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Exploring Desert Reservoirs With Terahertz Frequencies

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Abstract:
To locate oil in the desert, precise, nondestructive, and cost-effective exploration is necessary; unfortunately, current technology is incapable of providing direct and noninvasive detection. Terahertz (THz) prospecting was designed to extract sands from the surface of an oilfield in a desert and to determine the distribution of the reservoir. Currently, the accuracy of THz prospecting exceeds 80%. Generally used for reservoir appraisal, THz spectroscopy can detect trace organic chemicals flowing from a subsurface reservoir to surface sands. Using Fourier transform infrared spectroscopy, mass spectrometry, and a thermogravimetric analytical method, The authenticity of aromatic compounds, nitro organics, and long-chain alkanes has been independently verified. When trace organics were dissolved, the sands exhibited a THz response comparable to other sands. In dry conditions, the THz spectroscopy-based petroleum prospecting method is effective for improving and optimising the geophysical exploration system.

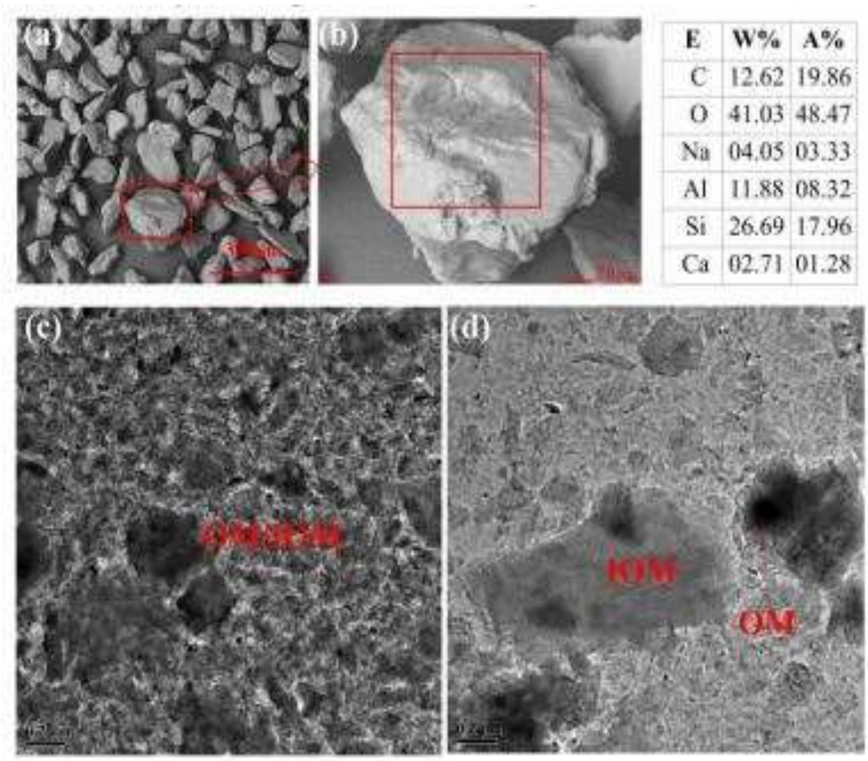
Keywords: Aquifer, terahertz spectroscopy, trace organics, and prospecting in a desert.

I. INTRODUCTION

The TERAHERTZ (THz) spectrum offers a plethora of exciting possibilities for fundamental science and application research[1]. The THz zone, The lattice vibrations, superconducting energy gaps, and spin quasiparticles in condensed matter are at 0.4 to 40 meV, which corresponds to photon energies between 0.4 and 40 meV [2,3] (3.3-330 cm-1 or 0.1-10 THz). Long ago, individuals who worked in THz ran across a problem: there was little motivation to create revolutionary approaches because nobody knew of any "killer applications." In view of the existing solid THz technology foundation [4,5], more applications, particularly 'killer applications,' should be investigated. Reduced conventional oil and gas production is being compensated for by the production of oil from sources that were previously inaccessible[6, 7]. Oil and gas production has evolved over the past few years thanks to unconventional oil and gas production [8, 10]. Conventional methods for evaluating unconventional oil and gas resources centre on two primary factors: the presence of petroleum in the trap and the volume of space filled by petroleum in the reservoir. Since the real oil storage locations are typically many kilometres below the surface, the surface sands of a desert may contain trace quantities of organic material, but the amount is negligible. The strata would be harmed by geophysical procedures such as seismic exploration, which would also be time-consuming and expensive [11,12]. It may be possible to search for surface sands in desert oil reservoirs by using THz geophysical imaging.THz radiation's sensitivity to water, oil, gas, solid organic materials, and minerals in reservoirs has been the subject of all previous theoretical and experimental research [13-18]. Technology for real-world THz petroleum exploration is provided by these investigations. This article presents the results of direct THz spectroscopy studies of surface sands in a desert oilfield that are 1.5 metres deep. In this case, an attenuation coefficient in the THz range was derived and linked to oil well distribution. THz spectroscopy aids in the exploration of oil resources in large deserts, as demonstrated by the 80+% accuracy achieved by THz geophysical prospecting.

