Gas sensors and their selection

F.Hruska, S.Plsek

Abstract—Measurement of constitution and feature of gas gives information in content of gas components in mix or in their physical parameters. This measurement is used for environment protection, control of qualities of air in interior, control of quality of combustion at combustion motors and kettles, control and monitoring of chemical processes etc . Measurement has to do with emissions of components of gases at processes and emission, i. e. content of components of mixture of gases. Research results play signification role and development of electrochemical sensors. These elements are realized next to laboratory and industry technical means of measurement and portable equipment of personal protection. There is necessary recognize to study of electrochemical sensors and their application research in detail their principles, positives and negatives of particular methods for determination of concentration of particular gases and is necessary have knowledge in fabrication technique of signals from these sensors.

Keywords—gas mix, measurement of gas concentration, sensor, signal conditions.

I. Introduction

Today expansion of technology first of all semiconductor provides base for the development of electrochemical sensors too (1, 2, 3, 4). Herewith there is made metering of composition and feature of mixture of gases fully electronical way. Equipment using these sensors have smallness, are cheap, support reliable fiction and dispense processing of metering in laboratories. They use is in everyday practice. E.g. every modern car goes with minimum unhealthy waste products thanks sensing element for metering of oxygen content in exhaust gas. Boiler plant using rating gas natural gas works safely thanks indication escape of gas. Contents CO2, CO, sulphur oxide, nitrogen etc. in air, which we have breathe, are measured by the help of sensors very easily. Modern air - conditioning systems and air changing systems of buildings work more effective thanks sensors of VOC (volatile organic compound).

In technical practice there are used for metering of compound and of feature of gas equipment making use method:

- heat conductivity
- paramagnetic feature
- spectral analysis
- catalytical combustion
- industrial gas chromatography
- humidity measurement of air
- changes of electrical charges,
- solid - state principles.

There are methods and principles of chemical or physical chemical processes. At chemical principles there are proceed in interference of elements measured matters and sensor with their chemical conversion (reaction), happens to changes of matters and traces significant change some physical quantity.

Chemical changes of kind of matters are not at physical principles and make use of only chase some physical quantity measured matters. Interaction of matters of sensor and molecules of gas rise by kind of principle at particular sensors changes of physical parameters of material or changes of energy acted to sensor.

Aspects of function of electrochemical sensors, their specialties and principles of conditions of electric signals are in the following parts introduced for chosen sensors.

II. Aspects of Selection

The gas sensors use a lot of principles and specifying. Accordingly there is it very important to know the aspects of selection.

There are a wide range of issues which must be considered in order to ensure that a gas measurement system is suitable for its intended application. There play many factors soma special roles.

III. Problems of Gas Hazards

In the praxis there are the range of flammable, toxic, and asphyxiated gases and vapors. They are presented as potentially dangerous level in a environment.

Technology	***Flammable***	***Toxic***	***Asphyxiant***
Electrochemical	no	yes	yes
IR photometry	yes	yes	no
Pellistor	yes	no	no
Chemiluminiscence	no	yes	no
Colourimetry	yes	yes	no
Electrical conductivity	no	yes	no
FID sensor	yes	no	no
Photo-ionisation	yes	yes	no
Paramagnetic	no	no	yes
Semiconductors	yes	yes	no
Thermal conductivity	yes	yes	no
UV photometry	yes	yes	no

Table I Suitable sensor technologies for gas hazards

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While many of the available technologies are able to measure the gasses, there are used only specific sensors. In the table I there is presented the suitable technologies of sensors for different gas hazards.

For example by carbon monoxide there is a mixture of 0,03% in air is toxic, a mixture of 11% in air is flammable and toxic, a mixture of 20% in air is asphyxiant and is also flammable and toxic.

A. Problems of concentration range

Other problem can depend on the likely concentration of the gas in many cases the choice of sensor. Although some technologies are over a very wide range in theory capable of measuring. In most safety applications only a relatively small dynamic range is required. If it is necessary to monitor of concentrations over a wide dynamic range then it may be necessary to use two or more different types of sensors together.

Technology	***ppm***	***% LEL***	***% vol***
Electrochemical	yes	n/a	yes
IR photometry	yes	yes	yes
Pellistor	yes	yes	no
Chemiluminiscence	yes	n/a	no
Colourimetry	yes	no	no
Electrical conductivity	yes	n/a	no
FID sensor	no	no	no
Photo-ionisation	yes	no	no
Paramagnetic	yes	n/a	yes
Semiconductors	yes	no	no
Thermal conductivity	no	no	yes
UV photometry	yes	no	no

Table II Suitable sensor technologies for measuring ranges

The table II shows suitability of sensor technologies for different concentration ranges be definitions of ppm (parts per million), % LEL (Lower Explosive Limit) a % volume.

For example a combination of a pellistor based principle and either a thermal conductivity or IR absorption can be used to measure flammable gas concentrations between around 1% LEL up to 100% vol. But next the pellistor cannot measure concentrations abouve 100% LEL.

