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System for Synchronous Detection Trace of Explosives and Drags Substances on Human Fingers

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Abstract

The sampling unit of the device, based on ion mobility spectroscopy technique, for detection of ultra small (trace) substances concentration on human fingers and documents is described. The vapor pressure of many dangerous substances is very small; so the heating of an investigated surface is needed for effective detection. However the direct heating of the human fingers by irradiation of the gas-discharge lamp is not effective because a small concentration of the melamine (pigment of the black or brown color) in the skin of the human palm. Therefore in this work the combination of the two methods is used: a grid is heated by the irradiation of the gas-discharge lamp and a grid heats the surface of the finger which is pressed to a grid.

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Keywords: laser; MEMS; microhotplate; gas sensor;

1. Introduction

The presence of residual molecules in the air is usually determined using highly sensitive gas analyzers such as ion mobility spectrometers which are suitable for detecting trace amount of explosives and other compounds [1-6]. Concentration of detected material molecules in the sample gas determines the sensitivity of such devices. However, one of the areas of practical interest is to detect trace amounts of substance on the surface.

Heating of surface [7-10] enhances vaporization, increases the concentration of molecules in the gas sample, and improves the sensitivity of the instrument with the direct study of the gas near the surface. The surface can be heated by the gas stream directed at the surface, the transfer of heat from the heated body to the surface by conduction through the air gap or by direct contact, radiative way directional flow of infrared or other material analyzed surface absorbed radiation.

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The momentum of heated normal flow of air is low enough due to the low heat capacity of air. In addition, the gas stream carries substances from the surface of the evaporation zone study or strongly dilutes gas near the surface. The use of the heating flow over the surface, such as water vapor, greatly complicates the design, followed by condensation on the surface, has limitations in the detection in environments with high humidity. Also strongly heated air is a problem due to overheating and damage of the analyzed surface.

The transfer of heat from the heated body to the surface by conduction through the air gap has a lower efficiency because of the low thermal conductivity of air. Heat transfer energy 60J to the surface 0,001m^2 with the air gap of 1 mm is available when the heater temperature is 500°C above the temperature of the heated surface. Together with the structural problems in the implementation of this method, the personal safety limitations arise, as well as the possibility of the analyzed surface overheating and the dust combustion on the heater surface.

The radiative heating does not cause significant disturbance of air near the surface being analyzed. In addition, the radiative heating can be performed remotely. Using the mechanism of surface heating by radiation, for the conditions listed in the previous example, the heat radiating surface will need a temperature of up to 400°C, which obviously has significant limitations related to the case of heating by conduction of the air gap. The effectiveness of surface radiative heating can be significantly improved by using a pulsed mode [11].

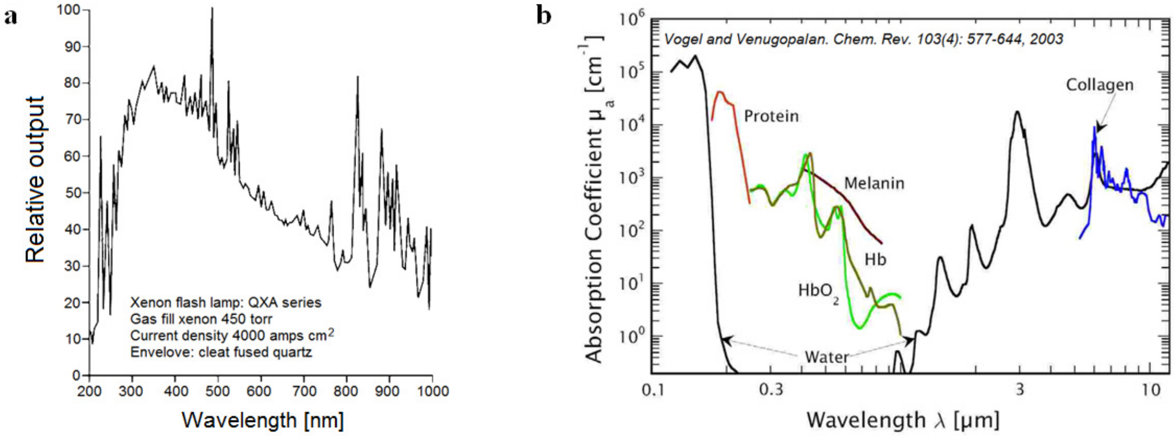

Fig. 1. (a) The emission spectrum of a xenon flash lamp with a high current density. (b) Optical absorption spectrum of human tissue.