II. METHODS AND PROCEDURES

Surface sands were recovered from reservoir locations. Organic matter (OM) was present in minute amounts in the sands, which were also mineral-rich (supplementary Figures 1 and 2). As shown in Figures 1 (a) and (b), sand particles range from 50 to 300 m in size (b). There were both metallic and nonmetallic components in the samples. Carbon, oxygen, and silicon were all nonmetallic elements. Silicon dioxide and carbonates, and organic molecules including C, O, and H were found in extremely high concentrations in reservoir sands, as determined by an elemental analysis. (H is not identifiable by SEM-EDS) An analysis of the TEM images in Figure 1(c) and (d) reveals that irregular particles make up a low proportion of the particles, while regular minerals make up a high proportion, which may include various forms of Organic Matters (OM). Figure 1 shows that inorganic matter (IOM) has a more uniform shape than organic matter (OM) (d).



E	W%	A%
C	12.62	19.86
O	41.03	48.47
Na	04.05	03.33
Al	11.88	08.32
Si	26.69	17.96
Ca	02.71	01.28

Fig. 1. Utilizing electronic microscopy to measure reservoir sands. Different sized and shaped reservoirs are depicted on a SEM picture. SEM/EDS examination of a sample particle from set B, along with an image of the particle's elemental composition as determined by SEM. This transmission electron micrograph analysis depicts reservoir sands that contain olivine and ichthyose octahedra in frames (c) and (d).

Compression plates made of sands and polyethylene with low absorption in the THz spectrum are utilised as samples for THz measurements. Figure 1 demonstrates the THz system with sand tablets. 2 (a) and additional Fig. 3 The scattering effect can alter THz spectra due to the similarity in size between particles and THz wavelengths. While smaller particle samples behaved as Rayleigh scatterers[19-21], bigger particles behaved as Mie particles, and their extinction was predominantly determined by THz wave absorption. As shown in figure 2(b), transmission THz time-domain spectroscopy can be generated by stepping different-sized samples of sand. The signal's power reduced as its magnitude increased. In addition, humidity levels must be considered because water vapour has pronounced absorption characteristics in the THz band. THz frequency-domain spectroscopy (THz-FDS) and THz time-domain spectroscopy (THz-TDS) are presented in figures 2 (c) and (d). As shown in Figures 2 (b)-(d), nitrogen-based measurements should be performed using the smallest sand compression plates. In addition, since water has such a high absorption coefficient, it must be determined if it affects the precision of THz geophysical prospecting. We arbitrarily picked 10 unique types of sand and separated them into two piles: piles that would be tableted immediately and piles that would be dried prior to being tabled. The THz-TDS of a wet and dry sand sample is shown in supplemental figure. Figure 4 shows the results. According to 2 (e), there were no water molecules in the sand samples. The different locations of the samples have produced different THz characteristics in the interim. The collected sands from diverse regions revealed a wide variety of chemical components that require further analysis. THz geophysical prospecting can be conducted immediately on the sands.

