As police moved in to arrest the robbers, two escaped in a stolen vehicle (which was later found abandoned), the third was arrested nearby. We were asked to establish whether or not there was a link between the arrested suspect and the vehicle. Tapings taken from the seats of the stolen vehicle were examined for fibers that could have come from the clothing worn by this suspect. After comparison microscopy there were 47 fibers matching those of the suspect's trousers (consisting of four fiber types) and nine fibers matching the jacket. The jacket was made of conventional and microfibers and all nine matching fibers were microfibers.

Visible microspectrophotometry was performed on a proportion of the suspect fibers matching the jacket and on control fibers from the jacket. All samples were tested using a Nanometrics Nanospec 10S spectrophotometer attached to a Leitz Ortholux II microscope. The spectra produced from suspect and control fibers were identical (Fig. 3). FTIR spectra were then obtained from suspect and control fibers and both were identified as Nylon 6 (Fig. 4).

All the suspect microfibers in this case were less than 1 mm long and therefore of insufficient length for TLC. When taken together with the 47 conventional fibers this evidence was reported as providing very strong support for the assertion that the clothing worn by the suspect had been in contact with the car seats. The suspect was found guilty and sentenced to seven years in prison.

A woman was attacked at her front door by a man who put his hands around her throat. The victim's flatmate heard her screams and opened the front door. The suspect ran away and was arrested nearby. Extraneous fibers were recovered from the suspect's clothing and compared with those of the victim's skirt and jacket. Two red viscose fibers matching fibers from the skirt were found on the suspect's trousers. The victim's jacket was made of gray polyester fibers and a similarly colored polyester microfiber with a slightly different level of delustrant. The suspect's sweatshirt was examined for fibers similar to those of the jacket and 16 were found that matched after comparison microscopy. One of these was a microfiber and matched after visible microspectrophotometry. FTIR spectroscopy identified the suspect and control fibers as polyester. The suspect fiber was 0.5 mm long, again of insufficient length for TLC. In the report prepared relating to this case, the fiber comparisons were evaluated as providing good scientific evidence of contact between these items. In addition, a small amount of blood was found on the suspect's sweatshirt which on testing could be attributed to a mixture of blood from the suspect and victim, but it was unsuitable for detailed analysis. In this case the suspect was acquitted.

