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USING SPECTROSCOPY OF THE NEAR-INFRARED TECHNIQUES TO DETECTION THE GAS

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Near-infrared spectroscopy is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum. In this paper we will explain the methane detector by using near-infrared radiation with different wavelengths ranges (800nmλ to 950nmλ) . The results, that have been obtained, had the greatest value within the wavelength 850λnm.
Keyword: diode lasers, near-infrared , absorbs , methane , detection , spectroscopic.

Ближня інфрачервона спектроскопія є спектроскопічним методом, який використовує ближню інфрачервону область електромагнітного спектра. У цій статті ми покажемо, як виявити газ метану за допомогою ближньої інфрачервоної радіації з різним діапазоном довжин хвиль (від 800 нмλ до 950 нмλ). Найбільше значення було отримано в межах довжин хвиль 850 нмλ.
Ключові слова: діодні лазери, ближній інфрачервоний, поглинння метану, виявлення, спектроскопія.

1. Introduction

Due to the important role of spectroscopy of the laser and found immediate application in various fields , one of these fields is the detection and identification . In this research we will explain methane detection by using near-infrared . Methane is a chemical compound with the chemical formula CH_4 . It is the simplest alkane, the main component of natural gas, and probably the most abundant organic compound on earth [1]. Methane is the main component of coal mine gas and natural gas, and it is closely connected with the people's daily activities and life. Since methane gas is inflammable and explosive, it is important to accurately detect the concentration of methane gas. All this made us think to design of this device to detect methane using Near-infrared. Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from about 800 nm to 2500 nm) [2]. Near-infrared spectroscopy is one of the most common spectroscopic techniques used by organic and inorganic chemists. Simply, it is the absorption measurement of different IR frequencies by a sample positioned in the path of an IR beam. The main goal of IR spectroscopic analysis is to determine the chemical functional groups in the sample. Different functional groups absorb characteristic frequencies of IR radiation. Using various sampling accessories, IR spectrometers can accept a wide range of sample types such as gases, liquids, and solids. Thus, IR spectroscopy is an important and popular tool for structural elucidation and compound identification.

2. Literature review

Methane sensors are based on various detection principles, such as catalytic combustion [3], metal-oxide-semiconductor (MOS) resistance [4], NDIR absorption spectroscopy [5, 6]. Our system consist of signal transmission unit , it is near-infrared radiation diodes its function emission near infrared waves at different wave-lengths ranging from (808 nm λ,850 nm λ, 880 nm λ, 940 nm λ, 950 nm λ). When we start emitting near-infrared to the tube which containing methane, the methane will absorb part of the radiation energy passing through This occurs because of Infrared radiation contains a wide spectral content , the stretching and bending of the covalent bonds in gas molecules and this radiation interacts with gas has the same frequency as the gas molecule's (natural frequency) the gas will absorbs some of the energy passing radiations . This vibration results in a rise in the temperature of the gas molecules. The temperature increases in proportion to gas concentration. On the other hand, the radiation absorbed by the gas molecules at the particular wavelength will cause a decrease in the original source strength. This radiation energy decrease can be detected as a signal by using photo diode which detect the quantum interaction between incident photons and semiconductor material and convert electromagnetic radiation energy changes into electrical signals . Amplification unit , in this unit is amplify the small signal which supplied by fiber optic into suitable (large signal) for read it with using display unit (Digital display) . Currently considered infrared rays with a wavelength of 1000nmλ to 1550nmλ is more common in the detection of methane and after the search we did not find the use of infrared with a wavelength of 700 nmλ to 900 nmλ , As is well known that the infrared energy in 850 nmλ is large compared with the infrared energy with a wavelength of (1000nmλ to 1550 nmλ) which provides an opportunity to use this device to detect on a larger scale and large distances .

3. Experimental

Infrared (IR) spectroscopy is one of the most common spectroscopic techniques, it is the absorption measurement of different IR frequencies by a sample positioned in the path of an IR beam. IR spectrometers can accept a wide range of sample types such as gases. Thus, IR spectroscopy is an important and popular tool for structural elucidation and compound identification. To illustrate the process of absorption of radiation energy by the gas The Beer-Lambert law expresses the fractional transmitted intensity of the optical wave with wave number through a path of L with an absorption coef-ficient. The transmission of monochromatic radiation at frequency ν through a uniform medium of length L (cm) (Fig.1) is given by the Beer-Lambert relation

$$\tau_\nu=(I_t/I_0)=xp(-\alpha_\nu) \quad (1)$$

where I_t and I_0 are the transmitted and incident laser intensities, respectively, and α_ν represents the spectral absorbance.

