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THE USE OF SCANNING ELECTRON MICROSCOPY FOR IDENTIFICATION OF CUTS AND TEARS IN FABRICS: OBSERVATIONS BASED UPON CRIMINAL CASES

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Abstract

Examination of fabrics to determine if they have been cut or torn may become an important issue in criminal investigations under a variety of circumstances. Since most fabrics are composed of extremely fine fibers, they present a difficult problem when such examinations are conducted by stereo light microscopy. This is particularly true when the cut fabric yarns are grossly displaced or disturbed from their original positions and where fabric edge characteristics lack the observable specificity to provide any definitive conclusion. The scanning electron microscope, due to its higher magnification, resolution and depth of field, provides an excellent technique for examination and differentiation of cut and torn fabrics. The acts of cutting and tearing produce different morphological characteristics on the separated fiber ends. Examination of these fiber ends at significantly high magnification and comparison with deliberately produced cut and torn fabrics will allow positive identification of cuts and tears. Three actual criminal cases involving man-made and/or natural fibers in woven and/or nonwoven fabrics demonstrate the usefulness of the technique where visual and stereo light microscopical examinations were inconclusive.

KEY WORDS: Criminalistics, scanning electron microscopy, fiber end surfaces, cuts and tears identification, actual case studies.

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Introduction

In violent crimes, and especially in rape cases, conflicting information is often provided by the victim and suspect. In order to determine what has actually occurred, it becomes necessary for law enforcement authorities to establish facts from the available physical evidence.

The criminalist is occasionally required to examine the victim's clothing for cuts and tears and is asked to formulate an opinion as to whether a particular fabric could have been cut with a sharp object or have been ripped by force. Although such examinations are sometimes crucial, little if any attention has been given to them in professional publications. The following cases illustrate such occurrences where conclusive identifications were made:

Case No. 1

This case involved an alleged rape wherein the victim stated that her panties and shorts had been cut off by a knife-wielding assailant. The suspect, however, claimed that intercourse was consensual disclaimed having a knife in his possession at the time. The victim sustained minor scratches to her neck and superficial cuts on her thighs.

Case No. 2

In a case involving an alleged kidnapping, aggravated assault and indecent assault, the victim stated that her assailant assaulted her with a glass beverage bottle. The assailant, she reported, then broke the bottle and cut through her clothing, producing superficial lacerations on her neck, breasts, inner thighs and abdomen. The victim claimed that the only cut in her clothing that was not produced as a result of the attack was a cut in the front of her shirt collar. Therefore, it was necessary to determine the cause of the remaining separations in the fabrics of the victim's shirt and pants.

Case No. 3

In an incident involving attempted rape and robbery, the victim was found tied with shoe laces around her neck. The laces were situated in such a way that whenever the victim moved, her breathing was cut off. The victim's T-shirt and shoe laces were submitted as evidence to determine whether or not they were cut, and, if cut, what object could have been used to cut them.

A determination as to whether a fabric has been cut or torn is sometimes possible with conventional methods (visual and stereo light microscopical examinations). The success of such examinations depends on the nature, construction and conditions of the separated edges of the fabric involved. Difficulties which arise in this type of examination usually are a result of one of the following factors: 1) The fibers used in the fabric (i.e., man-made and/or natural); 2) Fabric construction (woven non-woven, or knitted); 3) Dislocation of the cut ends of the yarn from their original position; 4) Multilayering of fabrics; 5) Separations consisting of an initial cut followed by a tear; 6) The details of extremely fine fiber ends are not visible at the low magnification associated with the stereo light microscope.

Cut and tear examinations of the fabrics involved in these cases using visual and stereo light microscopical methods led to no conclusive results. Thus, the scanning electron microscope (SEM) was used to study fiber end surfaces in greater detail than is possible with the light microscope. This report demonstrates that samples taken from questioned areas of clothing can be visualized and evaluated by the SEM. It also provides a set of reference scanning electron micrographs.

Materials and Methods

A JEOL Model JSM-35 CF scanning electron microscope was used for examination of the specimens. All of the standard and questioned specimens were examined using an accelerating voltage of 3kV. Polaroid® Type 52 film was used for the electron micrographs. To obtain film negatives, 102mm X 127mm Kodak® Tri-X Pan film was loaded in a cut sheet film holder which replaced the Polaroid® film holder on the SEM photographic recording system.