B. Types of measuring devices

The sensors could be applied for four type of devices: fixed installation, transportable, portable, or personal. Fixed and transportable implementation can be used for all technologies. The portable implementation can´t be for portable unit for chemiluminiscence principle. The personal devices don ´t use the chemiluminiscence, electrical conductivity, FID, photo-ionization, paramagnetic, thermal conductivity, UV photometry technologies.

C. Environment condition of measurement

The environment condition is very important to ensure that any sensors and measuring devices are able to perform satisfactorily. These conditions are: temperature, pressure, humidity of measured gas and air speed and a number of other parameters.

The table III has included typical parameters to right measurement of gas concentration.

Condition	***Flammable gas***	***Toxic gas***
Temperature	-25 to +55°C	-10 to +40°C
Pressure	80 to 110 kPa	90 to 110 kPa
Humidity	20 to 90% RH at 40°C	20 to 90% RH at 20°C
Air speed	Up to 6m/s	Up to 4 m/s

Table III Mean parameters of environmental conditions

The table IV demonstrates the sensitivity of sensor according to used technologies of sensors. There is showed, that environmental parameters can influence the result of sensor. A electronically circuits can compensate the influences.

Technology	***T***	***H***	***P***	***S***	***D***	***O2***
Electrochemical	yes	no	yes	no	no	yes
IR photometry	no	no	yes	no	yes	no
Pellistor	no	no	no	no	no	yes
Chemiluminiscence	no	no	no	no	no	no
Colourimetry		yes			yes	no
Electrical conductivity	yes	no	no	no	no	no
FID sensor	no	no	no	no	no	no
Photo-ionisation	no	no	no	no	no	no
Paramagnetic	no	no	yes	no	no	n/a
Semiconductors	yes	yes	no	yes	no	yes
Thermal conductivity	no	yes	no	yes	no	no
UV photometry	no		yes		yes	no

Table IV Sensitivity of sensor technologies to conditions (T-temperature, H – humidity, P-pressure, S-air speed, D-dust, O2 concentration).

Many safety applications require the measurement of low concentrations of hazardous gases. But there does problems the atmospheric air with an oxygen level around 21% vol. A reduced oxygen level may affect sensor function, depending on the type of principle. Some sensors require a minimum concentration to correct operate. In the table IV it is seen the oxygen doesn´t give the problem only for electrochemical, pellistor and semiconductor technologies.

D. Other influences for measurement

The gases consist a mixture of not one gas but of two and more gases. The concentration is function of partial pressure, e.g. for air in the atmosphere it is 210 mbar for oxygen, 780 mbar for nitrogen, 10 mbar for other gases for reference of 1000 mbar.

The sensor in transmitter needs to have the measured gas moved as far as on sensitive area of sensor. Some measurement systems have pump for transport of the gas into sensor. The flow must be constant and in given range.

Gas concentrations are expressed in a variety of units. The most used units are: volume fraction (v/v or vol), mass fraction as mass ratio or weight ratio (kg/kg), parts per million (ppm), % LEL (for low concentrations), mole fraction.

E. Encountered gases in the praxis environment

The list of encountered gases in the praxis environment is in the table V.

Name of gas	***Formula***	***Type of hazard***
Hydrogen	H_2	Toxic
Ozone	O_3	Toxic
Chlorine	Cl_2	Toxic
Nitrogen	N_2	Asphyxiant
Methane	CH_4	Flammable
Ethane	C_2H_6	Flammable
Propane	C_3H_8	Flammable
Pentane	C_5H_{12}	Flammable
Carbon monoxide	CO	Toxic
Carbon dioxide	CO_2	Toxic
Ammonia	NH_3	Toxic
Hydrogen sulphide	H_2S	Toxic
Hydrogen chloride	HCl	Toxic
Sulphur dioxide	SO_2	Toxic
Nitrogen monoxide	NO	Toxic
Nitrogen dioxide	NO_2	Toxic

Table V List of encountered gases and the principal hazard

F. Selection of industries and associated gases

Gas sensors are used for different application in industries. It is a wide variety of sites, ranges from car parks to power plants, from oil and gas platforms. The potentially dangerous gases associated with a selection of industries are listed in table VI.

Industry	***Hazards***	***Names of gases***
Water, wastewater treatment	Flammable, asphyxiant, toxic	Methane, hydrogen sulphide, chlorine, oxygen, ozone.
Steel	Flammable, asphyxiant, toxic	Carbon monoxide, oxygen.
Petrochemicals	Flammable, asphyxiant, toxic	Methane and other hydrocarbons, hydrogen sulphide, oxygen, carbon monoxide, carbon dioxide, nitrogen dioxide, sulphur dioxide, benzene.
Power plants	Flammable, toxic	Carbon monoxide, carbon dioxide, hydrogen, nitrogen monoxide and dioxide, sulphur dioxide, chorine, hydrazine.
Chemicals and pharmaceuticals	Toxic	Chlorine, carbon monoxide and dioxide, hydrogen chloride, oxygen, ozone, ammonia.
Agriculture	Flammable, toxic	Methane, carbon dioxide, hydrogen sulphide.
Semiconductors	Flammable, toxic	Solvent vapour, hydrogen chloride, hydrogen, chlorine, dopants such as arsine, stibine, germane.
Paper	Toxic	Chlorine, hydrogen sulphide.
Health issues	Flammable, toxic	Oxide, carbon monoxide and dioxide, ozone, ammonia, chlorine, hydrogen chloride.

