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Robot based Gas Detecting in Coal Mines

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Abstract—**As one of the largest coal production and consumption countries in the world, China is also one of the related accidents occurred frequently countries such as gas explosion, flood, breaking out of fire during the exploitation of coal mine. Coal Mine Detection Robot can be substituted or partial substituted for emergency workers to enter the mine shaft disaster site and detect hazardous gas and do some environmental exploration and surveying task. Coal Mine Detection Robot uses infra-red spectrum absorption way to detect methane, carbon monoxide and such gas simultaneously. The principle of gas surveymeter of infra-red spectrum is according to the selectively absorption of infrared radiation by the mash gas, CO to achieve the detection of their concentration. The advantages of this kind of hazardous gas detecting are: simultaneously and rapidly detecting methane, CO and high sensitivity, good selectivity and fast response.**

Otherwise, it is easy to be taken by robot due to its simple and light structure, have a lager detection range and probe is not easy failure to be poisoning and aging.

Keywords- Coal Mine Detection Robot; Methane; CO; Infrared Spectrum Absorption

I. INTRODUCTION

China is one of the largest coal production and consumption countries in the world, among its energy industry, coal accounting for about 70% in production and consumption structure of primary energy sources, and by 2050 its expect to accounting for more than 50%. For the poor geological conditions of the coal bed of China , there are so many highly gassy mine that accident occurred frequently such as fire damp explosion, water burst, breaking out of fire during the exploitation of coal mine. Therefore, how to accurately detect and prospect the incipient accident before it happens and how to rescue in maximum possibility after it happens is the most important thing. At recent times, there is little research about Coal Mine Detection Robot, only a little research on rescue robots for surface buildings' collapse and fire-fighting robot, and these robots are not suitable for detecting coal mine accident [1]. The research of Coal Mine Detection Robot (figure 1) can make the coal mine rescue works improving a lot, and reduce the casualties caused by mine accident. It will be substituted or partial substituted for emergency workers to enter the worksite and to carry out environmental prospecting and surveying task.

As the requirement of limited size and load for the robot in special circumstances, and many items to detect, the research of detecting by coal mine underground explorative robot have great practical significance and advanced natures.

Figure 1. Coal Mine Detection Robot

II. CHARACTERISTICS OF THE DETECTED GAS

Coal Mine Detection Robot mainly detects mash gas and carbon monoxide. The mash gas is the generic terms of the mixed gas which mainly make up of methane (CH4) in the underground of the coal mine shaft, and sometimes it abbreviate to methane. It is a kind of gas that formed during the process of coal-forming and stored in a large number among the coal bed, and the most damaging gas in the underground of the coal mine shaft. The mash gas is a kind of colorless, odorless, tasteless, non-toxicity gas, and its density is 0.7167kg/m³, when the content of methane in air is accounting for 5%~16%. It possesses the risk of explosion; when the content account for 9.5%, the explosive power is largest; when the concentration of methane in air is exorbitance, the harm to human body is it can killed people caused by suffocation when it is over the limitation, though the methane itself is nontoxic. CO is a kind of colourless, odourlessness, tasteless, nonirritant gas, and its proportion is 0.967kg/m³, almost insoluble in water. It could explode When it mixed with air and its accounting for 12.5~80% [2].

In the underground of coal mine haft, when the environmental temperature reaches certain condition, the coal will be spontaneous combustion, as the Oxygen supply of those places is insufficient, it will cause combustion inadequate and forms a large amount of CO. CO have a strong attractive to hemoglobin. When CO entered respiratory system it will cause anoxemia, and lead to histanoxia, and the inhibition of tissue respiration can killed people caused by suffocation. According to their features of the mash gas and CO they are both possess explosive, and dangerous for human body, and they are neither watersoluble, so watering can not dissolve, and its characteristics of colorless and tasteless makes people imperceptibly to taken in. So the detecting of methane and CO by Coal Mine Detection Robot is very important. As the proportion of these two kinds of gas is lighter than air, the sensor of detective robot should be put in the upper platen of the robot as shows in fig 1.

