Application of IR Spectroscopy in Textiles: A Review

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Abstract
The infrared (IR) is a suitable technique for the identification of substances present in textile products. Near Infrared, Attenuated Total Reflection Infrared (ATR) and Fourier Transform Infrared (FTIR) are used for identification of textile materials. These techniques are used with significant accuracy. Non-invasive fibres are also suitable for identification using these techniques. A library produced after thorough investigation of the compounds present in textile products can be useful for further research as references. A wide variety of impurities are mixed with cotton during cultivation and processing in industries. These impurities are easily identified by the IR spectrum. Important parameter micronaire value of cotton can be measured by the IR spectroscopic technique. Natural dyes can be identified by using Infrared spectroscopy.

Keywords: IR, Identification, Fibre, Compounds, Natural Dyes, Textiles.

1. Introduction
Infrared (IR) spectroscopy is defined as one kind of measurement of interaction. Here interaction includes IR radiation and matter by several methods such as absorption along with reflection/emission [1]. This technique is widely used for identifications of various functional groups of chemical substances in all common states, solid, liquid even in gaseous form. Generally, different functional groups show peaks in air spectrum in their corresponding frequencies. A list of frequencies of corresponding frequencies in IR Spectrum is given in Table 1 [2-3].

The IR spectrum is recorded by the IR spectrophotometers [1]. An IR spectrum is a graph consisting of absorbance or transmittance (%) *vs.* frequency (cm^{-1}). The Fourier Transform infrared (FTIR) instrument is commonly used to record IR spectrum in different fields of research laboratories for various purposes such as identification of newly synthesized textile materials, organic compounds or drugs. The infrared part of spectrum of electromagnetic radiation can be divided into three parts as near-IR, mid-IR and far-IR. The region 14000-4000 cm^{-1} belongs to near-infra red and it excites molecular vibrations. Functional groups present in newly synthesized compounds are commonly identified in the region 4000-400 cm^{-1} which is called mid-infrared. This region is used to study the structure of the compound using fundamental vibrations. On the other hand the region 400-10 cm^{-1} is considered as far-infrared which is to study mainly rotational spectroscopy. A comprehensive

Table 1. IR frequencies of different functional groups in chemical substances.

Sl.	Functional group	IR frequency (Wave number, cm^{-1})
1	C-H aliphatic (stretching)	2950-2840
2	CH aromatic (stretching)	3100-3000
3	O-H	3700-3100
4	C=O	1750-1720
5	C-O	1150-1050
6	C=S	1225-1025
7	P=O	1300
8	P=S	824
9	C≡N	2250
10	N-O	1560-1515 and 1385-1345

literature survey has been done on the application of IR spectroscopy in Textiles and is discussed in this review article.

2. Discussion

Peets et al. reported a possible option for identification of textile fibre [4]. This remarkable method is FT-IR belonging to reflectance property. In the reported work, author explained that this spectroscopy was suitable for a class of textile fibre which is non-invasive in nature. Non-invasive fibres are those fibres which do not show any tendency to spread. Authors used 61 single component samples for recording FT-IR spectra. After multiple experiments, authors recorded 4000 FT-IR spectra individually which was significant quantity of spectra for conclusion based on finding. Two types of instrumental techniques were used in this study. Those were "ATR-FT-IR" and "m-ATR-FT-IR". Both the advantages and disadvantages of zthese techniques were discussed. Authors have done an analytical technique named, "discriminant" method based on the principal constituent.

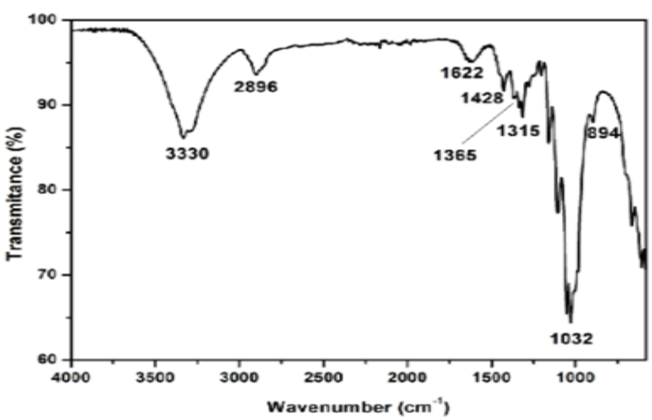

Figure 1. IR spectrum of cotton fibre.

They also used classification method belonging to random forest method for the proper identification of fibres. As per their finding, it could be mentioned that r-FT-IR was more effective comparing between ATR-FT-IR for differentiation between various fibres such as silk, polyamide etc. Authors mentioned a limitation of reflectance spectra (r-FT-IR). This technique is applicable only to study the surface of the sample. As a result, surface contamination creates problem to get an actual result. In this case, ATR-FT-IR is the suitable option to resolve surface contamination problem.

