Research on three fierce exploders' reflected terahertz spectrum

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Abstract—**The rapid development of the Terahertz technology has been the essential focus among all application fields. In order to applying the spectral technology to the security and analyzing all exploders' spectrum characteristics, the paper aims to three exploders' spectrums researches including the HNS, DNMT and DNAN. The three reflected spectrums are tested and analyzed, using the most advanced portable terahertz spectrometer, and the absorption peaks among 0.1~2.5THz are determined successfully.**

Keywords-Terahertz Spectrum, Spectral Technology, HNS, DNMT, DNAN

1. Introduction

The rotational level and the vibrational level of the most explosives' elemental molecules are in the terahertz frequency band. The terahertz wave has the fingerprint spectrum characteristics

For these given explosives, combining with the high penetrability and the low energy, the wave in the specific frequency band has an essential application value in the security check [1]. During several years' development, the research on the terahertz has been in the impending phase, especially the terahertz spectrum technology had been in the application. At present, the scientists in the University of Pécs declare they has found out a new approach which could generate ultrashort and high-power terahertz wave, and the possibility that the electric value of the pulse can be at 100 is existed. Thus in the near future, the terahertz security detector is believed to be used to provide the comprehensive security for people's life [2].

The difficulties in researching the terahertz spectrums of the explosives always are the hard materials drawing and the hard peak analysis. Especially the research on the military high explosives has a certain risk, which makes these explosives' terahertz spectrums are rare. The important application of the terahertz technology in the security and the defense domain make the approach on identifying the high explosives had more attention. This paper covers three military high explosives' spectrums measurement using the MINI-Z terahertz spectrograph. Considering the risk in measuring, the powder is tested directly and the absorbing peaks with the explosives in 0.1~2.5THz are analyzed.

2. Terahertz spectrum system

2.1 Measuring principle

The terahertz time-domain spectrum technology is the most developed terahertz technology, which has been in application. In the 1980s, T. J. Watson in IBM and other scientists in the A T&T Bell library developed a Coherent continuous detection technology, which named terahertz time-domain spectrum technology (THz-TDS) that could identify several materials' chemical properties by comparing the reference wave with the signal wave in terahertz band [1]. At present the technology has been widely applied in several important filed including physics, chemistry, biology, medicine, optoelectronics, communication, astronomy and other interdisciplinary subject [3-6].

The measured reference wave and the transmitted sample wave are transformed respectively as the frequency spectrum with the FFT, which are $A_r(\omega)\cdot e^{-j\phi_r(\omega)}$ and $A_s(\omega)\cdot e^{-j\phi_s(\omega)}$. A_r and A_s are the amplitude, $\phi_s(\omega)$ and $\phi_r(\omega)$ are phase. In, the samples' spectrum information is got from the compare with the two signals in transmitted spectrums:

$$\alpha = \frac{1}{d}\ln\frac{A_r}{A_s} \tag{2.1}$$

$$n = 1 + \frac{[\phi_s(\omega) - \phi_r(\omega)]c}{d\omega} \tag{2.2}$$

$$\kappa = \ln[\frac{4n}{(1+n^2)} \cdot \frac{A_r}{A_s}]\frac{c}{\omega d} \qquad (2.3)$$

α is absorption coefficient, d is the thickness, n is the refractive index, ω is angular frequency, c is the speed of light in vacuum, κ is extinction coefficient.

In measuring, two different thickness samples are the reference and the implement to avoid the Fresnel reflection loss. The terahertz wave uses in the spectrum measurement is expressed as the linear superposition with the frequency component, and each one is also expressed as the form:

$$\overline{E_0}(\omega) = A(\omega) e^{-i(\omega t - kz + \Phi_0(\omega))} \qquad (2.4)$$

$k = \omega / c$ is repetency, ϕ_0 is the ether wave' initial phase in certain frequency, t and z respectively are time and location.

In transmitted spectrum, the electrical filed of the terahertz wave transmitted samples is:

$$\begin{aligned}\overline{E_s}(\omega) &= t_1 t_2 A(\omega) e^{-i(\omega t - kz + \Phi_0(\omega))} e^{ik(\bar{n}-1)d} \\ &= t_1 t_2 \overline{E_0}(\omega) e^{-k\kappa d} e^{ik(n-1)d}\end{aligned} \qquad (2.5)$$

$\bar{t}_1$ and $\bar{t}_2$ respectively are transmissivity at sample's two interfaces.