III. PRINCIPLE OF THE GAS DETECTION

The detection methods of mash gas in the underground of coal mine shaft mainly have optical interference way, thermal conductivity way, semiconductor air-sensitive way, electrochemistry way, isotopic carrier catalytic combustion way, infra-red spectrum absorption way. The detection methods of carbon monoxide gas in the underground of coal mine shaft mainly have solid state sensor, electrochemistry sensor , isotopic carrier catalytic combustion way, infra-red spectrum way. The principle of carbon monoxide gas detection is just like the principle of the last four ways of mash gas detection.

Optical interference way is using spectral interferometric principle to detect

gas. Thermal conductivity way is using thermal conductivity gas-Sensing material for the thermal conductivity of gas and air, and realizes the difference of gas detection. Semiconductor air-sensitive way is using some metal oxide in heating conditions (600 degrees Celsius) the thin-film resistors with the concentration of gas detection contact and the characteristics of the gas detection. Electrochemistry way is using the diaphragm spreading the sorbent electrolyte measured by electrolysis gas. Carrier catalytic combustion type of detector is using sensitive elements of gas, gas in catalytic effect on surface, without flame combustion heat release, concentration of gas detection. Coal Mine Detection Robot detects hazardous gas according to the infra-red spectrum. The gas surveymeter of infra-red spectrum is a detection way base on the principle of mash gas, CO selectively absorb infrared radiation to achieve the detection of the concentration of mash gas, CO gas. It is based on the nature that diatomic molecule have a special absorption peak on infrared light, which means some kind of gas only have corresponding absorption of some certain energy of infrared light which in special waveband, the absorbed waveband is so called the infrared absorption peak of the particular gas, for the differences of the infrared absorption peak(for example methane absorption rate figure 2), it is not subject to the influence of other interfering gases, and the intensity of absorption in the region of infrared light is implied with the concentration of gas[3]. The gas absorption on nocturnal radiation follows the Lambert-Beer Law [4]:

$$I = I_0 e^{-\alpha(\lambda) C L} \quad (1)$$

In the formula: I-the light intensity before getting through the gas that to be detected; I0-Transmitted light intensity after being absorption by gas;
α（λ)is the absorption coefficient that gas components to be detected work on the nocturnal radiation which has a wavelength λ; C-concentration of gas that to be detected; L-the length of the being detected gas components that get through the nocturnal radiation. From formula (1) can get

$$C = \frac{1}{\alpha(\lambda) L} \ln\left(\frac{I_0}{I}\right) \quad (2)$$

From formula (2) can get, while the length L of the being detected gas components which get through nocturnal radiation is sure, α(λ) will be the constant for one kind of special being detected gas components. By means of detecting the light intensity before getting through the gas that to be detected I and the Transmitted light intensity after being absorbed by gas I0, we can know the concentration of the being detected gas components.