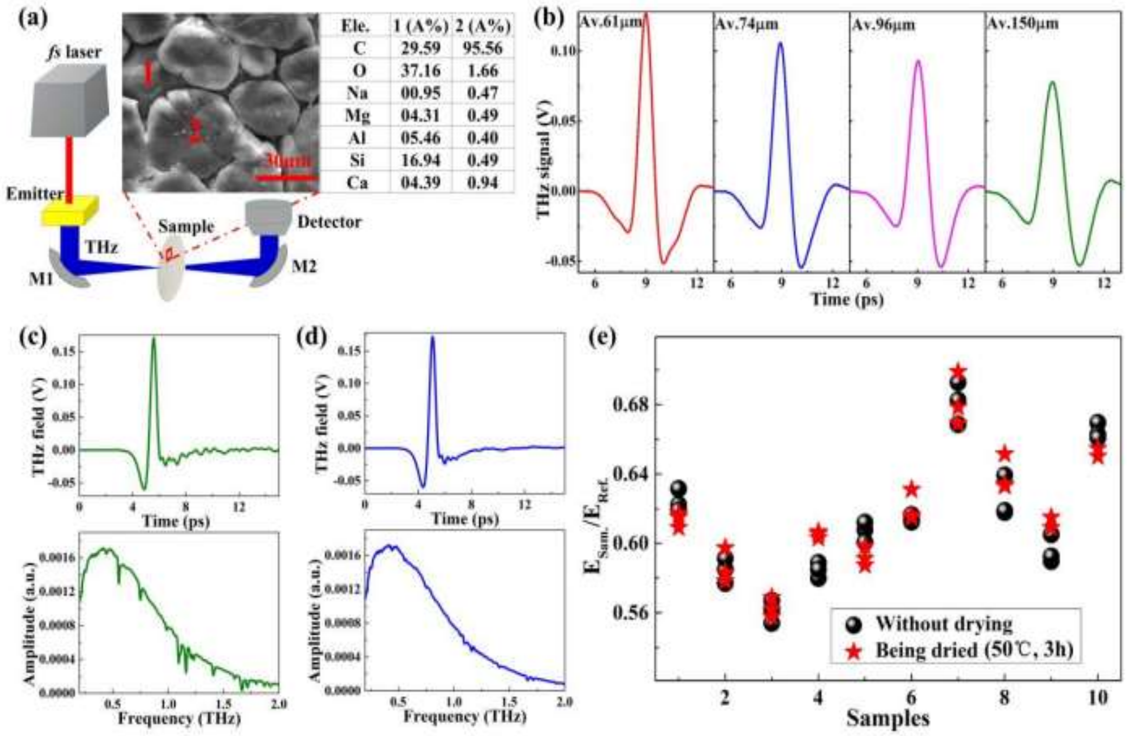


Fig 2: Assessing the most efficient methods for THz geophysical research. a. Formulation of a measurement approach for THz transmission. Using SEM and EDS, polyethylene and sand compression plates were directly scanned. THz-TDS technology was used to analyze 61-150 micrometre-sized sand samples. The transmission of THz-TDS and THz-FDS through the atmosphere (c). THz-TDS and THz-FDS spectra for nitrogen (d). An analysis of the signal-to-reference amplitude ratio for ten randomly obtained samples following exposure to 50°C for three hours .

III. RESULTS AND DISCUSSION

In order to collect a large number of samples, an oil field larger than a thousand square kilometers was selected for the test. For the THz measurement, 360 surface sand samples were taken from a depth of 1.5 metres. Each of the sixteen oil wells utilised as sample locations is depicted as a red dot in Figure 3 (a), which also displays the precise distribution of sample locations.By successively passing collected sands through multilayer sieves, Sand grains with a uniform diameter of 61 mm were obtained. An equal amount of polyethylene powder was added to each clean sand sample, and the resulting combination was compressed into tablets at 20 megapascals for two minutes (MPa). The created tablets have a thickness of 1.74 millimetres. Then, a THz-TDS device was used to scan each tablet three times. In Fig. 3 (b), THzTDS was depicted for the reference and one sample, as well as for all samples in S11 of Supplemental Fig. 5. Using a formula in which ER/ES/d represents the amplitudes of the reference and sample THz signals, the attenuation coefficient for each was determined by dividing each by the amplitude of the reference signal..The majority of the sample dependent in Fig. 3 (c) fluctuated between 0.75 and 1.05. As shown in Fig. A group of sample absorption parameters varied by up to 34.8%, demonstrating THz's sensitivity to minute differences in organic matter in sands. 0.0566 was the standard deviation, and 0.86783 was the mean value. Correlation of all samples with their relative positions (d) This region shows a wide distribution of THz responses in Figure 3. To reduce random errors introduced by sample collection, all samples were divided into two groups based on the value of. A sample with 0.86783 or greater is categorized as a '1', while a sample with less than 0.86783 is categorized as a '0'. THz responses were represented in two groups, respectively. In Figure 3, the THz response (e) is shown as being location-dependent. Contiguous distributions were observed for both high and low responses, demonstrating excellent conformity with actual geological conditions.In the meantime, wells were drilled in regions exhibiting a significant THz response. Results showed that 81.2% (19/16) of the 16 anticipated wells in this oil field were accurate using THz geophysical prospecting. Additionally, the location-dependent absorbance (- ln(ES/ER)/d) was calculated and agreed with the computation in (supplementary Figures 6 and 7). A typical accuracy of 60% was considered to be typical for THz spectroscopy, thereby enhancing geophysical prospecting efficiency.