Samples

Fabric samples of approximately 6mm X 4mm were cut from the questioned areas of the clothing with the aid of scissors while viewing them with a stereo light microscope. Control cuts and tears were produced in the clothing for comparative purposes. All control and questioned areas were marked for identification.

Mounting of Specimens

Standard aluminum 10mm X 10mm SEM mounting stubs were cleaned with acetone and placed in a stub holder. 3M Double Stick Scotch® Tape was applied to these stubs [1]. Fabric and/or fiber samples were mounted in horizontal or vertical positions on the tape strips and labeled. The samples were placed in a vacuum oven at 60°C for approximately 30 minutes to remove moisture and volatile contaminants from the fabric.

Coating

A gold/palladium coating of approximately 14nm in thickness was applied to the mounted specimens using a Hummer-VI Sputter Coater.

Results

The scanning electron micrographs of fabric edges and yarn/fiber end surfaces revealed characteristics which would be very useful in determining whether an item of clothing was cut or torn. Uniform and smooth yarn ends are indicative of cut edges. Figure 1a of a woven cotton fabric displays these characteristics. On the other hand, elongated yarn ends, and non-uniform and disturbed edges are usually considered as torn edge characteristics. Figures 2a and 3a are of cut cotton fabric edges, which, at low magnification (as under a stereo light microscope), give the false appearance of having been produced by tearing of the fabric. This appearance may result when cut fiber ends do not retain their original position in the fabric after being cut. The fiber ends, however, have a distinct and characteristic appearance of "cut" fiber ends when examined by the SEM at sufficiently high magnification.

Cut ends of cotton fibers appear to be uneven when examined at high magnification as shown in Figures 1b, 2b and 3b by SEM. Figure 4a shows the edge surface of a torn cotton fabric at low magnification by SEM. Broken filaments and stress fracture marks along the fiber shaft as depicted in Figure 4b, are specific characteristics of torn cotton fibers when viewed by SEM. The resulting stress fracture marks and varied elongations in cotton fibers occur near the site of the break. A previous study of the fractography of cotton fibers [2] indicated that different zones of density affect the fracture morphology and cracks develop where fractures are beginning to occur. Figures 5a, 5b, 5c and 5d illustrate broken end surfaces of man-made fibers. The fractured ends of the fibers in Figure 5a barely exhibit broken end characteristics at low magnification and, therefore, may appear to have flattened ends using low magnification light microscopy. However, the fractures and blunt fibrous characteristics shown in Figure 5b and elongated broken ends in Figures 5c and 5d are characteristic of "broken" (torn) polyester fibers.

The smooth ends and striation characteristics (tool mark impressions left by the cutting instrument) at the surface ends of cut polyester fibers are shown in Figure 6. Figures 7 and 8 illustrate deliberately control "cut" fiber ends produced by a razor blade and a pair of scissors, respectively. Figures 9a and 9b are fibers from the questioned shoe lace(s) referred

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Fig. 1a - Cut edge of a woven cotton fabric.