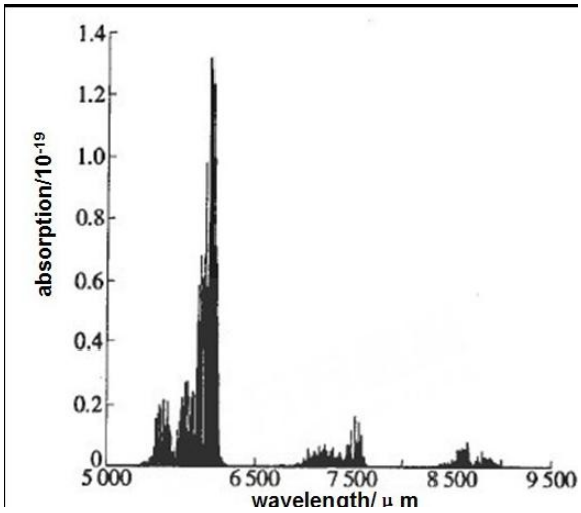

Figure 2. Methane 1.6654μm and 1.3312μm absorption rate

IV. HARDWARE DESIGN OF THE GAS DETECTION

The underground coal mine shaft detector uses infrared detector detecting the nocturnal radiation. The infrared detector contains photo-thermal detector and photon detector. According to the special environment of the coal mine shaft the detection system uses pyroelectricity detector, which has advantage of wide response wave band to detect methane, CO and such gas at the same time, and no need refrigeration, simple and light structure is easy to be taken, and suitable to work underground the shaft. Coal Mine Detection Robot has to simultaneously detect methane, CO and such gas. It uses infra-red spectrum absorption to simultaneously detect methane, CO with the methods of difference on three single-wavelength optical, the light source of three single-wavelength optical generally uses broadband light source to filter light through three filter plate that in different wavelength, and we can get three adjacent wavelength$\lambda 1$, $\lambda 2$ and $\lambda 3$, and $\lambda 1$ is at CH4 gas absorption peak, $\lambda 2$ is at CO gas absorption peak, $\lambda 3$ is hardly absorb neither of them, also hardly absorb other gas such as C2H2, NH3, H2O and so on. Therefore ray radiation of $\lambda 1$, $\lambda 2$ is considered as the detecting signal, and ray radiation of $\lambda 3$ is considered as the reference signal.

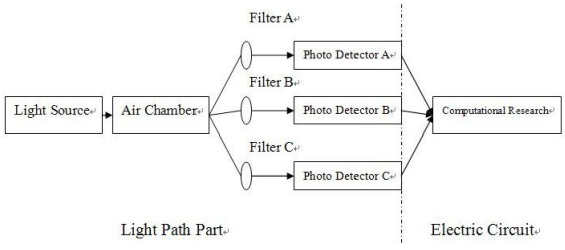

Figure 3. Block diagram of three-wavelength single light path

As shows in figure 3, the light emitted from light source entered detection chamber, and reach beam splitter through the air chamber, the beam splitter divided the luminous beam into three beams. Each of them get through interference absorbent which with the center frequency of $\lambda 1$, $\lambda 2$ and $\lambda 3$ to irradiate on the photoelectric detector, in where converted to electrical signal. According to formula (1), considering interference factor of light path, since the incident ray of the three kind wavelength passed the gas that to be detected, the output electrical signal that get through the detector are:

$$i(\lambda_1) = I_0 K(\lambda_1) D(\lambda_1) e^{-[\alpha(\lambda_1)CL+\beta(\lambda_1)]} \quad (3)$$

$$i(\lambda_2) = I_0 K(\lambda_2) D(\lambda_2) e^{-[\alpha(\lambda_2)CL+\beta(\lambda_2)]} \quad (4)$$

$$i(\lambda_3) = I_0 K(\lambda_3) D(\lambda_3) e^{-[\alpha(\lambda_3)CL+\beta(\lambda_3)]} \quad (5)$$

Among the formula, K($\lambda 1$), K($\lambda 2$), K($\lambda 3$) is coupling parameter of optical system; D($\lambda 1$), D($\lambda 2$), D($\lambda 3$) is the percent response of electrooptical device; $\beta(\lambda 1)$、$\beta(\lambda 2)$、$\beta(\lambda 3)$ is the interference factor of the wave path. [5]. From the formula (3), formula (4) and formula (5) the concentration of the being detected gas can be expressed as

$$C_{CH_4} = \frac{1}{[\alpha(\lambda_1) - \alpha(\lambda_3)]L}\left\{\ln\frac{I_0(\lambda_1)K(\lambda_1)D(\lambda_1)}{I_0(\lambda_3)K(\lambda_3)D(\lambda_3)} + \ln\frac{i(\lambda_3)}{i(\lambda_1)} + [\beta(\lambda_1) - \beta(\lambda_3)]\right\} \quad (6)$$

$$C_{CO} = \frac{1}{[\alpha(\lambda_2) - \alpha(\lambda_3)]L}\left\{\ln\frac{I_0(\lambda_2)K(\lambda_2)D(\lambda_2)}{I_0(\lambda_3)K(\lambda_3)D(\lambda_3)} + \ln\frac{i(\lambda_3)}{i(\lambda_2)} + [\beta(\lambda_2) - \beta(\lambda_3)]\right\} \quad (7)$$