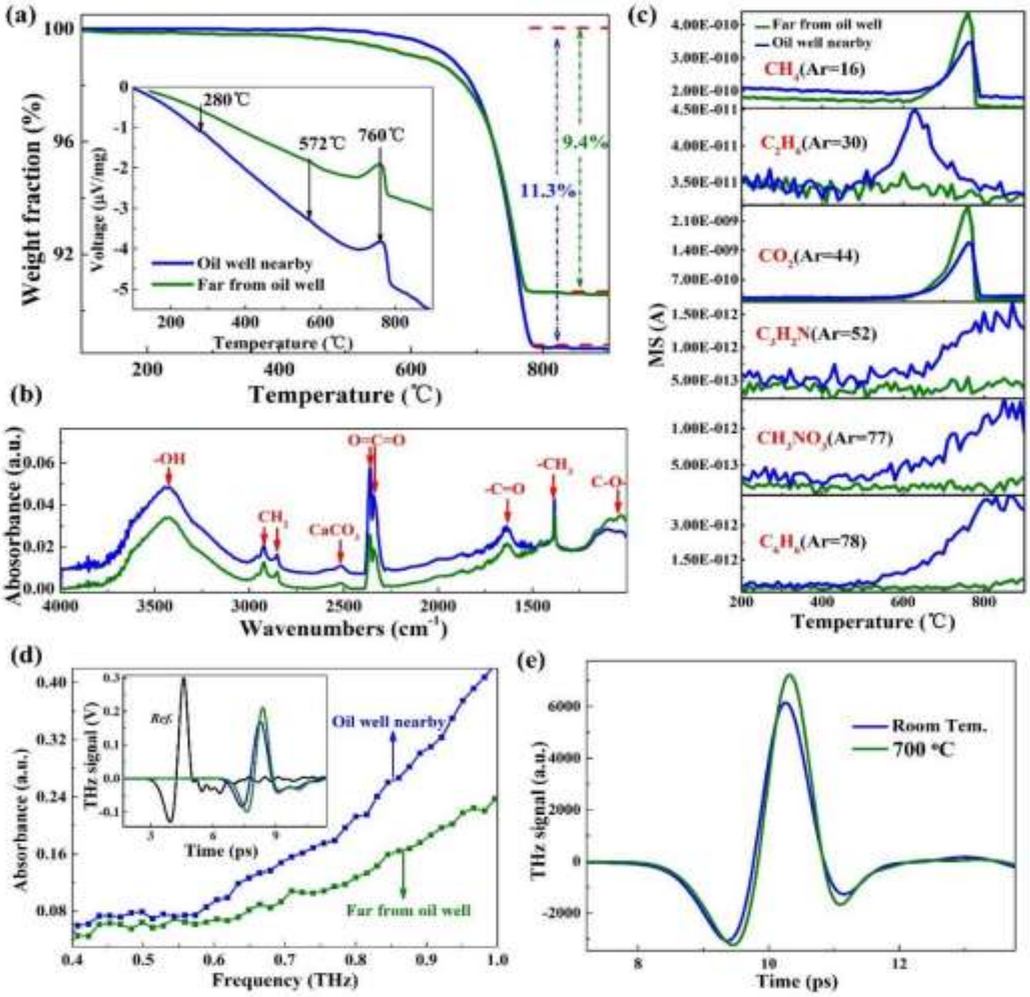


Figure 4: Qualitative evaluation of sand samples for THz geophysical exploration. (a)TGA curve of sands close to and far away from oil wells.b) IR absorption of sands depends on wavenumber. (c) The mass fraction (MS) of typical gases degraded by sands close to and far away from oil wells. The absorbance spectra and THz-TDS of two sand kinds. (e) THz-TDS of a sand sample near an oil well at ambient temperature and after heating to 700 degrees Celsius.