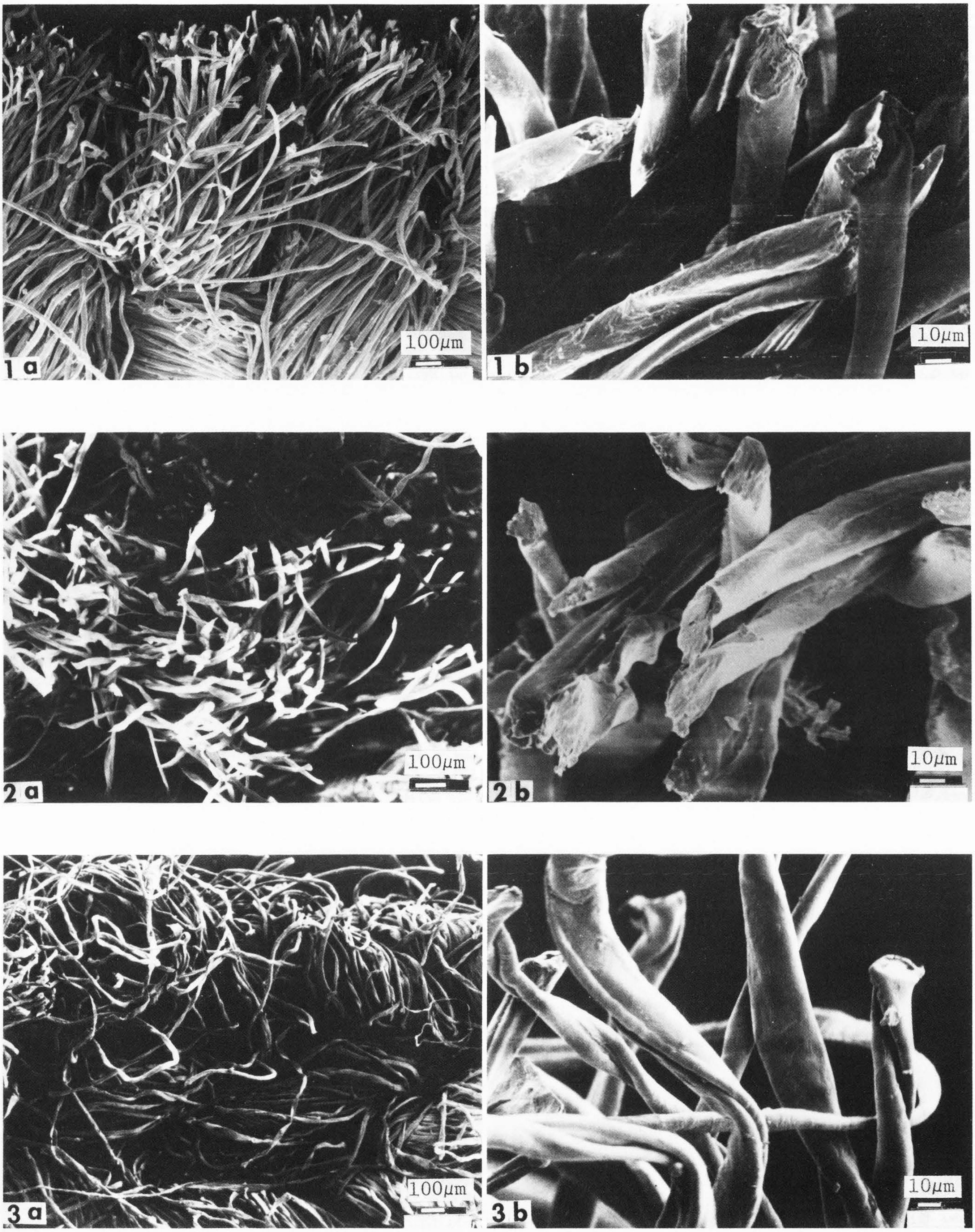
Fig. 1b - Cut end surfaces of cotton fibers shown in Figure 1a.