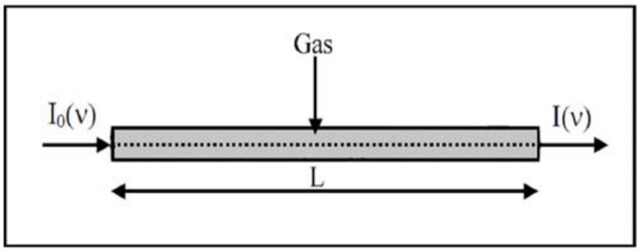

Fig. 1. Schematic of typical absorption measurements

For an isolated transition,

$$\alpha_\nu = P\chi_{abs}\, S(T)\, \Phi\nu L \quad (2)$$

where P is total gas pressure, χ_{abs} is the mole fraction of the absorbing species, T (K) is gas temperature, S (cm^{-2}/atm) and Φν (cm) are the line strength and lineshape function for the absorption feature [7].

The absorption rate depends on the (Absorption coefficient) it is defined by the position, strength, and shape of a spectral line. The determination of the absorption coefficient α of one absorption line of methane allows us to evaluate the feasibility of the proposed detection process. It can be expressed by:

$$\alpha(\nu)=k^P\, \Phi(\nu-\nu_0) \quad (3)$$

where ν is the wave number (in cm^{-1}), k^P the intrinsic intensity of the absorption line (in cm^{-2}/atm),and Φ(σ) the line shape function.

The intrinsic intensity k^P is expressed as a function of the line intensity k^N (cm^{-1}/molecule cm^{-2}) with the relationship

$$k^P=k^N\, N_L(T_0/T)(1/P_0) \quad (4)$$

where P_0=1 atm, $T_0=2.6868\times10^{19}$ molecule/cm^3 is the Lochsmidt number or the volume density under reference conditions.

The integral of the line shape distribution is normalized to unity

$$\int_{-\infty}^{\infty} \phi(\nu)d\nu = 1 \quad (5)$$

The line shape function Φ(ν) describes the effects of line broadening as a function of the pressure. At low pressure, the speed of the individual molecules is proportional to the square root of the temperature and the mass of the molecules. A photon which interacts with a given molecules has an apparent energy depending on the speed of the molecules, because of the Doppler shift. Φ(σ)can therefore be described by a Gaussian distribution in low-pressure regimes (P≤0.02atm). At high pressure (P≥0.1atm), collisions of the molecules are dominant and lead to a Lorentzian distribution of the line shape. At intermediate pressures, a Voigt profile is normally used to describe Φ(ν) Thus ,at atmospheric pressure , the main factor contributing to broadening of the absorption line is due to the collisions between the gas molecules, and Φ(ν) is completely determined with a Lorentzian profile with its full width at half maximum(FWHM) γ_L . The Lorentzian distribution is expressed by

$$\Phi_L(\nu-\nu_0)=1/\pi * \gamma L/((\nu-\nu_0)^2+\gamma^2_L) \quad .....(6)$$

and

$$\Phi(\pm\gamma_L)=1/\pi * 1/2\gamma_L=\Phi_L(0)/2 \quad .....(7)$$

γ_L is related to pressure and temperature through the following relation:

$$\gamma_L = \gamma_{L0}\frac{P_{gas}}{P_0}\sqrt{\frac{T_0}{T}} \quad (8)$$

where P_0 and T_0 are, respectively, the reference pressure and temperature, $\gamma_{L0}$is the FWHM under reference conditions [8]. At atmospheric pressure, the relative variation of γ_L is about 10 % between –10°Cand +60°C, and a broader tuning range for the laser is not necessary. The absorption line strengths for CH_4 at a reference temperature T_0 of 296 K are tabulated in high resolution transmission molecular absorption database [9]. The temperature dependence of the intrinsic intensity or line strength, for a given transition (k^P at transition i is generally expressed as S) can be expressed by:

$$S(T)=s(T_0)\frac{Q(T_0)}{Q(T)}\left(\frac{T_0}{T}\right)\times$$
$$\times\exp\left[-\frac{hcE''}{k}\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]\left[1-\exp\left(\frac{-hc\nu_0}{kT}\right)\right]\left[1-\exp\left(\frac{-hc\nu_0}{kT_0}\right)\right]^{-1} \quad (9)$$

where S (T_0) is the line strength at reference temperature (usually T_0=296 K), Q (T) the partition function of the absorbing molecule [10] , h(J s) Planck's constant, c (cm/s) the speed of light, k (J/K) Boltzmann's constant, E"(cm^{-1}) the lower state energy and ν_0 (cm^{-1}) the line center frequency of the transition .