In an another report, Wang and coworkers reported that the properties of yarn and fibre depend on the derivatives' performance of fibres because these are raw materials of textile products [5]. Identification of structures is essential to analyze raw materials of textiles. Authors reported findings of several common natural and man-made fibres such as cotton, polyester, wool etc. Near-IR technique was applied because of its superiorities in fibre identification. Moreover, this technique is very effective to achieve precise differences between different compositions and this technique is also capable of studying the morphology of the fibre. Authors reported spectral library of different fibres for rapid identification of corresponding fibre sample considering the reported spectra as a reference. Authors also used class analogy and modeling for characterization of textile fibres. As per findings of the paper, it can be stated that, a combination of principal component analysis and soft independent modeling of class analogy achieved full recognition rate in some cases but they got anomaly in case of some natural fibre such as wool where achievement of recognition rate was low. But achievement of accuracy was significant in cast of wool fibre using n-infrared spectroscopy. It indicates the superiority of IR technique to identify textile fibre rather than other conventional techniques.

Raditoiu et al. reported their findings in a scientific conference regarding the application of FT-IR in characterization of textile heritage products. Authors presented their finding & clearly that combination of FT-IR and ATR was applied on historical fibres for successful results.[6] Authors explained that they analyzed pillowcase which was found from a historical zone named Moldavia. One of the advantages of this technique is that it requires a small amount to prepare sample. The relic is made of two types of materials, those are both of colored and supporting fibers. Wool and flax along with hemp are conventionally used for such historical textile products. It was observed that wool was characterized easily using FTIR spectroscopic technique because of its intense peak in spectrum.

Some impurities are found in cotton fibre. These impurities need to be identified. IR spectroscopy is a good technique for identification of these impurities. Zhang et al. reviewed application of n-IR for this purpose [7]. Authors stated that, n-IR is a modern technique to analyze impurities present in cotton. Impurities of cotton hampers for production of quality textile products. The sources of contamination of cotton by impurities are harvesting and processing after harvesting. Authors also mentioned that n-IR was used in both of laboratory and field measurements.

Yang et al. reported analysis of the degradation of textile products using FT-IR spectroscopy with photoacoustic method [8]. Photoacoustic is a method which belongs to making waves of sound by absorption of radiation on a sample. This technique is applied to study degradation of textile products by oxidation. Authors explained that this technique is applicable to differentiate between near surface and bulk of textile products. This IR technique is applicable as an analytical technique for qualitative estimation. It does not produce band distortion.

Liu et al. reported use of n-IR in micronaire measurement of cotton fibre [9]. Micronaire value is applied to estimate maturity as well as fineness of cotton. It is determined in the laboratory by sophisticated instrument with HVITM system. Combine method of near infrared (NIR) and calibration model is a better method to determine the above parameter of cotton. Authors mentioned that, more than 97% accuracy can be achieved with ± 3 standard deviation.

Application of IR spectroscopy can play a vital role to elucidate structures of newly synthesized natural dyes isolated from natural products. Babatunde reported IR spectroscopic analysis of natural product isolated from a perpetual plant Sorghum bicolour.[10] Authors mentioned significantly that attractive parts of natural plants such as leaves or flowers produce variety of colors. Dyes extracted from natural products are eco-friendly because those are not hazardous but biodegradable. Authors reported that they investigated different dyeing parameters such as dyeing quality using mordant, required temperature and pH. Authors confirmed the existence of different groups and linkage such as C=C, OH and C=O by FT-IR in extracted natural product from the above mentioned plant.

3. Gap Analysis and Recommendations

Further works are necessary to develop the structural development works by IR spectroscopy in textiles. As per literature survey some gaps are found. Most of the research works are done by IR spectroscopic technique related to characterization of components and impurities in fbre. A limited number of works have been reported to study dyeing performances of dyed fabrics. Based on these gaps following recommendations have been proposed for future development in this area.

(a) Eco-friendlier synthetic dyes should be synthesized which would be relatively less harmful for environment. Most of the synthetic dyes are synthesized from petrochemicals so those are harmful for environment. More regenerated fibres need to synthesize from naturally occurring cellulosic fibre. These fibres should be characterized by IR spectroscopy.

(b) There are many natural sources available for isolation of natural dyes. Though some research works have been published in literature but these are not enough. More works are required to be done to isolate and identification by IR spectroscopy.

(c) There is a scope to use IR spectroscopy to identify harmful components in wastewater generated after textile processing. This technique could be applied on effluent before and after treatment in ETPs. IR spectroscopy is helpful to estimate pollution load of harmful matters present in wastewater.

(d) Nationwide sustainable projects should be implemented based on IR application in textiles.

4. Conclusion

The application of IR spectroscopy is significant for the identification of components in textiles. This technique is applicable in different purposes in textile sector. This technique is unique for identification of functional groups present in textile materials. From the above discussion of this article it is observed that IR spectroscopic technique is used to characterize functional groups in cotton and man-made fibres to measure micronaire in cotton fabric, to identify natural products etc.

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