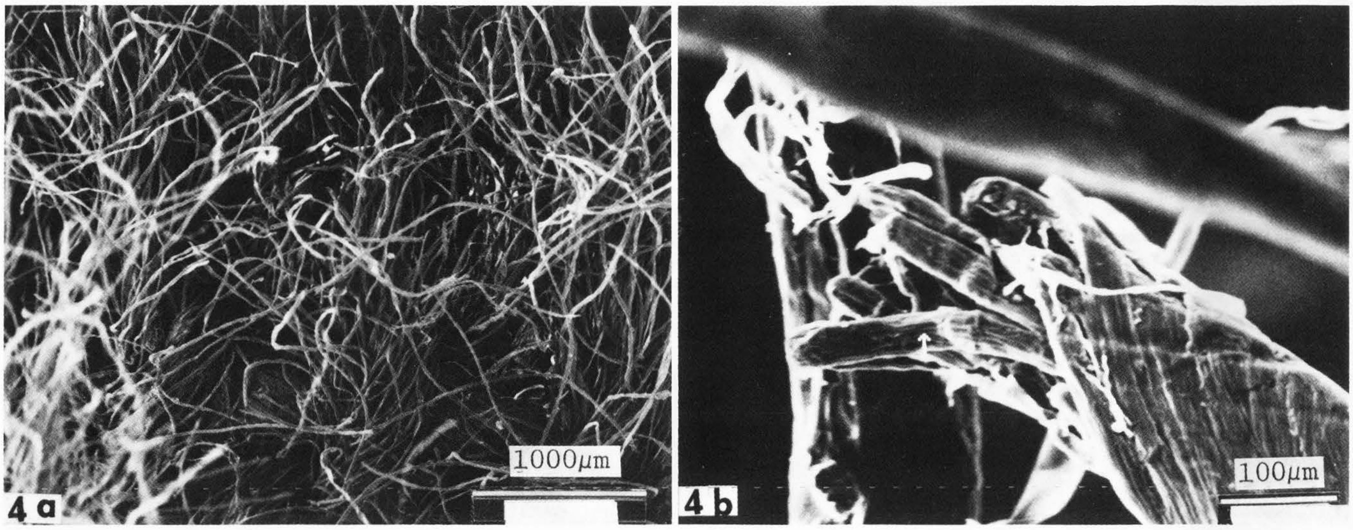
Fig. 2a - Disturbed cut edge surface of woven cotton fabric.

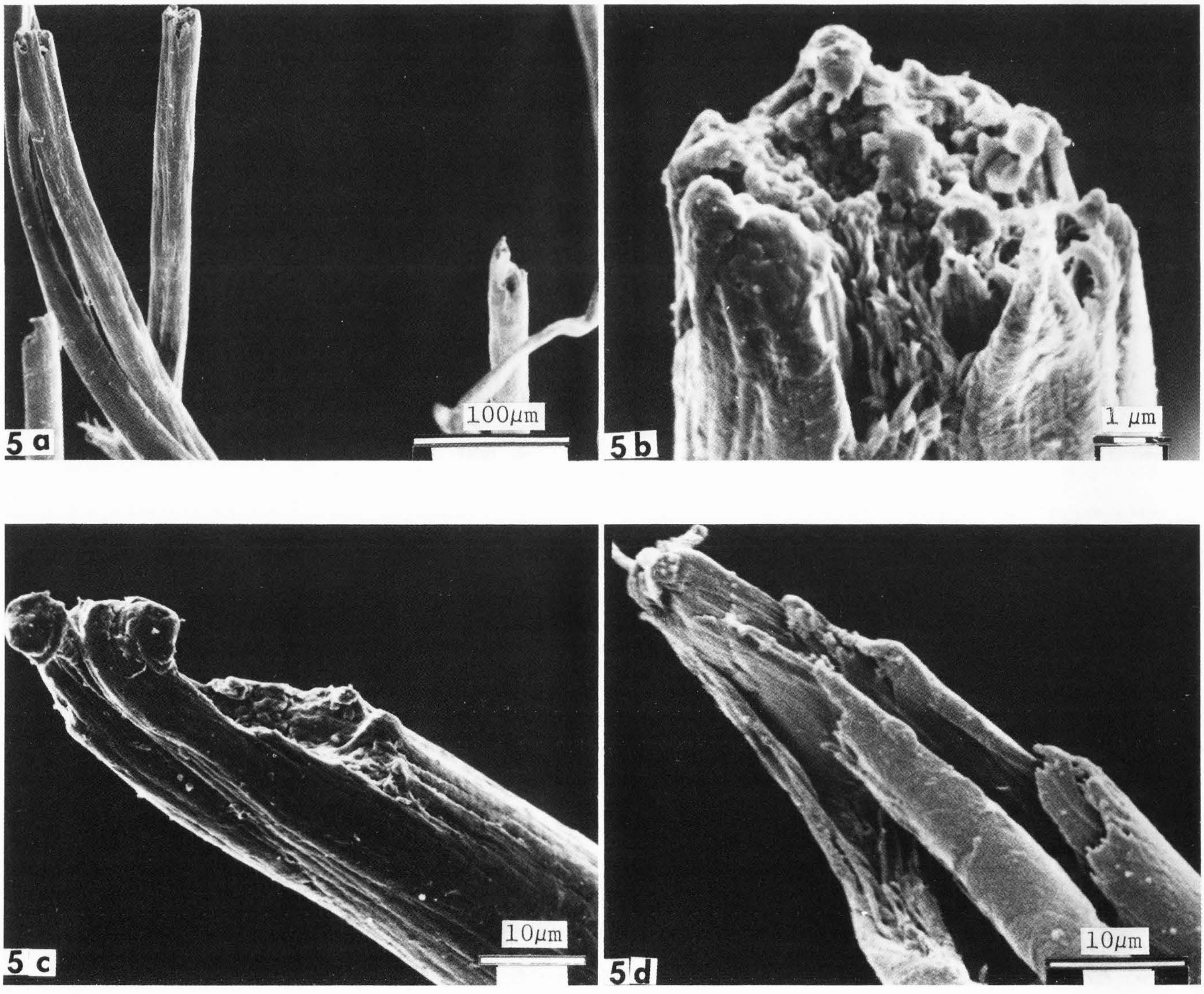
Fig. 2b - Cut end surfaces of cotton fibers shown in Figure 2a.