The experimental conditions (room temperature, 1 bar of relative pressure), At our pressure and temperature conditions, the effect of thermal broadening is negligible. Therefore, only broadening due to collisional effects will be taken into account. Thus, the line shape function of the individual transitions will be Lorentzian [11]. To achieve high detection sensitivity, it is desirable to use as strong an absorption line as possible. And that the radiation used in the experiment is near-infrared at different wavelengths (808 nmλ , 850 nmλ , 880 nmλ , 940 nmλ , 950 nmλ) . Laser diode (emitting diode) has been used as a source of infrared (LL-503 IRT2E-2AC , TSAL 5100, SFH484-2, HIRB5-43G-D, QED 222)* laser diode was applied as the light source and operated under threshold level functioning as a LED**[12]**. The characteristics of the laser diodes are as follows: the wavelength range is (800 nmλ–950 nmλ), the current threshold at 25 C° is 13 mA, the temperature tuning rate is 0.1 nm /C°, and the current tuning rate is 0.01nm/mA. (Fig. 2) shows a diagram of a preferred embodiment of the methane detection system based upon laser diodes with the deferent frequencies.

The near-infrared laser beam is transmitted through the tube containing methane. Initially the experiment is carried without methane is then re-trial in the same conditions, but with methane to identified the amount of energy that has been absorbed and knowing the value of the response for each wavelength near-infrared radiation . When we begins emitting near-infrared from the transmitter unit (IR diode) through the tube which containing methane the methane will absorb part of the radiation energy passing through , this occurs because of Infrared radiation contains a wide spectral content, all the atoms in molecules are in continuous vibration with respect to each other.

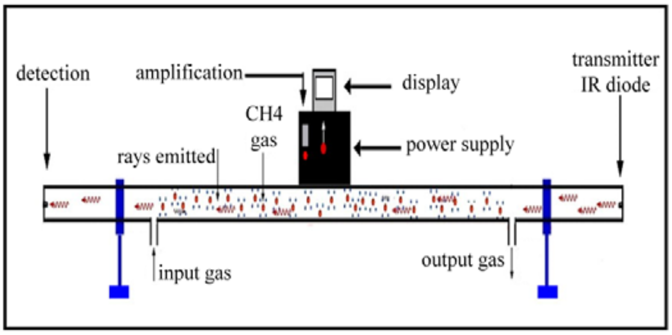

Fig. 2. Diagram of a preferred embodiment of the methane detection system

The stretching and bending of the covalent bonds in gas molecules have a certain frequency which is called (natural frequency) , when the frequency of a specific vibration is equal to the frequency of the IR radiation directed on the molecule the radiation will interacts with the gas that has the same frequency as the gas molecule's , so the gas will absorbs some of the energy passing radiations . As the gas molecules absorb this radiation, the molecules gain energy and vibrate more vigorously. This vibration results in a rise in the temperature of the gas molecules.

4. The Results of the experiment

The Fig. 3 and the Table 1 indicates that the amount of energy lost to near-infrared ray when passing through the methane were recorded and displayed on the computer.

Table 1

Respond to infrared with and without Methane

wavelengths	without gas (mV)	With gas (mV)
800nmλ	67	64
850nmλ	50	32
880nmλ	50	42
940nmλ	84	82
950nmλ	26	24

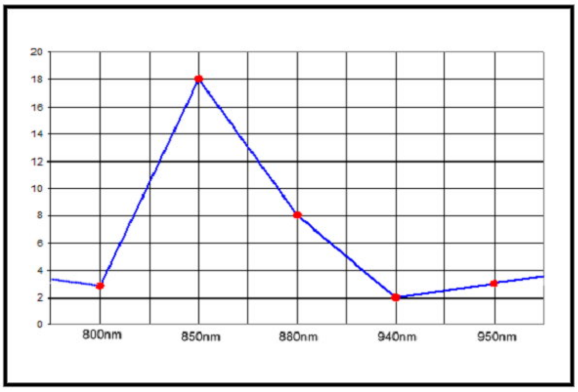

Fig. 3. Chart of the absorption rate of methane for the various wavelengths

The chart showing the highest value of the absorption was in the wavelengths 850 nm λ range.

