Non-destructive detection of drugs using scattering of terahertz waves and spectral fingerprints

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Abstract: In this paper, we show that the non-destructive detection of chemicals hidden in envelopes can be achieved using terahertz radiation in a simple two-step procedure: First, scattering of the terahertz waves is an indicator of the presence of powders in the envelope; second, the identification of the chemicals is done by spectral fingerprinting.

Keywords: Terahertz-wave, Spectroscopy, Non-destructive, Scattering

1. INTRODUCTION

At present, there is no technique available for non-destructive inspection of illicit drugs hidden in mail envelopes. Therefore, such mail can be easily sent over the international borders or through the domestic post [1]. In most countries, the law forbids opening the correspondence without a search warrant. Current methods of mail screening in Japan and elsewhere typically use X-ray scanners or trained dogs, or swiping its outside with a chemical trace detection system. However, the ability of X-ray scanners is limited to visualizing the shape of a plastic bag and the presence of a tablet or organic substance, but not the type of the drug, which would provide sufficient grounds for opening the envelope for examination. Trace and canine detection can only be effective if there are detectable signs outside the envelope, such as a scent or trace amounts of the concealed drug.

On the other hand, development of detection systems is also underway in the range of millimeter waves, but the lack of fingerprint spectra in this region makes it difficult to identify the types of drug. In infrared, where chemical fingerprint spectra do exist, the high degree of absorption and scattering in paper prevents an accurate measurement. In contrast, the THz wave is suitable for drug detection purposes, being able to screen the contents of envelopes and our results have proven the existence of fingerprint spectra peculiar to illicit drugs in the THz region.

We demonstrate the drug detection method using a Terahertz Parametric Oscillator (TPO) as source [2], as well as an FTIR spectrometer. The method consists of two steps: At first, scattering of the terahertz waves is an indicator of the presence of powders in the envelope by using the TPO source; second, the identification of the chemicals is done by spectral fingerprinting using the FTIR.

2. EXPERIMENTAL

A schematic of the system we set up for measuring the scattered component of the terahertz waves is shown in Fig. 1. The terahertz wave emerging from the TPO is divergent. Therefore, we collimated it with a cylindrical...
lens, after which the beam is focused with a TPX lens and directed to the sample with 20 degrees to the sample surface. If fine particles are enclosed in the envelopes, then the terahertz waves are scattered various directions. Some of scattered component will follow an optical path like shown by the strength color in Fig. 1 and is detected by a Si bolometer. On the other hand, direct component shown as a subtle color is not detected. As sample, we used crystalline fructose of various grain size ranges: 32–38 μm, 212–250 μm, 500–600 μm. First, the scattered intensity \( I_0 \) was measured without particle (envelope only) and taken as a reference for measuring the samples \( I \). The scattering degree is quantitatively described by defining the parameter \( S \) as the ratio \( S = I/I_0 \). When powder is not contained in the envelope, \( S \) is close to 1.

Figure 2 shows the scattering intensity of fructose powder hidden in an envelope, measured at 160-240 μm (1.2 - 1.9 THz). When the powder is placed in the envelope, the parameter \( S \) increases from 5 to 25 times, showing a large effect due to scattering, and allowing us to determine whether fine particles are hidden in the envelope.

3. FTIR SPECTRA

We measured the terahertz absorption spectra of about twenty kinds of illicit drugs by using FTIR. These include: methamphetamine HCl, cocaine HCl, MDMA, 2C-B HCl. All the illicit drugs that we measured have distinctive spectra with several absorption peaks in the measurement range (100 cm\(^{-1}\) ~ 30 cm\(^{-1}\)). Figure 3 shows the terahertz absorption spectra of some well-known illicit drugs. Figure 4 shows the terahertz absorption spectra of cocaine HCl (20 mg) and usual envelope. The substrate was placed in a small 15x15 mm polyethylene bag. The bag was then placed inside a usual air-mail envelope. The spectrum \( I_0 \) of the envelope was first measured and used as a reference for measuring the spectrum \( I/I_0 \) of the cocaine HCl placed in envelope. The terahertz absorption without cocaine HCl shows a weak absorption. Above 100 cm\(^{-1}\) paper becomes very absorptive. Two absorption peaks can be seen in the cocaine HCl spectra, at 51 cm\(^{-1}\) and 70 cm\(^{-1}\). Placing the cocaine HCl in an envelope has no visible influence on its absorption spectrum. Therefore, it can be concluded that the identification of substances hidden in envelopes is possible.

4. CONCLUSION

In this research, the non-destructive inspection of the prohibited chemicals in the mail was proposed by using terahertz waves, and the verification experiments were conducted to confirm the principle of the method. Since many chemicals that can pose specific threats are manipulated in the form of fine particles, it can be assumed that the detection method that we proposed will be effective. The two-step method, consisting in a preliminary confirmation of the existence of a scattering medium in the envelope, followed by the identification by FTIR, was demonstrated to allow the detection of substances hidden in mail. Our plan is to try the application of the diffused reflection technique in terahertz spectroscopic imaging.

REFERENCES