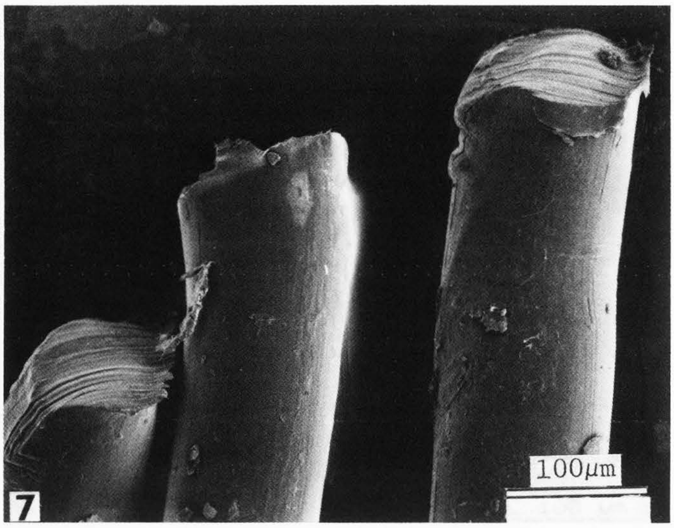
Fig. 3a - Cut edge surfaces of a knitted cotton fabric.

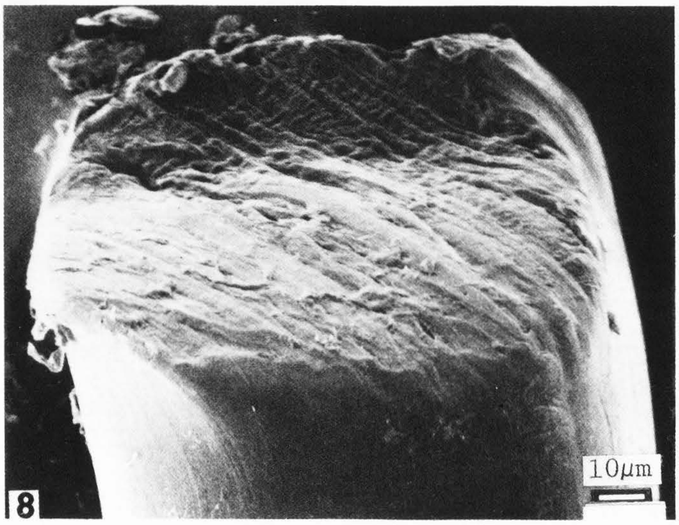
Fig. 3b - Cut end surfaces of fibers as in Figure 3a.