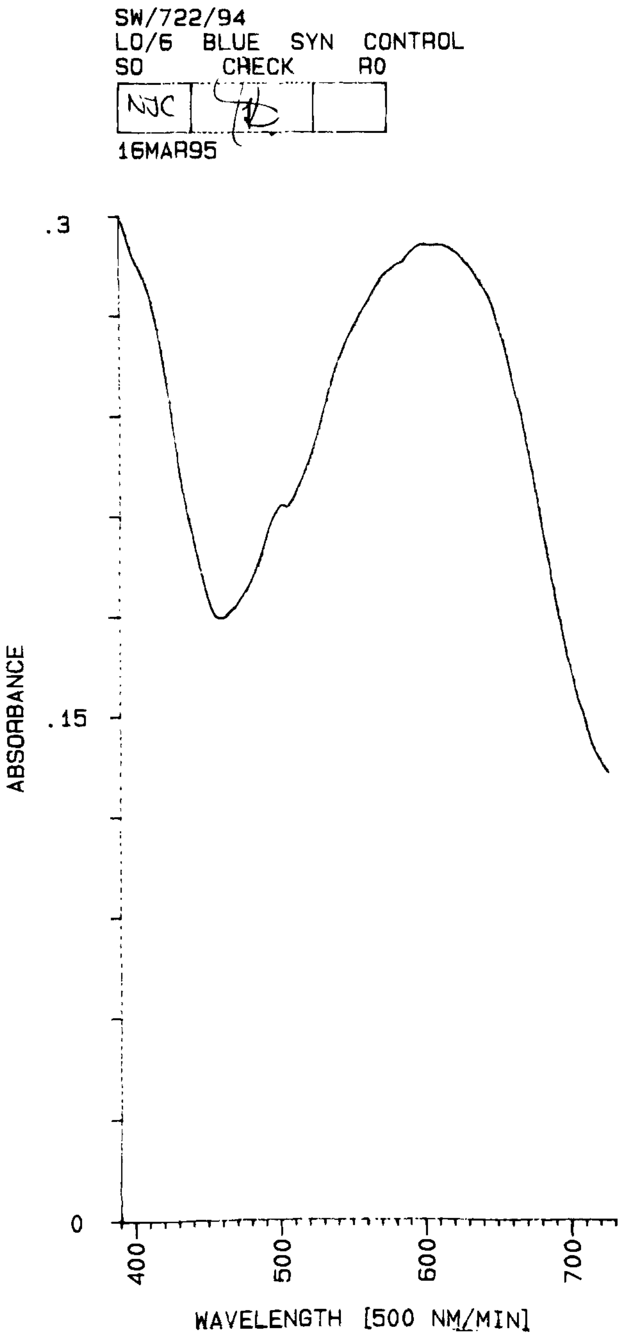

FIG. 3—*Visible spectrum of microfiber.*

As the amount of microfiber fabrics on the market increases (recent figures suggest that microfiber fabrics may, for example, now account for over 80% of the sales of casual jackets) a greater proportion of fiber examinations undertaken by the forensic scientist may involve the analysis of microfibers. Developments in UV microspectrophotometry may enable more information to be obtained from such small samples.

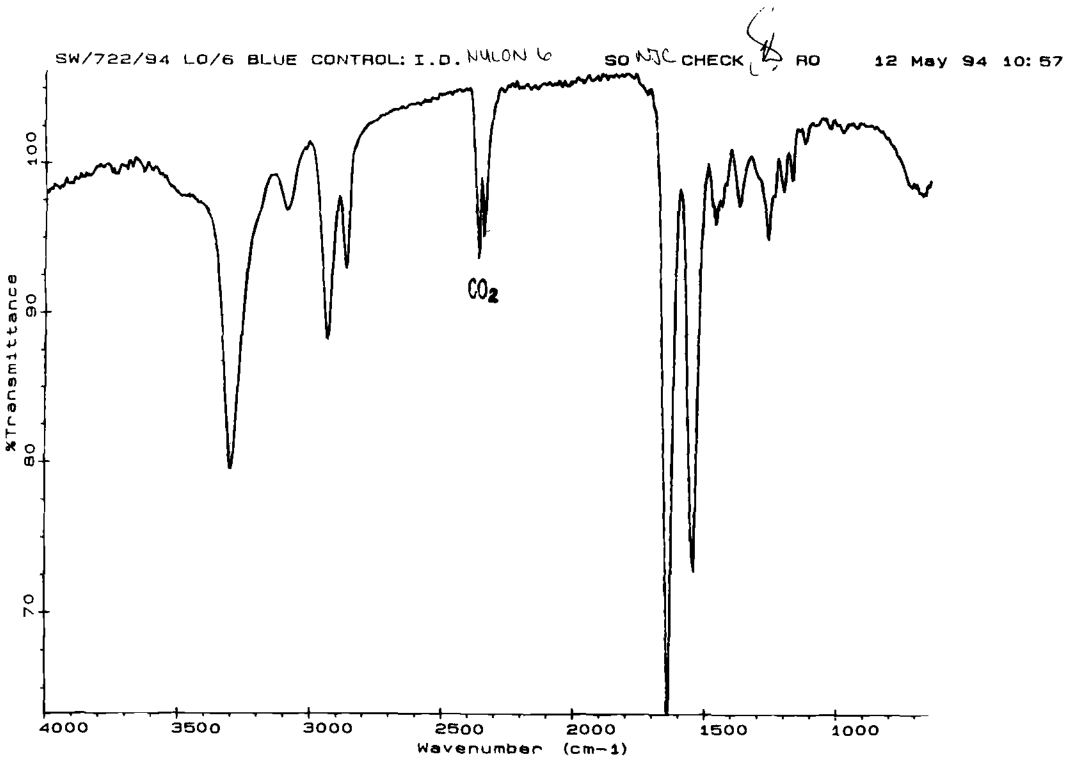

FIG. 4—*Fire spectrum of microfiber.*

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