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Optical differentiation between cashmere and other textile fibres by laser diffraction

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This paper reports a novel method to differentiate cashmere from synthetic fibres and even from other wool fibres with the help of laser diffraction patterns. In the diffraction pattern, only natural fibres depict additional spots above and below the actual diffraction plane. These spots can be used to distinguish different fibre materials by comparing their length-to-height aspect ratio with standard values. Especially, it can be recognized that the diffraction lines above and below the diffraction plane are significantly longer and finer for cashmere fibres than for any other wool.

Keywords: Cashmere, Fibre imitation, Fibre mislabeling, Laser diffraction pattern

The textile market nowadays offers a broad range of different fibre materials for a variety of application areas. Especially in the fashion industry, numerous techniques exist to meet the customers' requirements of qualitative and affordable garments.

For the analysis of different properties of whole fabrics, several techniques are used. Fabrics can be analyzed in terms of optical, mechanical, chemical and other parameters. While several methods touch or even destroy the sample under examination, optical methods can normally be used without alteration of the textile fibre, yarn, or fabric. Besides direct optical examination methods such as microscopy, confocal laser microscopy, or SEM (scanning electron microscopy), indirect optical methods use diffraction patterns of textile materials to get an insight in the surface structure.

For instance, Shlyakhtenko[1] proved that the bend of threads in webs can be visualized by laser diffraction. Sodomka and Komrska[2] used a laser diffraction method to determine different parameters of fine-mesh wovens. Toba[3] described a method to discriminate different weave structures and periodic effects. Mallik-Goswami and Datta[4] detected defects in fabric surfaces with a collimated laser beam. Similar approaches to extract defects of textile fabrics by image processing of diffraction patterns were made by other groups[5-10].

Another possibility to analyze textile surfaces is a method described by Shlyakhtenko *et al.*[11] by investigating the angular distribution of the fibres in a fibrous material and giving a closer insight in the surface of a semi-finished textile. A similar method is reported by Gong and Newton[12]. In comparison to synthetic fibres, natural fibres are relatively expensive in production; silk being most expensive and wool following afterwards[13].

This causes the industry to focus on a steady development to make the fibre production as cheap as possible. Therefore, the use of synthetic raw materials increases.

Due to these circumstances, the number of imitations of natural fibres has rapidly increased over the last years. In the 1990, 60 % of the textile samples examined by the German Wool Institute were mislabeled[14], while 15 % of garments claiming to contain cashmere were found to be mislabeled[15].

Several norms and standards techniques are used to distinguish between correctly labeled and imitated fibres. Most of them are time-consuming and not affordable for incoming goods departments. Using a standard light microscope is often insufficient due to the limited resolution. An SEM, on the other hand, is not always available. A confocal laser scanning microscope (CLSM), with a resolution between both these instruments, can be used very well for the identification of different fibres[16]; however, it is also quite expensive and normally not accessible for incoming goods inspections. On the other hand, burn tests, commonly used to distinguish among man-made fibres and wool, cotton, viscose, etc, cannot differentiate among cashmere and other woolmaterials[17].

Thus, attempts have been made to examine textile fibres by laser diffraction. Laser diffraction has often been used to determine the diameter of nano carbon

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fibres[18-23]. Light scattering profiles have also been used to study uniformity of different fibres along the filament[24]. Diffraction patterns, however, contain much more information.

In this study, attempts have been made to observe how a simple and inexpensive laser diffraction experiment can be used to distinguish different fibre materials, with the focus on the valuable cashmere fibres in comparison with some materials often mislabeled as cashmere.

Experimental

In order to detect the diffraction patterns of various natural and synthetic fibres, an experiment is set-up using opto-mechanical equipment by Linos (now Qioptiq Photonics GmbH & Co. KG) and a laser with green light (wavelength 532 nm, power ~ 1 mW). On contrary to lasers used to modify textile surfaces[25-27], the laser used in this project needs only low power like a common laser pointer. The set-up is depicted in Fig. 1. Fixing the laser in a mechanical mount, the laser beam is collimated by a lens (75 mm focal length) onto the fibre which is hold in a frame. The resulting diffraction pattern is visible on a white paperboard. The main diffraction plane is oriented 90° to the fibre (Fig. 1).

Fibres were extracted from several material examples, such as cotton, wool, viscose, polyester, tussah-silk, flax, mulberry silk, polyamide and polyacrylics, and glued vertically on the frame successively to examine their diffraction patterns. In our experiment, pure fibres – without coating and with natural color, i.e. white or translucent – were tested in order to set a base for future research in the form of a first-principle study. The influence of a coating or other finishing methods will be examined in a future project.