100μm
1 a
10μm
1 b
100μm
2 a
10μm
2 b
100μm
3 a
10μm
3 b


1000μm
4 a
100μm
4 b


100μm
5 a
1 μm
5 b
10μm
5 c
10μm
5 d





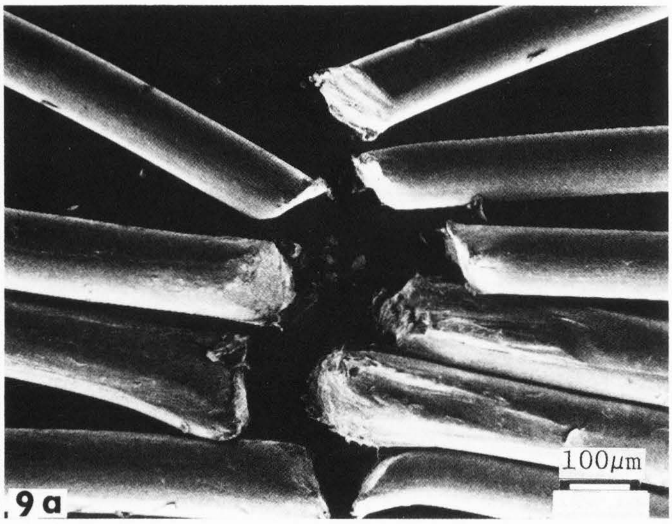


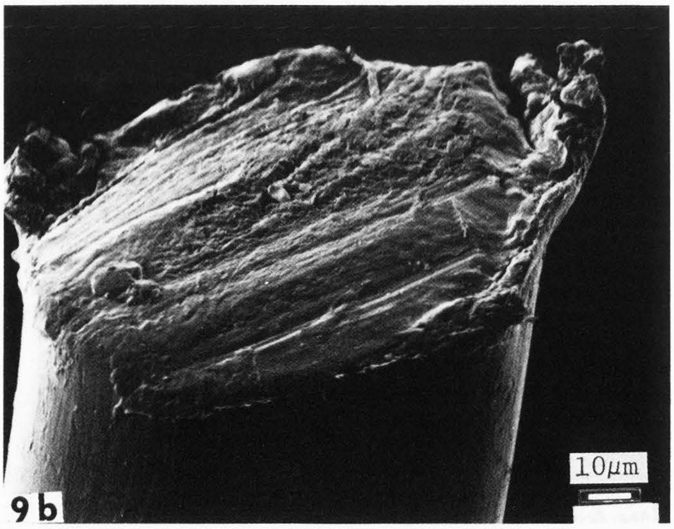
Fig. 4. (a) Torn woven cotton fabric edge illustrating uneven and scattered fibers at the edge surface. (b) Broken end surface of cotton fiber as in Fig. 4a, illustrating broken fibrous filaments and cracks in the fiber shaft.

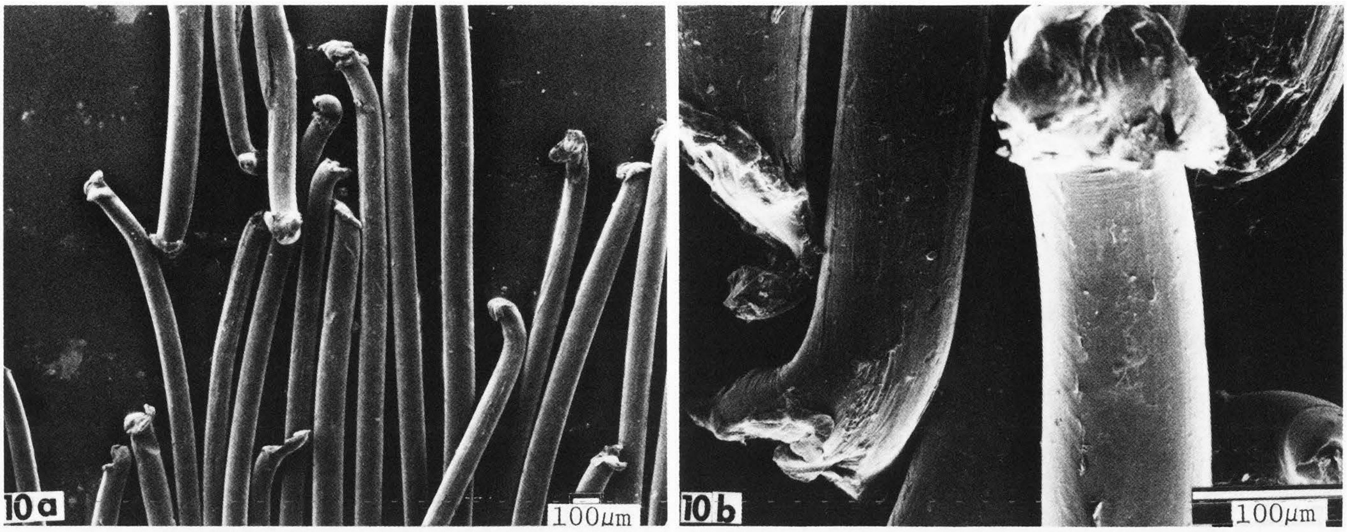
Fig. 5. Polyester fiber. Broken end surfaces (a and b); broken elongated fractured end surface (c); and broken elongated fractured end surfaces of another polyester fiber (d).