According the 2.5, ignoring the Fresnel reflection loss, the modulations including the Amplitude attenuation and the phase delay are defined by the imaginary part and real part of the complex refractive index. The attenuation can be displayed as a absorbance $\alpha = k\kappa$. The absorbance α has different forms for different samples. The absorbance in explosives' spectrum can be displayd:

$$\alpha(\omega) = \ln \frac{I_0(\omega)}{I_s(\omega)} / m \qquad (2.6)$$

I0 is the initial power of the THz wave，IS is the implement power of the wave transmitted samples, m is the mass [7-8,4].

2.2 Experimental System

The diagram of THz-TDS system is as shown in Figure 1. Terahertz wave can be generated and detected by GaAs. The super-short pulse light source is the clamping titanium sapphire femtosecond laser with center wavelength of 800 nm, repeating frequency of 80 MHz and pulse width of 100 FM. Laboratory's temperature is 23.8 C ° and humidity is 33%.

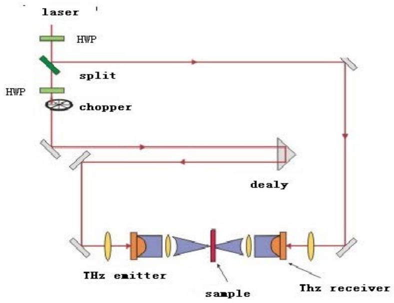

Fig 1 THz-TDS system diagram

The experiment system in this research adopted MINI-Z Terahertz spectrum instrument developed by Brian Schulkin, who is a physicist professor of Rensselaer Polytechnic Institute in New York. This system is mainly characterized by small volume and high stability. Therefore, its high stability guarantee sample experiment safety.

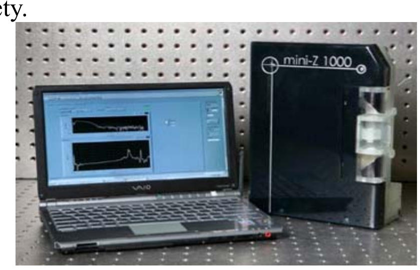

Fig 2 MINI-Z THz spectrograph

In the spectrometry, after the femtosecond laser pass the optical lens, the light is bunched and expanded respectively, then the light is divided as pump light and detect light by the half wave plate and polarization beam splitter. The pump light focalizes on the photoconductive antenna clearance of the THz emitter by the delay line and the optical system. The iris diaphragm in system guides the beam into the THz emitter and detector.

2.3 Experimental Samples and Measurement

Three monomer high explosives' Terahertz absorption spectrums including hexanitrostibene(HNS), 2,4-dimitroanisole (DNAN) and 2,6-dimethylnitrobenzene (DNMT) are measured, are used by military force which. HNS is usually used as a heat resistant explosive, which has stable chemical and physical character including the low mechanical sensitivity and excellent radioresistance, and is widely applied to the heat-resisting military or many kinds of civilian blastingsupply. The explosive was made into the primacord for temblor detection in Apollo Program, which is recommended to use in-line explosion sequence in the military standard MIL-STD-1316. As the primary explosive in detonator tube, HNS-Ⅳis defined to be the main component in slapper plate detonator. HNS is difficult to be analyzed in traditional approach, but using the quantum chemical simulation the absorbance peaks of the explosive are calculated at 1.9THz and 3.3THz. Terahertz time domain spectrum technology can measure the frequency range in 0.1~4THz, the frequency of HNS is in which, so that the approach is a valid measurement for analyzing HNS [9]. 2, 4-Dimitroanisole is a new low sensitive cast explosive, which firstly as the substitutes for the cast explosives based on TNT go into people's sight. Comparing with the TNT, DNAN has a smaller energy loss and density loss and the sensitivity of the explosives are lower than TNT, so that it has been in commercial [10]. 2,6-Dimethylnitrobenzene (DNMT) is a novel synthetic high energetic compound which belong to the tetrazole compound. The explosives is the energetic ligand in the energetic complex and the significant component of the propellent and bluster, meantime it is the important immediate of synthesizing other high energetic mixture, which has a wild development and application value [11]. At present, the scientists in Capital Normal University declare the THz spectrums of HNS are analyzed, but the THz spectrums of other ones are not detected in land, especially the measuring frequency band is above 500cm^{-1}. For the sake of the abundant THz spectrum database, the THz reflective spectrums of three military explosives are detected in this paper, and the characteristic absorbance peaks are deeply analyzed.

