# Identification of Fabric Fibers and Their Blending Ratio by Terahertz Spectroscopy

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***Abstract*—Absorption spectra of cellulosic fibers in THz region show discriminative absorptions which are derived from crystallized cellulose, when we prepare the samples by cutting at a length of about 0.1-0.2 mm. The blending ratio of two different kinds of fibers has been examined by using this method, and the spectra were analyzed by an analysis of principal component as a multiple classification analysis after the first derivation of the spectra. The result means the blending ratio can be identified with considerable accuracy at a few percent of reliability.**

## I. INTRODUCTION

The adulteration of fabric fibers for regenerated fibers and mammalian fibers has now become common and is one of the latest mislabeling problems that confronts the textile industry. For an assay certificate, surface structures of the fibers are currently observed under a microscope by experts, in addition to the tests of physical and chemical characterization. However, the process is very labor-intensive and not fully reliable because some types of fibers which look similar to each other. In this study, we demonstrated THz spectroscopy for identifying several types of fabric fibers and their blending ratio by the use of original process of sample preparation.

Generally, fiber is uniform in a length direction and the structure is radially-oriented. Before this study, fibers were grinded into particle at 77 K with a mixer mill to prevent thermal alteration during the process for THz spectroscopy [1]. However, it was found that the process of grind at 77K is not suitable to analyze a crystal structure, intermolecular link, or higher-order structure in the fibers by our research.

In this study, a fiber of the sample was cut at constant length by a microtome at room temperature instead of grind process at 77 K. As a test portion for THz spectroscopy, each sample which was cut homogeneously was mixed with fine polyethylene, and was pressed to form pellets containing 6.0 wt% of the sample [2].

## II. RESULTS

As a comparative study for the sample preparation, we chose fiber of cotton, since the dominant component is crystallized cellulose in a monoclinic system containing several polymorphs. THz spectra of cotton depending on the sample preparation are shown in Fig. 1. The spectra in THz region show discriminative absorptions which are derived from crystallized cellulose "cellulose I", and the intensity depends on the preparation methods or the size of cutting strongly. As for the grinded sample, the fibers were milled into particle about 100 μm size under the condition of process for 3 min at 77 K. In Fig. 1, "grinded (3 times)" means the sample prepared by 3 times repetition of the grinded process, which induced a fatal damage because the discriminative absorption peaks were almost disappeared. On the other hand, the samples of cutting were prepared at 0.1, 0.2, and 0.4 mm, respectively. From the results, the samples of cutting are suitable than the one of grinded, since the spectra are sharp distinctly. In addition, the size of cutting may be suitable for 0.1-0.2 mm length. Then, we employed 0.2 mm of cutting for the examination of fabric fibers by THz spectroscopy.

The blending ratio of components of cotton and Lyocell processed "Tencel" as regenerated cellulose fiber has been examined at 10% intervals as shown in Fig. 2.

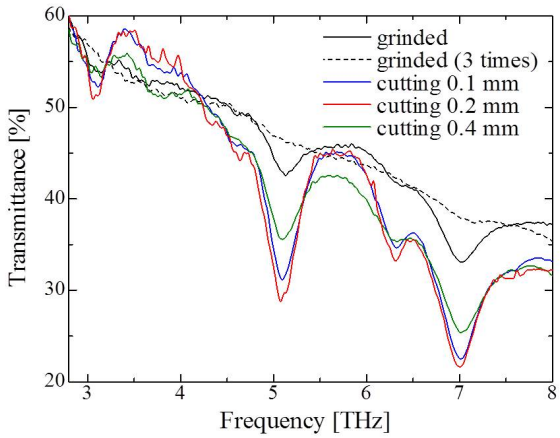


Fig. 1. THz spectra of cotton prepared with a different method, grinded and cutting samples in different length. The range from 4.5 to 5.5 THz correspond to the absorption of "cellulose I", and the range from 3.5 to 4.5 THz correspons to "cellulose II", respectively.

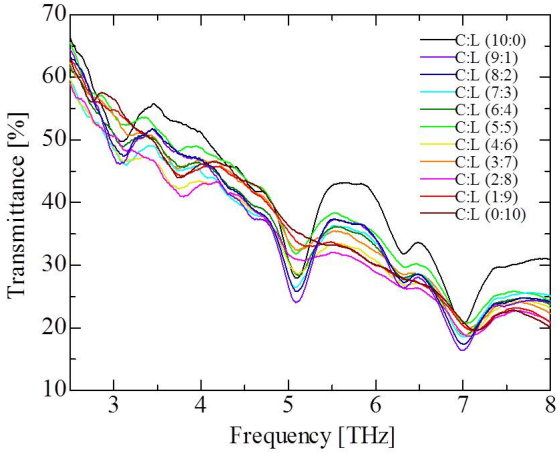


Fig. 2. THz spectra of blending components of cotton (C) and Lyocell (L) at 10% intervals of the ratio by using 0.2 mm cutting samples.