Because the differences between $\beta(\lambda 1)$, $\beta(\lambda 2)$, $\beta(\lambda 3)$ is quite small, and the ray radiation almost enter and pass the being detected gas at the same time, therefore, there is approximate to:

$$\beta(\lambda_1) \approx \beta(\lambda_2) \quad (8)$$

$$\beta(\lambda_2) \approx \beta(\lambda_3) \quad (9)$$

Appropriate adjustment of optical system makes

$$I_0(\lambda_1)K(\lambda_1)D(\lambda_1) = I_0(\lambda_2)K(\lambda_2)D(\lambda_2) \quad (10)$$

$$I_0(\lambda_2)K(\lambda_2)D(\lambda_2) = I_0(\lambda_3)K(\lambda_3)D(\lambda_3) \quad (11)$$

Then formula (3-6) can simplified as

$$C_{CH4} = \frac{1}{[\alpha(\lambda_1) - \alpha(\lambda_3)]L} \ln \frac{i(\lambda_3)}{i(\lambda_1)} \quad (12)$$

$$C_{CO} = \frac{1}{[\alpha(\lambda_2) - \alpha(\lambda_3)]L} \ln \frac{i(\lambda_3)}{i(\lambda_2)} \quad (13)$$

During practical application, the light with wavelength λ1, λ2 correspond to the absorption line of gas that being detected , light of wavelength λ3 can not be absorbed by detected gas(reference wavelength), during the process of testing it is null value, have 1

$$\frac{i(\lambda_1)}{i(\lambda_3)} < 1; \frac{i(\lambda_2)}{i(\lambda_3)} < 1;$$

to carry out

Taylor expansion of $\frac{i(\lambda_1)}{i(\lambda_3)}, \frac{i(\lambda_2)}{i(\lambda_3)}$.

$$\ln \frac{i(\lambda_3)}{i(\lambda_1)} = -\ln\left[1 + \left(\frac{i(\lambda_1)}{i(\lambda_3)} - 1\right)\right] \approx \frac{i(\lambda_3) - i(\lambda_1)}{i(\lambda_3)} \quad (14)$$

$$\ln \frac{i(\lambda_3)}{i(\lambda_1)} = -\ln\left[1 + \left(\frac{i(\lambda_1)}{i(\lambda_3)} - 1\right)\right] \approx \frac{i(\lambda_3) - i(\lambda_2)}{i(\lambda_3)} \quad (15)$$

The gas concentration is

$$C_{CH4} = \frac{1}{[\alpha(\lambda_1) - \alpha(\lambda_3)]L} \frac{i(\lambda_3) - i(\lambda_1)}{i(\lambda_3)} \quad (16)$$

$$C_{CO} = \frac{1}{[\alpha(\lambda_2) - \alpha(\lambda_3)]L} \frac{i(\lambda_3) - i(\lambda_2)}{i(\lambda_3)} \quad (17)$$

Among wavelength λ1, λ2, λ3, as follows, if the absorption coefficient α（λ1）, α（λ2）, α（λ3）of gas can be measured, then the gas concentration of the two gas can determined through testing of i(λ1), i(λ2), i(λ3). It can be seen from the above formula that this kind of testing not only eliminated interference factor of wave path in principle, at the same time it eliminated influence of light output power instability. To survey and evaluate voltage signal of output mV level through pyroelectricity type detector, after amplified by the amplifier transferred to A/D to transform, after converting the digital signal put into the single chip, the single chip carried out relevant treatment and write in EEPROM, the single chip to do data read through IIC Communication. For the characteristics of pyroelectricity type detector have a certain degree of dependency with environmental temperature, and then add to temperature compensating circuit on circuit, to improve the accuracy and reliability of the detection circuit. Methane, CO uses a reference voltage to carry out calculation, reduce the circuit power consumption and singlechip data calculation. Infrared absorption gas sensor with Internal Integration temperature compensation sensor, can detecting the room temperature of coal mine shaft online, as illustrated in figure 4. The sensor can simultaneously satisfy the use of sniffing robot under situation of limited load capacity, the much higher density of integration of items of data detection underground of coal mine shaft.