2. Experiment

The objective of the development was to analyze available on the pulsed discharge lamp IFK-120 with emission spectrum present on Fig. 1, a. The peculiarity of the lamp is small in size (the body of the luminous part is U-shaped and have 5 x 23 x 30 mm dimensions) at a sufficiently high energy flare. Operating voltage is low. It is designed for portable handheld flash and alarms.

The absorption of light determines the optical properties of absorption in the visible light for the human tissue (Fig. 1, b) by hemoglobin (Hb and HbO_2) and melanin. In the superficial layers of skin absorption is predominantly in the melanin - the pigment of brown and black, which determines the color of skin, hair and iris of the eye. As a rule, the content of melanin in the skin of human hands is low so it should expect that the heating of human skin by light flash lamp will exist at a sufficiently thick layer, the share or unit millimeters. Therefore, the advantages of pulsed heating associated with an active energy release in a thin surface layer to the surface of human hands have significant limitations.

In the study of the surface of the documents in the presence of trace amounts of explosives and other compounds, pulsed radiation heating may be subjected to paper or cover paper. As a general rule, identification documents made of thick colored paper. For such a material reflection of light it is not exceeding 50%, and the absorption of the passage of a single sheet of up to 80%. This result corresponds to a complete separation of the sheet (typically thickness $0.125*10^{-3}$m) to 40% of the energy of the incident light. When the absorbed energy 10J section of the paper and the density of 0,15 kg/m^2 square 0,001m^2 warmed by more than 60°C. If the efficiency of generation of a light bulb is 25%, for the example above, will need electrical power flash 100J. This option is in the operating modes of the lamp IFK-120. The absorption of light in the plastic cover is a similar absorption in paper or better (except for the transparent cover). Contact method can solve the problem by the heating of the surface of human skin. This process creates a pulse heating with a small net mesh size, such as $0.5*10^{-3}$m and optical transparency of 50%. The surface of a finger pressed against the grid. One possible way, that is either electrical or radiation, the grid pulsed heat and contact heat transfer of the analyzed surface. The optical transparency of the mesh provides an effective evacuation of evaporation from the surface.

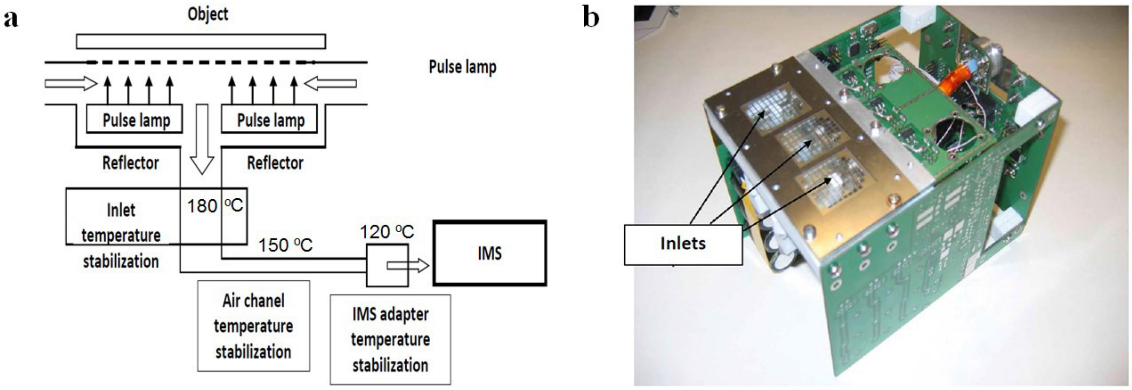

Fig. 2. (a) Block diagram of the sampling device with a pulse of radiation heating of the surface; (b) Sampling device, the front view.

3. Result and discussion

The structure of the sampling device present in Fig. 2, a. The test object takes place at the information areas of the study, made in the form of a grid of high transparency and low thermal capacity. From the volume under the mesh is continuously sampling the air, the gas enters the channel ion mobility spectrometer. After placing the object under study, it is initiated to the grid flash lamp pulse, resulting in rapid heating of the surface of the object and the evaporation of particles of matter. The air flow delivers vapor to the ion mobility spectrometer.