THz geophysical prospecting, which caused no harm to the strata, yielded reliable data from below-ground that was utilised in reservoir studies. Sand samples from an oil field were utilised to investigate the THz geophysical prospecting procedure. A thermogravimetric analysis (TGA) and Fourier transform infrared (FTIR) and mass spectrometric analysis (MS) were used to monitor the thermal disintegration of the grains. A, B, and C of Figure 4 show typical TGA, FTIR, and MS curves for sands near and far from wells. Up to 500°C at room temperature, no sand type had a significant reduction in volume. Numerous chemical compounds commonly encountered in nature demonstrate IR absorption. According to Figures 4 (a) and (b), surface sands sampled at a depth of 1.5 metres contain OM, although in low concentrations. As shown in Figure 4(c), several gases generated from sand were subjected to mass spectrometry. As a result of the decomposition of carbonates (mainly $CaCO3$), carbon dioxide was released. Standard organic gas was created at temperatures ranging from 400 to 800 degrees.Chlorofluoroalkanes, nitro organics, and aromatic compounds dominated the OM in the sands, including $CH4$, $C2H6$, $C3H2N$, $CH3NO3$, and $C6H6$.Due to the great reactivity of these organics in the THz region, it is now possible to comprehend THz geophysical investigation.

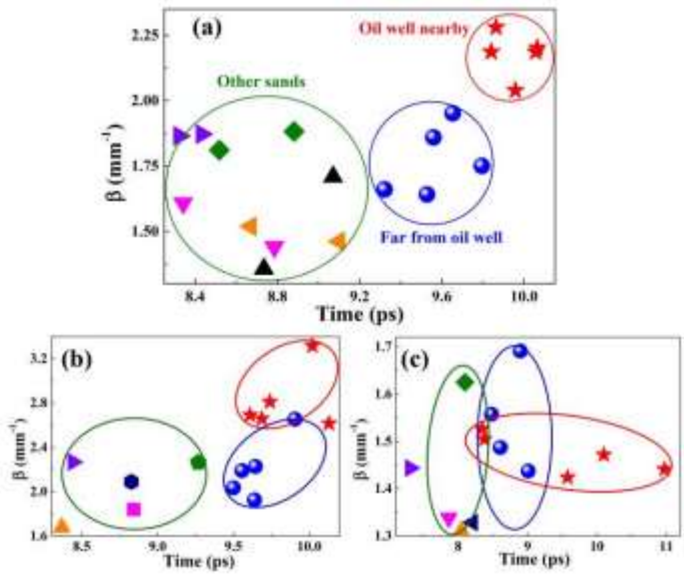


Fig. 5 As a result of pyrolysis under 200 °C, at 600 °C, as well as at ambient temperature, the system compared the delay times of sands from nearby and distant oil wells.

The mechanism was confirmed by analysing beach sands from Xiamen, Qinhuang Island, and adjacent mountains using THz. Both at room temperature and after heating to 700 degrees Celsius, oil well sands were analysed. Figure 4(d) demonstrates THz responses of sands placed closer to oil wells were larger than those of those placed further away (d).Organic components, Such as THz response was attenuated during heating to 700 °C due to the presence of long-chain alkanes, nitro organics, and aromatic compounds, which reacted more strongly than minerals in the THz range..According to Figure 5, the delay duration of selected samples at room temperature is related to pyrolysis temperatures of 200 to 600 °C. Figure 5 demonstrates that the absorption of sands around oil wells was greatest at 200 °C, the temperature at which water vaporises completely (a). The pyrolysis temperature of 600 °C, when increased to the temperature of adjacent oil wells, resulted in almost no organics remaining in the sands, even though they reacted similarly to THz. Figures 4(d,e) and 5 show similar results, showing that a larger THz response was caused by more organic matter as shown in the previous figure. Since the OM data was determined by comparing the THz spectra of sands from different locations that had the same quantity of waste water and IOM.In arid regions, THz spectroscopy provides an inexpensive and simple method of finding oil in sands

IV. **CONCLUSIONS**

This study concluded with a proof-of-concept evaluation of THz spectroscopy's potential for essential petroleum geophysical prospecting applications in arid conditions. The precise analysis of THz spectroscopy described in this article presents a novel technique for a complex industry or sector by giving a comprehensive and in-depth evaluation of organics in surface sands. Desert reservoir requires an efficient prospecting strategy due to the vast deposits and high expenses of conventional methods. Future quantum exploration and prospecting, as well as technological innovation, may profit from this method's capacity to identify trace organic components.

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