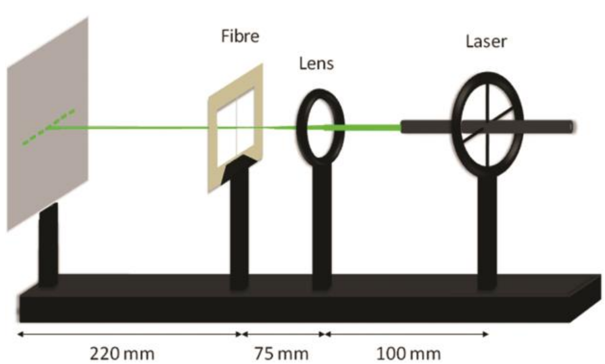

Fig. 1—Experimental set-up for diffraction pattern detection of textile fibres

For each experiment, 5 fibres of the same material were examined one after the other. Figure 2 shows typical diffraction patterns for cashmere and some fibre materials often used to mimic cashmere, defining typical fibre diameters, scale structures or cross-sections respectively. Since examination in this first-principle study is performed “by eye”, a statistical evaluation of quantitative results has to be shifted to a future project dealing with automated fibre inspection. It is well known that the fibre diameter is correlated to the inverse distance of the diffraction maxima. Thus, finer fibres will show broader maxima and broader minima between.

Results and Discussion

Figure 2 shows the diffraction patterns (left panels) and SEM pictures (right panels) of cashmere and different fibre materials which are often used to imitate cashmere garments. Below each pair of pictures, the material as well as a short description of the respective diffraction pattern is given. The linear parts of the diffraction pattern on the left and the right side of the center spot are referred to as “diffraction plane”, the areas above and below as “outside”.

It should be mentioned that all dimensions of the diffraction patterns do not only depend on the fibre diameters, as described before, but also on the distance between screen and lens as well as on the camera settings used to take the photographs. Thus, it is not convenient to give quantitative values for the lengths or widths of the diffraction spots in the diffraction plane or outside.

Comparing the diffraction patterns shown in Fig. 2, the differences among wool and synthetic fibres are evident. Wool fibres show significant spots outside the actual diffraction plane, while the diffraction patterns of synthetic fibres are clearer and mostly concentrated on the diffraction plane. They have nearly no spots or lines above and below the center line. This finding can be attributed to the micro-structure of the different fibres (respective SEM pictures). While polyester and viscose have straight, even cross-sectional forms (in case of viscose fibre used here with several fibrils, but nearly without a radius change), all wool fibres show clear scales. The surfaces of these scales are, opposite to all extruded synthetic fibres, not parallel to the fibre axes. This effect leads to the strong diffraction spots and lines outside the diffraction plane, while synthetic fibres show only diffraction spots in this plane, similar to a