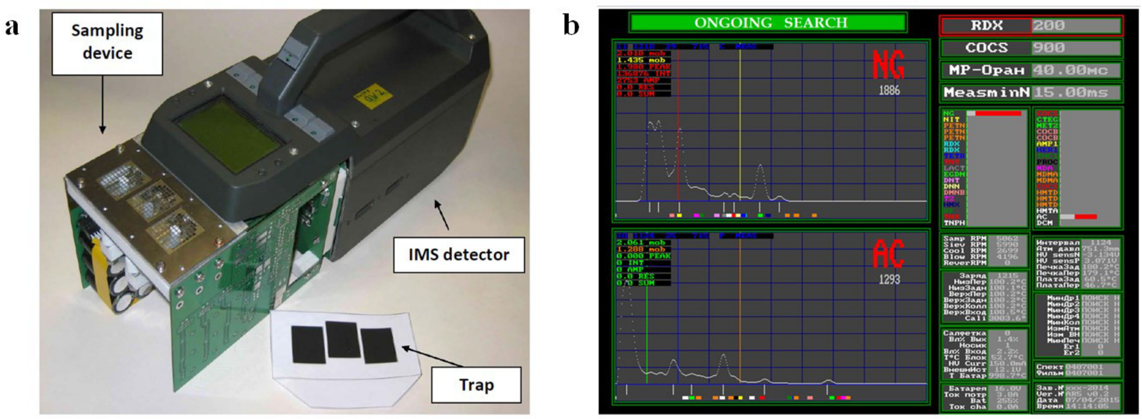

Fig. 3. (a) The sampling device connected with ion mobility spectrometer; (b) Screenshot of ion mobile spectrometer service program. The result of simulations detection of explosives and drugs. Top spectrum is negative and show response to trace of Nitroglycerin. Bottom spectrum is positive and show response to Procaine.

Structurally the sampling unit of IMS device has three separate areas - windows for sample inlet (Fig. 2, b). Person should locate three fingers or at intermediate carrier of the replica (napkin). The two gas-discharge lamps settle down input grid areas. The grids are transparent and have a subtle thermal capacity. After location an examined object above grids, the flash of gas-discharge lamps is started. That leads to a very quick heating of the tested object surface and evaporation particle from the surface. The impulse power equals 25J, and the time of the energy release is $5*10^{-2}$ s. The evaporated molecules move from tested surface as narrow group to ion mobility spectrometer (Fig. 3, a). The sampling unit has a system with three levels of the temperature stabilization: 180°C in sample inlet area, 150°C in gas transfer channel, 120°C in interface module where the sampling unit has links with the ion mobility spectrometer. Operating software synchronizes the initiation of the gas-discharge lamp operation, molecule group moving and the process ionization in the ion mobility spectrometer. Thus, the sampling unit and spectrometer are integrated into total construction and control program device. Finding space object on the grid can be accomplished by conventional methods, using optical or capacitive sensors. To ensure proper operation of the system requires stabilization of the temperature of all elements of the gas channel. The sampling device has a separate system of temperature stabilization in three successive areas of transportation of the sample.

The ion mobility spectrometer has two drift tubes and corona discharge source generating positive and negative ions that gives opportunity in same time to analyze both drugs and explosives [5]. The results of simulations detection of explosives and drugs are presented on Fig. 3, b. During experiments as imitator traces of explosive used Nitroglycerin tablets, and as imitator of drugs used Procaine tablets which touched by people take part in test of developed system (Tablets were taken in the hand once for a few seconds).

4. Conclusion

The device was designed and created during the experiments which showed its functionality and suitability for the detection of trace amounts of explosives and drugs. Studies include experiments with samples of used Nitroglycerin and Procaine by ion mobility spectrometer with corona discharge ion source. Applying the mentioned above construction allowed to provide reliable high-speed sampling of trace concentrations of explosives and drugs from the surface of the fingers. The module structure of the device makes it easy to upgrade the system to the real conditions of detecting trace amounts of chemicals. In particular, there exists the need to optimize power consumption and software to reduce the size and modify the mechanical component of the system.

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