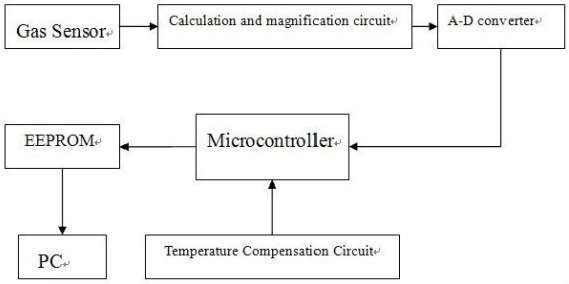

Figure 4. Gas Detection circuit Working Principle Block Diagram

The specific gravity of mash gas and CO which Coal Mine Detection Robot detected is little bit light; the sensor should be placed in the top of the sniffing robot. The advantages of infrared absorption gas sensor: simultaneously and rapidly detecting methane and CO, high sensitivity, good selectivity and fast response. The structure is simple, lightweight and portable, easy to be carried by sniffing robot, the range of

detecting of sensor is wide, and the search unit is not easy to be poison to aging. The sensor element, optical device and so on does not directly contact with the gas, be sacred from impact of gas itself, without problems of aging, weariness or burnout of sensor, easy to achieve structure meets explosion-proof requirements, agree with requirements for coal mine shaft explosion. During the detecting there is no need of oxygen and air, is suitable for gas detection in oxygen lack environment.

V. CONCLUSION

Coal Mine Detection Robot is required to detect various kind of gas, while the loan capacity of the explorative robot is limited. So the detection system of the explorative robot is mainly developing to microminiaturization, integration intelligentize, multi- functionalization, generalized and network and flushbonding Internet-based. At the same time high requirements for robot on long term operation stability, interchangeability, easy to be maintainability in increasing. The explorative robot uses improved infrared ray absorption prospecting instrument to detect methane, CO and temperature of such three group data, it has strong integration and microminiaturization. Moreover, multiple data can be detected and calculated simultaneously, so the response is fast using the same reference value. The range of the measurement is wide, under the situation of unknown circumstances of underground coal mine shaft it also can accurately detecting the gas content.

REFERENCES

[1] WANG Zhong-min, LIU Jun, DOU Zhi, Du Zhanling. Research and Application Status and Development of Search and Rescue Robot for Mine Disaster[J]. COAL MINE MACHINERY 2007, 28(11) . (in Chinese)

[2] Yang R T, Saunders J T. Adsorption of gases on coals and heat-treated coals at elevated temperature and pressure. Fuel, 1985 : 314-327. (in American)

[3] NADEZHDINSKII A, BEREZIN A, CHERNIN S, etal. High sensitivity methane analyzer based on tuned near infrared diode laser. Spectrochimica Acta Part A, 1999,55(10);2083-2089. (in Russian)

[4] Wartinell i R U. Near—infrared InGaAs／InP distributed-feedback lasers for spectroscopic applications. Proc. SPIE, 1994, 2 148 : 292-307. (in American)

[5]L. A. Kulakova, Zotova'V. Nonna, Karandashov, A. Sergey, Matveev, A. Boris. Si—Te Acousto-optic Modulator for Fiber Optic Gas Sensor Based on Midwave InGaAsSb／InAsSbP diode laser . Proceedings of SPIE . 1996 , 2895 (6) : 267-271. (in Russian)