Table V List of industries and associated gases

IV. Principle of Spectral Analysis

Absorption of electromagnetic or ionisation radiation at transit throught of mix gases is function of mixture proportion, its density and longitude of passing radiation (5). Dilution of intensity of radiation energy uses formula:

$$E = E_1.e^{-\mu\rho z} \qquad (1)$$

where's E_1 source intensity, μ mass coefficient of dilution (m^2/kg), ρ density, z distance of direction of radiation.

Mass coefficient of dilution for UV radiation at λ=147 nm is $1,7.10^4$ m^2/kg. Two - molar gases indeed have absorbing maximums for explicit wave longitude. E.g . CO_2 has absorbing maximum at wave longitude l=4,26 μm, H_2 at e=2,59 μm.

Absorption of monochromatic radiation in gas volume is controlled Lambert formula:

$$e^{k.l.c} = \left(\frac{I}{I_{out}}\right) \qquad (2)$$

where is k absorption coefficient depended upon wave longitude, kind of flow a gas concentration, l longitude track ray in flow, c gas concentration , I intensity ray on entrance (W/m^2), I_{out} intensity of beam in output (W/m^2).

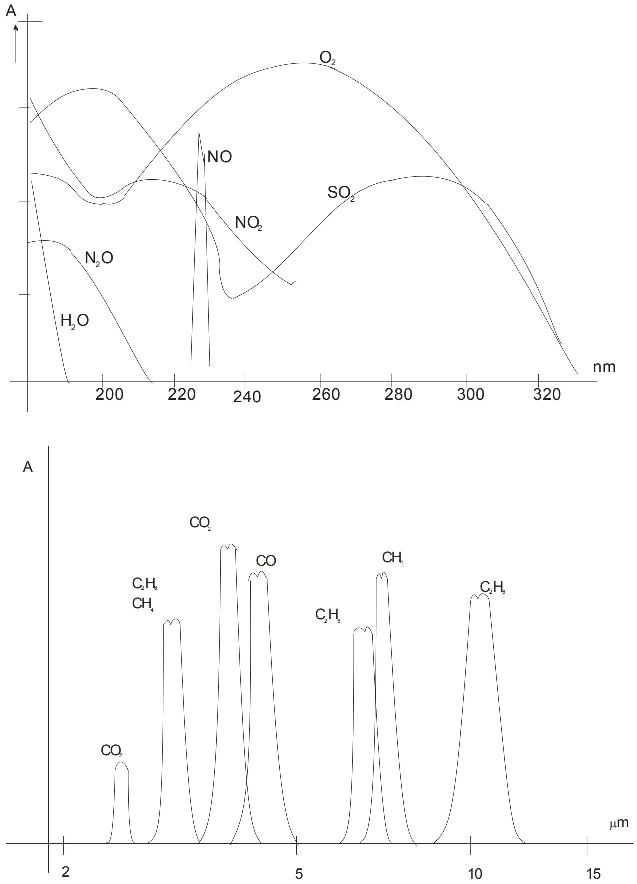


Fig. 1 Graphs of absorption dependencies of electromagnetic radiation at range of UV and IR for some gases.

Scheme of analyzer using principle of absorption of electromagnetic radiation is in Fig. 2.

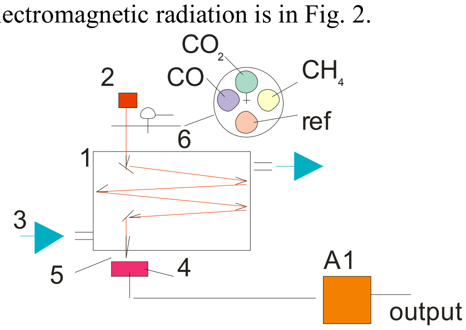
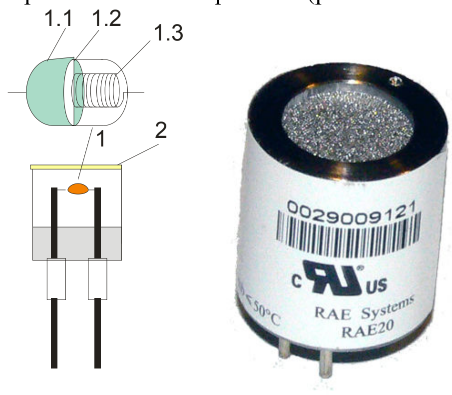


Fig. 2 Graphs of absorption dependencies of electromagnetic radiation at range of UV and IR for some gases

Sources of radiation (2) are accordance with type of radiation LED diode or special vacuum tube with short range of wave longitudes and accordant with input of intensity radiation. Beams are guided into chambers (1) and generally are multiple reflected on walls. Their intensity decreases and permeates across filter (5) into sensor (4). Signals from sensor are modified in unit (A1).