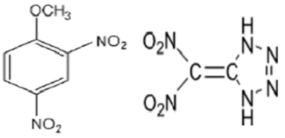

Fig 3 the molecule structures of DNAN and DNMT

For the sake of danger degree of these explosives, in the experiments the measurement states of explosive sample have been changed from disk-type into powder-type. In real environment, most of explosives are existed at the powder or crystal, so the measuring state is more close to the real measuring condition. The implement samples are in Fig 4.

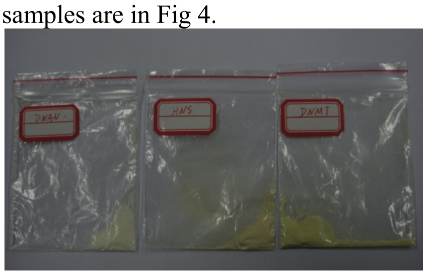

Fig 4 the states of the implemental samples

The detection frequency is 0.1~2.0THz. Though the effect of flake is inferior to the one of powder-type, the characteristic absorption peaks of three explosives can be gotten by comparison.

3. Result and discuss

Using the MINI-Z terahertz time domain spectrometer three explosives powder are detected, the results are Fig 5 to Fig 7. As the figures shown, the absorbance curves of the samples are displayed. Through the comparison, the characteristic absorbance peaks of these samples are analyzed.

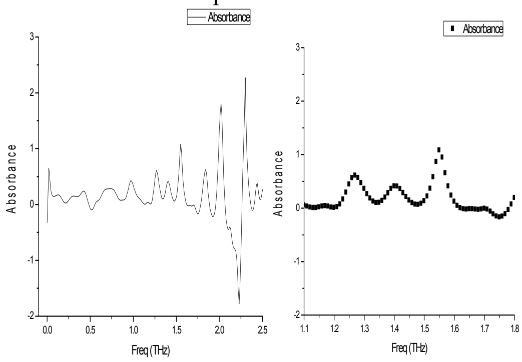

Fig 5 the reflective THz spectrum of HNS

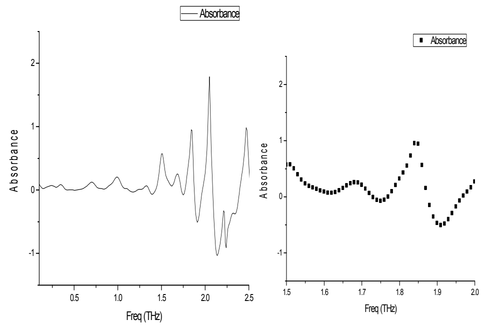

Fig 6 the reflective THz spectrum of DNAN

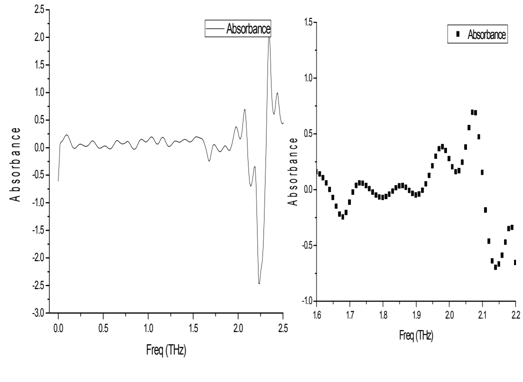

Fig 7 the reflective THz spectrum of DNMT

The research displays the explosives have the apparent absorbance peaks in the range 0.1~2.5THz.

Fig 4 shows the information of DNAN. As the figure shown, although at 1.42THz the explosive has a apparent peak, but through the comparison with the air, which is caused by the absorbance of the air. Thus, using the same method, the peaks of DNAN are calculated to be at

1.27THz and 1.55THz, the method is used in the HNS and DNMT. The analyzing results in table 1. In the frequency band 0.1~2.5THz, The THz time-domain spectrums of the explosives, DNAN and DNMT, are firstly detected, and the peaks of HNS are the same with the results in Capital Normal University [8].

Table 1 the THz absorbance peaks of the samples

sample	the peaks	Frequency band
DNAN	1.27，1.55	0.1~2.5
HNS	1.85	0.1~2.5
DNMT	1.75，2.075	0.1~2.5

4 Conclusion

The THz spectrums of three military high explosives, HNS, DNAN and DNMT, are detected by THz-TDS technology and the characteristic absorbance spectrums of these samples. The location of the absorbance peaks are analyzed in 0.1~2.5THz. The results indicate the significance of the THz-TDS technology in detecting the absorbance spectrums of these explosives. The detecting results are real and reliable, and the distinctive absorbance characters of the explosives have essential application value in the fields of the dangerous identification and safety detection.

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