Fig. 6. Cut end surfaces of polyester fibers illustrating tool mark impressions of an unknown cutting object.

Figs. 7 and 8. Razor blade cut (7) and scissors cut (8) man-made fibers from a shoe lace.

Fig. 9a and b. Cut end surfaces of questioned man-made shoe lace fibers.





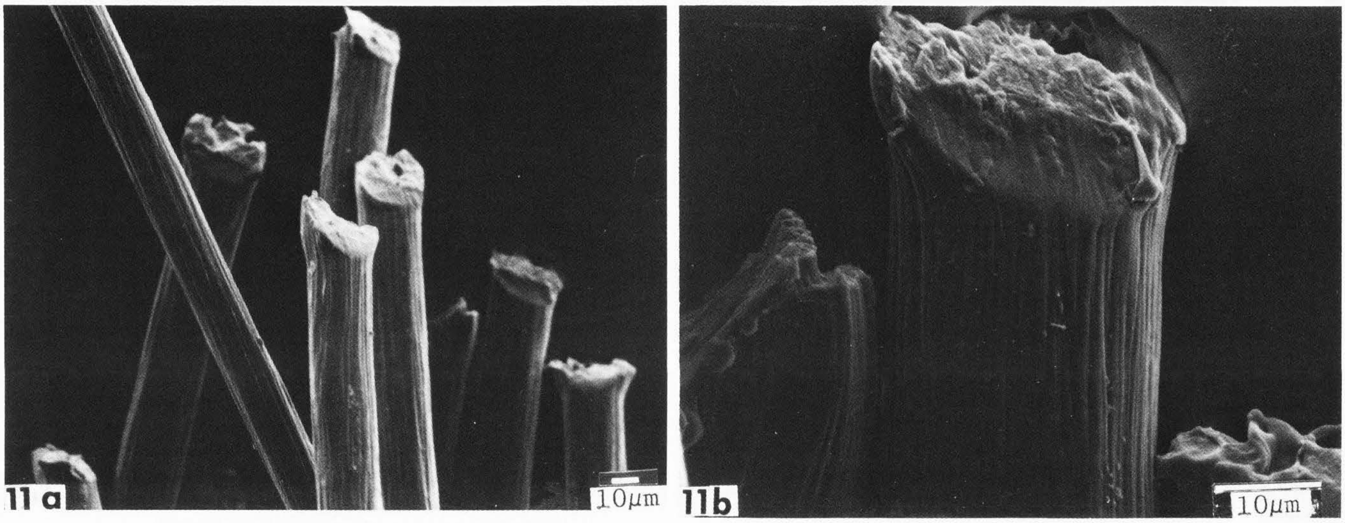


Fig. 10a - Broken end surfaces of man-made shoe lace fibers illustrating deformed surfaces.

Fig. 11a - Staple acrylic fibers showing compressed ends and irregular cut surfaces.

Fig. 10b - Broken end surfaces of man-made shoe lace fibers shown in Figure 10a.

Fig 11b - End surfaces of staple acrylic fibers shown in Figure 11a.

to in Case No. 3. Figures 10a and 10b show blunt, fractured ends of broken shoe lace fibers used as a control. Figures 11a and 11b are staple acrylic fibers at low and high magnifications, respectively, showing the compressed ends and irregular cut surfaces.