V. Principle of Catalyses

Catalytical combustion is a simple method to measurement of mixture of inflammable gas on hot-wire element (3,4,6, 8). Principle scheme displays fig.6. Technical solving of sensor is dual type. Design a) in Figure 3 is implementation with measuring chambers and evaluation electronics, design b) is compact sensor called pellistor (pelletised resistor).



a) b)

Figure 3 Catalytic sensor (a-schemes, c-real sensor RAE Systems)

Sensor accordance with design (b) in Figure 3 is compact version of catalytical principle. In cell there is pearl (1) on which measured gas inputs across strainer (2). Pearl is from mass of catalyzer (1.1, separation ceramics (1.2) and hot-wire element 1.3). Measured gas is oxidized, rises warm, which turns value of electrical resistance of hot-wire element. These changes are rate of concentration combustible gas. Actual implementation of sensor is shown in c) part of figure.

Output of limit sensor is described according to formule LEL (Lower Explosive limit):

$$V_{LEL} = K.D_{12}.\Delta H.(LEL) \qquad (3)$$

where K is constant of construction of pellistor and is structured in relation $m.c_{pp}.t_p$ of formula, D_{12} is diffusion coefficient , ΔH is thermal energy of oxidation, LEL is indicated output in % .

Diffusion coefficient has formula:

$$D_{12} = b.T^{1,5} / (\mu^{0,5} \delta_{12}^{2} \Omega(T^*)) \qquad (4)$$

where is b constant, T absolute mixture temperature of gas, μ is reduction of molecular mass of air and of gas, δ collision cross factor, Ω(T*) is collision integral.

Next formula is :

$$\mu = M_a M_g / (M_a + M_g) \qquad (5)$$

where M_{and} is molar weight of air, M_g gas,

$\delta_{12} = 0{,}1866.V_c^{1/3} Z_c^{-1,2}$, V_c is critical volume and Z_c is compression of gas and for

$$T^* = kT / \varepsilon_{12} \qquad (6)$$

where k is Boltzmann constant, e_{12} is Lenard- Jones parameter of power interaction as function of critical temperature and compression for air and gas.

VI. Potentiometry Principle

The principle makes use of gas detection , which are electrolytically convertible or oxidate on metal catalyzer, as are platinum or gold. Principle is analogue to electrochemical cells. Electric voltage between anode and cathode in electrolyte is changed according to gas concentration. Output can be voltage change (potentiometry) or in circuit with load resistor change of current (amperometry) (4).

According to the number of electrodes have produced sensors as two, tri and four - electrode.

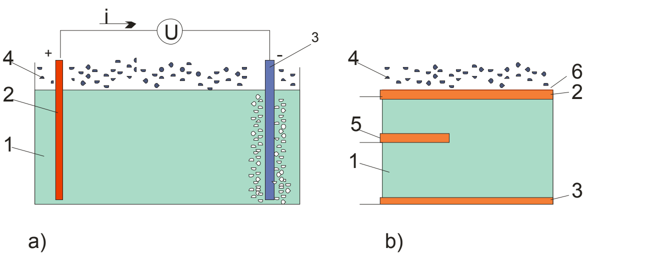


Figure 4 Graphs of absorption dependencies of electromagnetic radiation at range of UV and IR for some gases

In Figure 4 is: 1-electrolyte, 2 - sensing electrode/anode, 3 – cathode, 4 – measured gas, 5 – reference electrode, 6 – membrane.

Chemical formulas for reactionary action at metering of oxygen are:

$$O_2+2H_2O+4e^- = 4OH^-$$
$$2Pb + 4OH^- = 2PbO+2H_2O+4e^- \quad (7)$$

Formulas for oxidation reaction for CO are :

$$CO+H_2O= CO_2+2H^++2e^-$$
$$\tfrac{1}{2} O_2 +2H^++2e^- = H_2O \quad (8)$$

Potential rises or lead of electric potential generates at reduction process according to 4 electrons, at oxidation 2 electrons.

Signal condition circuit makes use the electronical evaluation the output signal. A Example of that evaluation is in Figure 5. The sensor has three electrodes, the output from the sensor is amplified, next two electrodes have auxiliary function.

