Abstract — A variety of fabrics are examined using near and mid-IR, Raman and THz time-domain spectroscopy. Different types of textiles are shown to have different optical properties, which may be employed for textile identification.

I. INTRODUCTION AND BACKGROUND

Along with the boom in multi-component blended fabrics, counterfeiting and adulteration of high-value textiles has been growing worldwide. Although a variety of examination methods have been employed in textile testing [1-4], the identification techniques can be improved by introducing new technology. Complex optical spectroscopy can provide a means of reliable, rapid, nondestructive and noncontact testing for fabric identification and condition, as well as for combating fraud. Near-IR (NIR) and mid-IR (MIR) spectroscopy has gained increased attention for the qualitative and quantitative evaluation of textile and polymer products due to the possibility of obtaining well resolved spectral structures. Great attention has been paid recently to far-IR (THz) spectroscopy of fabrics that often demonstrated scattering properties rather than specific absorption spectra [4]. Raman spectroscopy can provide molecular structure information to complement infrared analysis of molecular identifications. In contrast to IR, it often permits any shape or form of samples with no sample preparation. Besides, it can examine samples through plastic packaging or in glass containers with no interference and is insensitive to water: spectra can be obtained even from aqueous samples. Nevertheless, it has not been widely applied to most plant-based (e.g., cloth fiber, paper, and leaves), bio-based (e.g., tissues, blood, and serum), and synthetic materials (e.g., ink, color dyes, and explosives) mainly because most “real-world” samples are vivid in color. Dyes, when illuminated by light, produce background emission (fluorescence) thousands of times stronger than Raman scattering, overwhelming the Raman signal that carries chemical-specific information. Applying infrared (near-, mid- and far-IR) and Raman spectroscopy, coupled with differential scanning calorimetry (DSC), to raw compounds and fabrics can reveal more information for identification and anti-counterfeiting.

A range of fabrics composed of different natural and artificial fibers were tested. Near- and mid-IR, Raman and THz time-domain spectroscopy together with DSC analysis were used to obtain the absorption and scattering spectra or/refractive indices between 2 and 800 μm. Spectral signatures of the fabrics were correlated with their fiber compositions, structures and geometric parameters.

II. RESULTS

Powdered (1) and granulated (2) material of two synthetic threads was first analyzed by DSC (Fig.1) with a Netzsch DSC 204 F1 Phoenix Differential Scanning Calorimeter to confirm single compound composition.

Fig.1 confirms single compound composition of each of the two synthetic threads that were further studied by Raman spectroscopy with Thermo Scientific Nicolet NXR 9650 FT-Raman spectrometer: excitation at 1064 nm with a 2.5 W Nd:YVO4 laser, spectral range 100-3500 cm⁻¹, spectral resolution ≤ 0.8 cm⁻¹ (Fig.2).

In Fig.2 it is seen that the recorded Raman spectrum is well in coincidence with that of polycaprolactan (Nylon 6). This approach may therefore reveal the presence of Nylon 6 admixture in fabrics composed mainly of natural fibers. Fig.3 presents Raman spectra of selected wool fabrics, showing common spectral features, i.e. the same synthetic thread.
admixture but in different proportions.

Successful detection of Raman spectra in these fabrics is due to the 1064 μm pump laser which significantly reduces dye fluorescence, scattering and heating effects.

Examples of well resolved MIR absorption spectra for selected fabrics are presented in Fig.4, recorded in the transmittance mode using an FT-IR Spectrometer Thermo Scientific Nicolet 6700 with a XT-KBr™ beam splitter that can cover a range of 375-11000 cm⁻¹ with a spectral resolution of 0.09 cm⁻¹ and installation accuracy of 0.01 cm⁻¹.

In Fig.4 the fabrics studied are made of natural fibers: fabric 1 (S3) is 100% linen, whilst fabric 2 (S7W) is 100% merino wool. In the case of mixed synthetic fabrics, complicated and clearly resolved spectra in the main part of MIR were observed.

THz transmission spectra were measured for single- and multilayer fabrics to estimate the contribution of scattering effect (Fig.5). THz-TDS data varies depending on the orientation of fabric structure relative to the THz polarization. In Fig.5 it is seen that scattering is the dominant effect in the formation of spectral features of recorded THz spectra.

Different raw fleeces were also studied (Fig.6). A clear dependence of the attenuation coefficient on the fleece hair thickness can be found. Absorptivity of wool hairs appears to be very high, producing almost totally absorbing spectral bands, so that the resulting spectrum is usually extremely difficult to interpret. It can be proposed that hairs, as well as some other natural fibers, need to be preprocessed for THz spectroscopy.

Other fabrics investigated in this study were several types of cotton, linen, silk and wool, as well as nylon, rayon, acrylic and multi-component blended fabrics. There are clear differences in the NIR, MIR absorption, and Raman spectra of studied fabrics. Therefore, we suggest that NIR, MIR, and Raman spectroscopy, in combination with appropriate differential scanning calorimetric data, and with THz data after pre-processing, could be an effective technique to identify reliably fibers and their mixtures.

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REFERENCES