Conclusions

Examinations of the scanning electron micrographs of cut and torn fiber ends revealed that the structural changes produced varied from one generic type of fibers to another. This suggests that the fracture resulting from breaks in different fibers are not identical. On the other hand, smooth fiber ends, with or without the presence of tool mark impressions, are typical cut fiber end characteristics. The presence or absence of well defined tool marks depends upon the condition of the cutting instrument and the generic type of man-made fiber involved.

The method of examination (i.e., combination of stereo light microscopy followed by electron imaging) yields detailed information about separations in fabric, irrespective of its type, nature and conditions. The traditional policy of drawing conclusions based only on stereo light microscopical examinations is subjective and not always convincing. The proposed method of using the SEM is simple, fast, conclusive and has the capability to eliminate many of the uncertainties produced by the use of conventional techniques to differentiate cut from torn fibers. Though this method may never allow the analyst to identify a specific cutting instrument, the characteristics revealed by SEM are nevertheless of great significance in criminal cases. These characteristics can be documented by individual photomicrographs which are clearly advantageous with respect to courtroom presentation of the evidence.

Acknowledgements

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The author wishes to thank the personnel of the Photography Section of USACIL-CONUS for their assistance in photographic work.

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2. Hearle JSW, Sparrow JT. (1979). Further studies of the fractography of cotton fibers. Textile Res. J. 49, 268-282.

Discussion with Reviewers

T.G. Rochow: What is the identity of the "synthetic fibers" of Figs. 7, 8; 9a and b; 10a and b?
Author: No attempts were made to identify the generic type of the man-made shoe lace fibers at the time the examinations were conducted.

T.G. Rochow: Have you considered wool, nylon, and other relevant and common fibers?
Author: Subsequent to the preparation of the manuscript, nylon fibers involved in another case were examined for such determinations. These fibers displayed characteristics which were similar to the characteristics revealed from the man-made fibers cited in this paper. As yet, no studies have been conducted on wool or other relevant types of fibers.

H.A. Deadman: More detail should perhaps be presented regarding the control cuts and tears, especially the method of tearing.
Author: The standard approach used to facilitate the comparative examination involved:

1. Use of the item in question for test cuts and rips using an undamaged area of that item.
2. The cutting instrument found at the crime scene or recovered from the subject was utilized to make the test cuts.
3. In lieu of a suspect cutting instrument, single and double blade cutting instruments available in the laboratory were used to produce the test cuts.
4. Tearing was produced by grasping the item in both hands and pulling or a cut was initiated followed by a tear. The tearing tests were conducted in areas which were similar in construction to the questioned area.

H.A. Deadman: I disagree with the thought [that the traditional policy of drawing conclusions based on stereo light microscopical examinations is subjective and not always very successful]. I maintain that comparisons of this type, even with the SEM, always involve elements of subjectivity.
Author: It is the opinion of the author that, when using the characteristic morphological features referred to in this paper, conclusive determinations can be made in most cases provided that: (1) A sufficient number of fibers from the questioned area are examined and (2) the characteristics observed are compared with fibers from deliberately produced cut and torn fabrics (controls).

H.A. Deadman: This paper would have a stronger impact on the reader if the author were able to describe cases where the SEM examination resulted in findings different from those obtained after examinations without magnification or with low power magnification.
Author: In fact, case no. 1 was initiated when an item of evidence was examined by SEM after results from stereomicroscopic examinations were deemed inconclusive. These additional examinations (SEM) revealed that the item had in fact, been cut.

H.A. Deadman: There is little discussion of attempting to reproduce the separations in the same manner as that found in the actual items by using the same fabric and instruments, and then comparing the test separations with those in the actual items. In my opinion, this should be the standard approach to questions involving fabric damage.
Author: What you have described is the usual and standard practice in all forensic types of examinations and this method was used in these case studies.

P.A. Tucker: How much does aging and fiber degradation influence the observed morphology?
Author: I have not conducted such studies therefore, I don't have a basis for establishing age effects.

P.A. Tucker: Does an industrial, high tenacity fiber appear different than a low tenacity fiber of the same generic type?
Author: In these case studies and testing, high tenacity industrial fibers were not encountered.