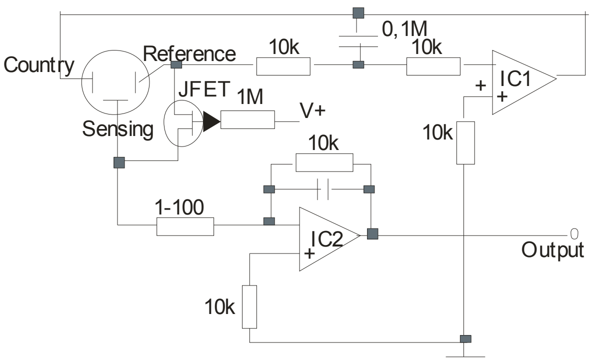


Figure 5 Scheme of circuit of signal evaluation of three-electrode sensor

Electrolyte is liquid, gel or solid substance. Sensors with solid electrolyte are potentiometric sensors too (9). Sensors with solid substance are used first of all measurement of content of oxygen in mixture of gases. Electrolyte is from substances of zircon, zirconium oxide- oxide zircon with ingredient yttrium oxide- oxide itria. Movement of ions is at higher temperatures above 300°C. Construction is given double - sided sheeting of cylinder material of electrolyte with porous metal (platinium, gold or silver). On one's side there is measured gas, on second is electrode to react with reference gas or atmosphere and air. According to differences of oxygen concentration (or differences of their partial pressure) at measured and reference gas rises on electrodes potential according to differences of concentration of oxygen. It is possible create also circuit with metering of current when in use external power supply. Chart of sensor with solid electrolyte is in Figure 6.

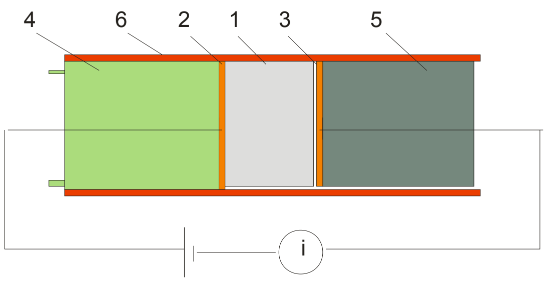


Figure 6 Scheme of solid electrolyte sensor

Solid electrolyte (1) is placed between two platinum electrodes (2, 3) between measuring chamber (4) and reference chamber (5). The sensor is heated of layer (6) on temperature several hundred degrees of Celsius. Measuring circle includes power supply and changes of flow are rate of concentration of gas. Supply potential have to create limit current accordance with concentration of measured components.

VII. Chemo-Resistor Principle

Chemo-resistor contains material, which changes valuables of electrical resistance accordance with concentration of measured of gas in mixtures, which is with its in contact. Sensitive material is generally built - up like thin layer on carrying flat. According to kind of these materials is achieved for concrete gases concrete parameters of range of interaction, i. e. measurement, accuracy, reproducibility, sensibility, response time etc .

At present world - wide manufacturers use by production of sensors metal-oxide and solid-state materials or polymeric materials.

Scheme of chemo-resistor with a thin layer of metal oxide is in Figure 7.

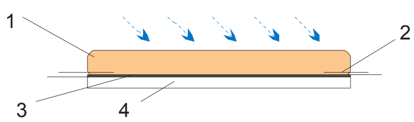


Figure 7 Structure scheme of chemo-resistor

Resistive material (1) turns its conductivity accordance with present of gas round. Sensitivity is established from heated filament (3). Measuring circuit is connected on electrodes (2). Optimal processes of measurement are for combustible and toxic gases, e.g . H_2, CH_4, C_3H_6, CO, NO_X, H_2S, AsH_3, SO_2, NH_3.

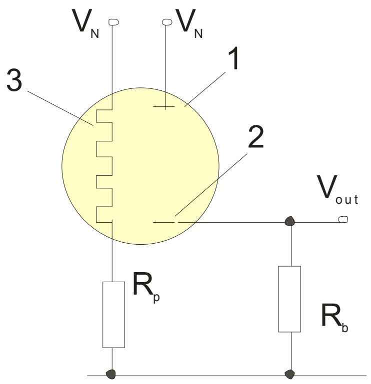


Figure 8 Electrical scheme of chemo-resistor

Wiring of chemo-rezistor is in Figure 8, where $\boldsymbol{V_H}$ is voltage of heating, $V_{\boldsymbol{n}}$ is voltage of power supply of active layer, $\boldsymbol{R_b}$ loading resistance, $V_{\boldsymbol{out}}$ is output signal.

Active layer of chemo-resistor created from conductive polymeric materials works so, that the measured gas is absorbed into those layer then there are come up changes of electrical resistance of whole layer. Acceptable there are e.g . thin layers from clean polymers as is polypyrrolene, polyaniline (it measures of gases methanolate, tetrachloride, ethanol, toluene, acetone, ammonia etc) or from composite polymeric materials doped most with black. Good results are achived also by polymers on base of polystyrene for humidity measurement in air and polyalinile for measurement of ammonia with range of change in resistance from 1Ω to the 1GΩ values.

VIII. Semiconductor Principle of oxidation

Solid - state oxidation sensors there're intended for detection of oxidation or reduction gases. The sensors have sensitive area on surface or are active whole capacity (13).

More ordinary sensors with surface detection are typically compound from area of oxide of metal (ZrO_{22}, SnO_{22}, TiO_2 etc.) round fine heating meanders (platinum or various oxides of metals). Areas absorb molecules of oxygen and when is it heated, happens to reaction activated oxygen with molecules of oxidation or reduction gases on surface area and is changed electrical conductivity of oxide area. So it is possible detect almost any oxidation gas and sensitivity is in range 20- 100 ppm.