The spectra obtained in Fig. 2 were processed by an analysis of principal component as multiple classification analysis after the first derivation of the spectra for the purpose of quantitative assay of the blending ratio.

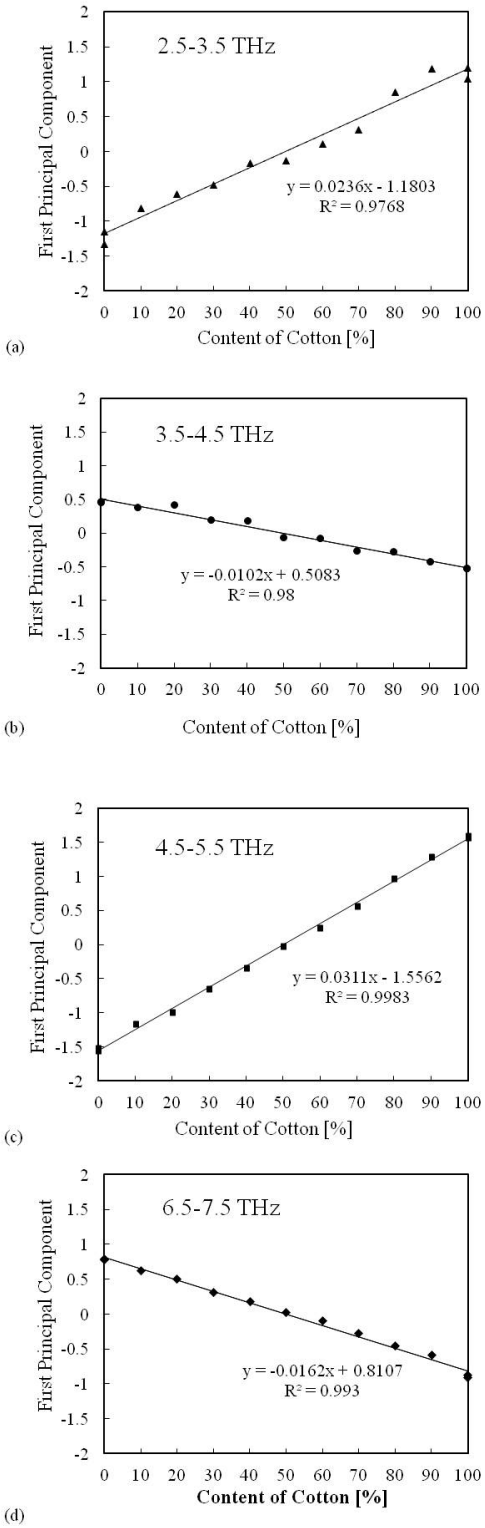


Fig. 3 The first principal components of the first derivation of the spectra of blending components shown in Fig. 2 in percent of cotton, the range from 2.5 to 3.5 THz (a), from 3.5 to 4.5 THz (b), from 4.5 to 5.5 THz (c), and from 6.5 to 7.5 THz (d),

The results of the spectra-analysis of blending cotton and Lyocell are shown in Fig. 3. The first principal components of the derivative spectra depending on the content of cotton in percent are shown. When the spectral ranges are selected from 2.5 to 3.5 THz as shown in (a), and from 4.5 to 5.5 THz as shown in (c), the gradient of the graph is positive with good linearity, respectively. These spectral regions may correspond to "cellulose I" absorption, which is dominant component of cotton fiber as crystallographic structure of cellulose, then, we considered that the first principal components of the two spectral regions were proportional to the content of cotton.

On the other hand, the ranges from 3.5 to 4.5 THz as shown in (b), and from 6.5 to 7.5 THz as shown in (d) lead to a negative gradient with good linearity for the content of cotton, respectively. These spectral regions may correspond to the absorption of "cellulose II" which is derived from regenerated process of cellulose. Therefore, the first principal components of the two regions showed negative gradient with linearity for the content of cotton, or the components were proportional to the content of Lyocell. When we chose the frequency range adequately as shown in Fig. 3, the coefficient of determination, $R^2$ was as high as 0.98, and someone was higher than 0.99 as indicated in the figure. This fact shows the analysis of principal component of these spectra has been performed at high-reliability.

Furthermore, this method has also been applied to examine the blending ratio of regenerated cellulose fibers for viscose processed rayon (Modal) and cuprammonium processed rayon (Cupra) in a similar analytical accuracy, as will be shown in other paper.

## III. Summary

We demonstrated the method for an identification of fabric fibers and their blending ratio by THz spectroscopy. The first priority was the preparation of samples by cutting at a length of about 0.1-0.2 mm to achieve a sensitive spectroscopy of high-order structure of fibers such as crystallographic structure of cellulose. The next was the spectral analysis by multiple classification analysis after the first derivation of the spectra for the purpose of quantitative assay of the blending ratio.

We consider that this method enables to analyze the blending ratio of fabric fibers with considerable accuracy, even when the constituent materials are not distinguishable by traditional analytical method, since we can measure the degree of crystallographic structure of the species, or the inter-species differences of the materials.

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## REFERENCES

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