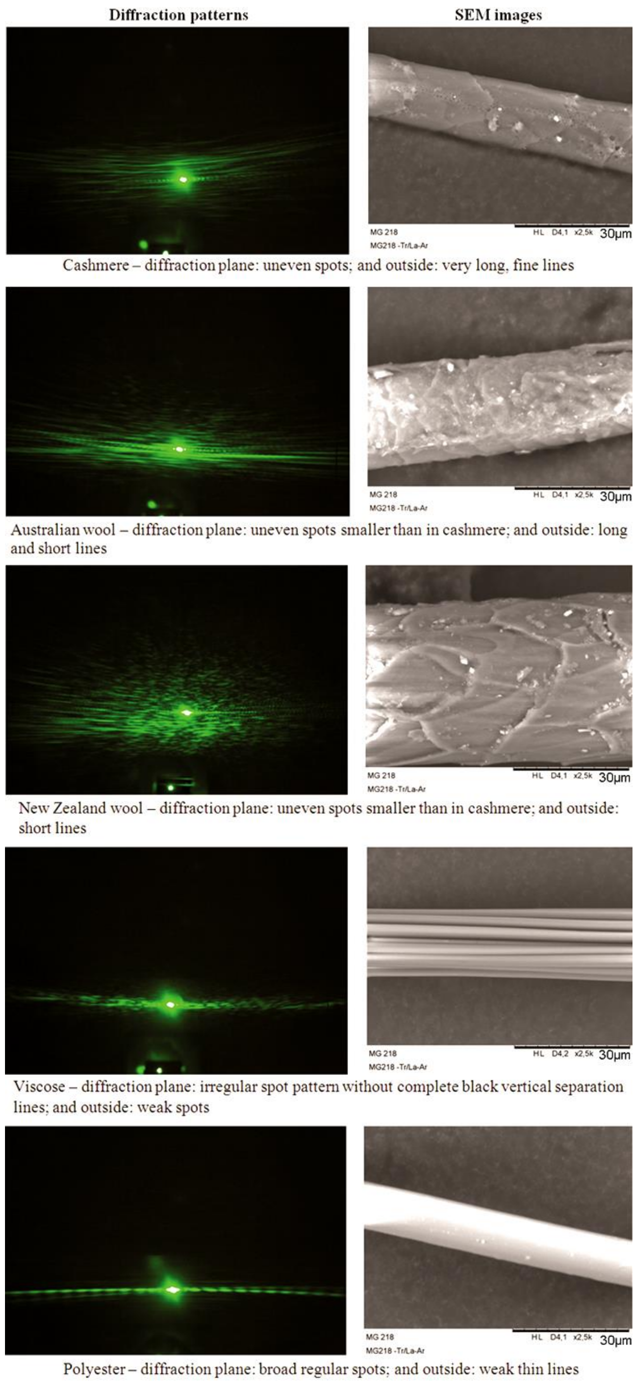

Fig. 2—Diffraction patterns and corresponding SEM pictures of different textile fibres

usual wire. Even the fibrils of the viscose fibres, which have been chosen to test the influence of such irregular cross-sections without a radius change, do not result in additional spots outside the diffraction plane. In the same way, polyester fibres with different cross-sections never show diffraction spots outside the diffraction plane (not depicted here). Different wools, however, can be distinguished from each other due to their different scale structures. Other wools, such as wool from the Texel sheep or the Mountain sheep, show still different diffraction patterns. These differences in the scale structures can be explained by acclimatization in different regions of the world.

Most importantly, cashmere fibres are clearly distinguishable from other wool materials due to their unique “bamboo-like” scale structure. These scales, surrounding the whole fibre, result in the very long lines visible above and below the center spot, while smaller scales result in shorter lines. This is opposite to the mosaic-like scales of other wool / animal hair, as shown in SEM pictures of New Zealand wool and Australian wool. New Zealand wool shows relatively short lines above and below the diffraction plane, compared to Australian wool and cashmere, and can thus easily be distinguished from the latter. However, the differentiation between Australian wool and cashmere is less trivial. Nevertheless, a comparison between the length-to-width ratio of the diffraction lines above the diffraction plane between Australian wool and cashmeres clearly shows that this aspect ratio is on average higher for cashmere, with its finer and longer diffraction lines. Numerical limits for this differentiation depend on the exact definition of the borders of the diffraction lines and will thus be defined during transfer into an automated evaluation of the diffraction patterns.

With the easy and inexpensive technique described above, cashmere fibres can be differentiated from each synthetic fibre, even from those with a non-circular cross-section, as shown here by a viscose fibre. While this would also be possible by a simple burn test, the diffraction technique even allows for differentiation from other wool fibres. For an automatic procedure, however, a large set of samples has to be tested to define exactly which criteria have to be met if a fibre shall be accepted as cashmere. Additionally, the influence of coatings or other finishing methods has to be tested in a new study. These tasks are planned for the near future, after optimizing the optical setup, to get a broader data base containing a large variety of fibre examples with their respective diffraction patterns.

Nevertheless, the previous results clearly indicate the chances of this simple new test procedure to become a helpful tool in identification of imitated fibres. This first-principle study can be used as a base to build up a tool enabling differentiation between a variety of fibre materials, while future investigations have to show further possibilities as well as limits which will necessitate combinations with other optical techniques and evaluation methods.

It should be mentioned that an indirect optical method, such as the diffraction method described here, always lacks the connection with well-known pictures, e.g. of wool scales. For the evaluation of the diffraction patterns thus either some experience or a simple tool is necessary which helps the investigator to test reliably, whether a certain diffraction pattern belongs to the claimed material or not. In this way, seeing a direct picture by an SEM is surely more comfortable. However, constructing mathematical algorithms which transfer a diffraction pattern into information about the material under examination is possible. Due to focusing the laser beam on the fibre under examination, the calculation of expected diffraction patterns is not trivial, since neither Fraunhofer nor Fresnel diffraction limits can be used here as an approximation. Thus, the development of mathematical descriptions of the diffraction patterns will be performed in a future project, based on a respective patent application[28].

A new possibility to distinguish among cashmere, other wool and synthetic fibres has been studied using an inexpensive and easy experiment based on diffraction pattern examination. While the differentiation between wool and synthetic fibres is undoubtedly possible at the first glance, different wool fibres result in similar diffraction patterns, which can nevertheless be used to detect whether the fibres under examination consist of cashmere or another kind of wool. This difference between cashmere and other materials is of utmost importance due to the high amount of mislabeled “cashmere” products.

In a future project, other fibres will be examined to ascertain which materials can also be differentiated, e.g. to determine more imitated fibres or undesired fibre modifications.

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