If is reducing gas (H_{22}, CH_{44}, CO, H_{22S}, alcohol, izobutane), gas acts like donator of electrons into semiconductors and increases conductivity of surface of sensitive layer. Contrariwise, if is oxidizing gas (O_{22}, Cl_{22}, NO_{22}), it is acceptor of electrons and conductivity is decreased.

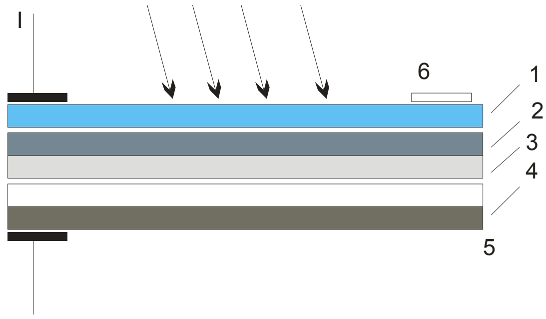


Figure 9 Scheme of oxidation semiconductor gas sensor

Scheme of solid - state sensor features Figure 9. Sensitive layer (1) is out of SnO_2 or ZnO with conductivity of N type and is in contact with measured gas. Other layers are: layer (2) out of SiO_2, layer (3) out of ferrite, layer (4) out of RuO_2 and layer (5) is substrate and isolation. Sensor is heated from temperature 200 as far as 450 °C. Contact layer (6) is out of gold, as well as leads. If power supply of sensor is constant DC voltage current *I* is turned accordance with adsorption of measured gas.

IX. CHEMFET Principle

At semiconductors CHEMFET there is achived potential between gate and substrate in consequence of adsorption of some gases on controlling electrode (14).

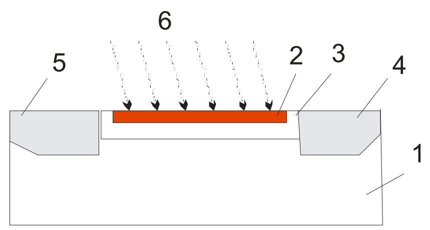


Figure 10 Scheme of CHEMFET sensor

In Figure 10 is: Substrate (1) is base of sensor from Si solid - state material with conductivity *PP*. Gate is metal control electrode made from Pd. It is sensitive to hydrogen and to gases, where is possible hydrogen split off, e.g . NH_3, H_2S. Gate is from substrate and from collector and source electrode separated for layer (3) from SiO_2 or TiO_2 or ZnO. Collector (4) and source electrode (5) are formed of semiconductor with conductivity of type *N*. Measured gas (6) has accessed to gate. Gas has molecule H_2, it is dissociated on surface Pd and rising dissociable atoms are adsorbed and further diffused as far as on interface gate - insulation material. There is created dipole-layer, which changes original potential and conductivity FET structures. Gate from metal Pd is able to function also like catalyzer and therefore conductivity is influenced also oxidation gases, like is O_2, Cl_2 or at higher temperature also reduction CO in mixtures H_2.

X. UV-ionosation Principle

Modern and newly evolved principle in the field of electrochemical sensors is principle photo-ionization (PID) by the help of radiation in the UV radiation (2). Scheme of sensor shows Fig. 11.

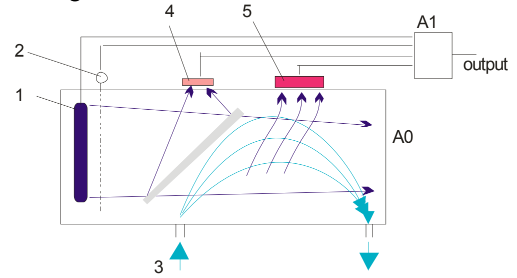


Fig. 11 Scheme of UV photo-ionization sensor

Sensors PID are suitable for measurement of concentration of hydrocarbons from steps of carbon C6 as far as C9, for gases and exhalation from petrolic fluids, O_{22}, VOC, H_{22}, H_{22S} and next toxic gases.

This method is very fit and highly sensitive for measurement of gas mix in interiors. There is used high energy of UV radiation from the source (1) showed in fig.6 regulated on grid (2). Electron is moved from neutrally charged gas molecule through elektro-luminiscence energy. Greater or more reactive molecules have lower ionizing energy than smaller or little reactive molecules. Greater molecules are more easily measurable. This principle has opposite characteristics against catalytical method. Therefore there're this methods complementary.

Intensity of UV radiation is measured sensor (4). Passing gas (3) trough chamber forms electro-luminescence, which is scanned photomultiplier (5). Electronic unit evaluates concentration of gases in mixtures and at the same time controls of processes of measurement.

XI. Thermal Conductivity Principle

The thermal conductivity is defined generally as a formula:

$$\lambda = \frac{Q.d}{S.\Delta t}, \tag{9}$$

where is Q thermal flow, S penetration area, $\Delta t=t_1-t_2$ difference of temperature, d thickness of layer.

Scheme of thermal flow across wall is demonstrated in fig. 12. The thermal conductivity of gas is a function of absolute temperature, molecular mass. It is independent on pressure up to range of technical vacuum. The thermal conductivity of choose gas is showed for 0°C in table VI. There is a relative thermal conductivity of gas to air.