Optical depth of a gas medium between points s1 and s2 is defined as

$$\tau_v(S_2;S_1)=\int_{S_1}^{S_2} k_v(S)ds \quad (10)$$

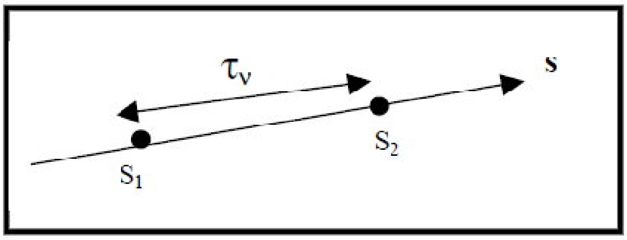

Fig. 4. Optical depth of a gas medium

Where k_v is the absorption coefficient of the gas.

$$k_v= S f(\nu - \nu_0) \quad (11)$$

where S in the line intensity and f is the line profile:

The optical depth is unitless.

Also the IR energy absorption is directly proportional to the molecular structure of the hydrocarbon (in addition to the concentration of the hydrocarbon present) . The received signal (optical beam) is converted to an electrical current via a photodiode and amplified by a pre-amplifier. An electronic circuit receives the signal coming from the amplifier and processes it.

Finally, the data output of the processing circuit is acquired and processed digitally using a Voltmeters . It should be noted that the detected laser signal consists of a potentially small intensity variation caused by methane gas absorption superimposed on a much larger intensity variation caused by laser power increasing with current.

5. Conclusion

Capturing and using methane can offer both opportunities to generate new sources of clean energy and mitigate global climate change. Also methane is an efficient energy source. To access the energy from methane, people burn it. It is a preferred energy source, because when it is burned, it does not create much CO2 . The advantages of using infrared radiation to detection the methane is remote detection capability, safety in a hazardous environment , and improved sensitivity leading to better capability for the detection, also it is simple, low-cost, multiple sensor strands , loops that save size, have increased reliability and field-service lifetime. In this research we were able to detect methane using near-infrared within the range of 850 nmλ, where the wavelength is characterized by high powered Compare wavelengths 1230 nmλ –1550 nmλ , which is common in the detection of gases and which provides us the possibility of detection of the largest ranges. In General we can say that this kind of devices falls under the heading of "gas monitoring equipment", this equipment can simply detect a variety of gases in a more profound way .We can say that the importance of this device or any device that uses spectroscopy to detect gases can't be ignored within the research and scientific studies.

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AERODYNAMIC STATE DIAGNOSING METHOD OF AIRCRAFT WITH THERMAL FIELD USAGE

© V. Kazak, D. Shevchuk, A. Babenko, M. Levchenko

The method of aerodynamic condition of the aircraft on the thermal fields was developed as a research result. Based on the mathematical and natural experiments, there are identified the regularities of formation of temperature gradients in the boundary layer of air that occurs after damage of external contours; there are detected parameters that affect the behavior of the temperature gradient arising from damage.
Keywords: external contour, damage, plane, aircraft, temperature gradient, thermal method, boundary layer, diagnostics.

В результаті проведених досліджень було розроблено метод аеродинамічного стану літака по теплових полях. На основі математичного та натурного експериментів, встановлено: закономірності формування температурного градієнту у прикордонному шарі повітря, що виникає за пошкодженням зовнішніх обводів; виявлено параметри, які впливають на поведінку температурного градієнту, що виникає за пошкодженням.
Ключові слова: зовнішні обводи, пошкодження, повітряний корабель, температурний градієнт, тепловий метод, прикордонний шар, діагностування.

1. Introduction

The issue of safety, including reducing the number of aviation accidents with fatalities worldwide, regardless of the amount of air transportation is a primary objective of the international Civil Aviation Organization (ICAO: Global Aviation Safety Plan, 2011, Montreal, Canada). According to the Federal Aviation Administration USA (FAA) annually in civil aviation there are about five huge aircraft accidents in which an important role is played by the collision of aircraft with biological, mechanical or electrical forces. At the same time every year a growing number of aircraft collisions with external forces, due to several factors, namely the increasing intensity of operations and the increase in bird populations. In particular, the number of aircraft collisions with birds in flight over the period 2005–2013 biennium. Has almost doubled – from 36,000 to 70,000 cases of collision per year for all types of civil aviation [1–3].

Thus the danger of accidental injuries in the collision of aircraft with the above units is that the appearance of lesions can not be predicted or detected in a timely flight. Analysis of Accident Investigation showed that the highest probability of collision with mechanical, electrical and biological formations appears