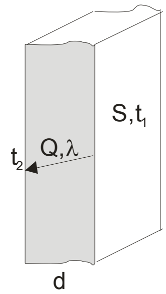


Fig. 12 Scheme of thermal conductivity across a wall

	λ (W/(m.K)	Realation to air
xenon	0,00519	0,215
crypton	0,00870	0,361
H_2S	0,01292	0,536
helium	0,01430	0,593
CO_2	0,01430	0,593
argon	0,01634	0,678
hydrogen	0,01720	0,714
CO	0,02333	0,968
nitrogen	0,02400	0,996
air	0,02410	1,000
oxygen	0,02450	1,017
acetylene	0,02991	1,241
methane	0,03020	1,253
neon	0,04583	1,902
SO_2	0,08332	3,457

Table VI Thermal conductivity of choose gases

The thermal conductivity is dependent on temperature too. The dependence can be a linear function (e.g. mathene) or a nonlinear and decreasing function (e.g. acetylene).

The total thermal conductivity of gas mixture is function of mol concentration of gases m_i and its thermal conductivity. The function is equal:

$$\lambda = \sum_i \lambda_i.m_i \tag{10}$$

Scheme of measuring equipment ("i.e." according to English abbreviation "TCD" – thermal conductivity detector too) of gas mixture according to thermal conductivity principle is showed in fig. 12.

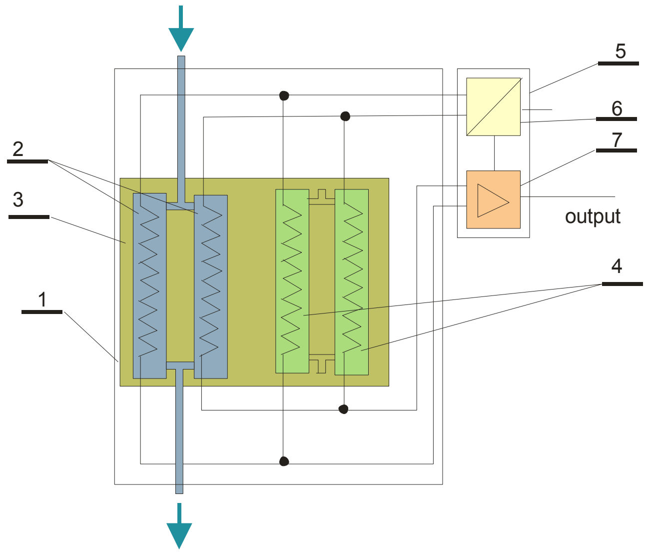


Fig.12 Scheme of measurement of gas mixture according to thermal conductivity

The measuring system contents for measured cuvettes, a source of heat and glow wires and electronic circuits with signal condition. There are two cuvettes with measured gas

(2) and two reference cuvettes (4) with comparison gas. The glow wires into the cuvettes are resistance sensors at once. They are from platinum. The thermal conductivity of tested gas changes the thermal flow from glow wires, at the same time there is changes intern temperature and next resistance of wires. The system is into specific thermal block (3).

The glowing is for constant electric power $\boldsymbol{P_q}$ that has according to proportions and parameters of chamber value:

$$P_q = R_0(1+\alpha t_d)I^2 = \frac{2\pi l\lambda(1+\beta t_p)(t_d - t_p)}{\ln(r_p/r_k)} \qquad (11)$$

where is α thermal coefficient of wire resistance, I supply current, t_d wir temperature (it is from 50 up to 200°C), R electric resistance of wire, λ coefficient of thermal conductivity of chamber walls, β coefficient of thermal conductivity of gas, t_p gas temperature , r_d diameter of wire, r_k diameter of cuvette.

The measurement system is connected to electronic unit (5) with supply (6) and amplifier (7).

Thermal conductivity sensors are produced in MEMS technology too. They only have a one half bridge unit with Ni temperature sensor and heat source. The power is about 5mW, time constant up to 5ms, time delay of gas filling is about 100 ms.

The thermal conductivity sensors can measure in range from 0 up to 100% vol. The one has combined with catalytic sensors at range of % LEL. The sensor has had high sensitivity, "e.g."the type NAP-21A at NEMOTO up to 0,2mV/% vol of CO_2.

The main advantages of thermal conductivity sensors are:

- fitness to binary mixture
- high sensitivity at gases with higher thermal conductivity (He, H_2, Ne, CH_4)
- quick response.

The negativeness is:

- output signal is dependent on extern temperature
- without possibility to measure more component mixture of gases
- without possibility to measure gases with small thermal conductivity ("e.g." CO, O_2, N_2, NH_3).

The fig.13 shows design of real thermal conductivity sensors and view on the MEMS sensor.

Fig.13 Design of sensors of measurement of gas mixture according to thermal conductivity and picture of its MEMS technology (NEMOTO).

XII. IMPORTANT PARAMETERS OF SENSORS

Now there are produced a lot of gas sensors with different principles. Main parameters of sensors, which are very important for its selection, are:

- Accuracy and repeatability
- Operating range
- Interference
- Warm-up time
- Response time
- Zero and span drift.

The accuracy of gas sensors is fundamental parameter that it involves a comparison with a true or accepted value. At the moment, the gas sensors have the accuracy up about 2% and more. Repeatability compares results of other measurements made in the same way.

The operation range of gas sensor is depended on used principle. It can be e.g. in ppm units, or % of LEL, or % of concentration.

Big problems come during the measurement of gas concentration with interferences. Gas sensors are affected to some extent by contaminations other gas than that is measured. In the real word there aren´t the concentrations with only the calibrated gas. The output can be changed up to high or low output signal. The ideal principle is which has sensitivity only for one gas.

Warm-up time is defined as the time necessary to measure with full performance, and the right accuracy after being turned on. The real value is from some seconds up to hours.

The response time is the important parameter with association the dynamic accuracy. The output signal of sensor has other characteristic by change of gas concentration. Often response time is defined as T63. The time signifies how long time is necessary to rich of 63% of final value. In the praxis there are used other parameters: T50 (for 50% of final value) and T95 (for 50% of final value). Learning and Comparison of modern gas sensors are very qualifiedly present in web-sides (6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20).

XIII. CONCLUSION

Presented text has given basic information in choice types of sensors for measurement of concentration of gas, which are going to be subject of interest at applied research in to next period at workplaces of faculty. It is going to have to perform analyses their possibilities and values of parameters to realize requirements. Between critical points there are parameters of range of measurement, direct and cross sensibilities of measurement, accuracy and uncertainties in measurement, characteristics, parasitic influences and further problems of condition of output signal. The information of paper helps to perfect decision to next work.

REFERENCES

[1] HRUSKA F.-PLSEK S. Electrochemical sensors for gas mix analysis. In: Proceeding of the 16th WSEAS International Conference on Systems. Pp. 345.- 350. ISBN 978-1-61804-108-1. Kos Island, Greece, July 14-17, 2012.

[2] HRUŠKA,F. *Senzory. Fyzikální principy,úpravy signálů, příklady použití.* (Ssensors. Physical Principles, signal conditions, Using examples.)Učební texty/Textbook. 2.vyd. Zlín: UTB ve Zlíně, září 2011, s.202. ISBN 978-80-7454-096-7

[3] Fraden J. Handbook of Modern Sensors. Physics, Designs, and Aplications. Springer, 2004, 3rd. edition, 579 p. ISBN-10:0-387-0750-4

[4] Vojáček A. Chemické senzory - chemiresistor & CHEMFET. Automatizace, 2007.

[5] SIRA Gas Detector Selection and Calibration Guide. First ed.,London-Witherby&Company Limited.Sira Technlogy Limited. ISBN 1-856-09-297-6, 2005..

[6] ALFASENSE. PID Sensors. 2011. In: http://www.alphasense.com/alphasense_sensors/pid_sensors.html

[7] EDINST. Omega Sensors. In: http://www.edinst.com/oemgassensors.htm

[8] PEWATRON. GasSensors. 2011. In: http://www.pewatron.com/de/produkte-loesungen/sensoren/physikalische-sensoren/gassensoren/

[9] E2V. Sensor IR1. 2011. In: http://www.e2v.com/assets/media/files/sensors_datasheets/IR/ir1xxx_ir2xxx_ser_1.pdf

[10] E2V. Sensor VQ500. 2011. In: http://www.e2v.com/assets/media/files/sensors_datasheets/pellistors/vq500_series.pdf

[11] ALFASENSE. Datasheet CHA3. 2011. In: http://www.alphasense.com/pdf/CHA3.pdf

[12] NENVITECH. Datasheet DS NET 4. 2011. In: http://www.nenvitech.com:8080/data_sheets_and_manuals/catalytic/ds-net4-10s

[13] CITYTECH. Datasheet of 2FO. 2011. In: http://www.de.citytech.com/PDF-Datasheets/2fo.pdf

[14] CITYTECH. Datasheet of AO3Z. 2011. In: http://www.de.citytech.com/PDF-Datasheets/a3oz.pdf

[15] MEMBRAPOR. Sensor-Brochure. 2011. In: http://www.membrapor.ch/sheet/Membrapor%20Brochure.pdf

[16] FIGAROSENSORS. Sensors. 2011. In: http://www.figarosensor.com/products/general.pdf)

[17] E2V. Sensor MICS. 2011. In: http://www.e2v.com/assets/media/files/sensors_datasheets/metal_oxide/MICS-5521.pdf

[18] E2V. MOS sensors. 2011. In: http://www.e2v.com/products-and-services/instrumentation-solutions/gas-sensors/application-notes/#metal_oxide

[19] NEMOTO. Sensors. 2011. In: http://www.nemoto.co.jp/en/products/sensor/index.html

[20] MEMBRAPOR. Sensors. 2011. In: http://www.membrapor.ch/sheet/Membrapor%20Brochure.pdf