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Fluctuation-enhanced scent sensing using a single gas sensor

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ABSTRACT

Scent or aroma sensing during aromatherapy can be carried out by applying only a single resistance gas sensor (TGS – Taguchi Gas Sensors). This paper considers the efficiency of detection of essential oils by DC resistance and its fluctuations observed in TGS sensors. A detailed study has been conducted for scents emitted by five popular essential oils using three sensor types (TGS 2600, TGS 2602, TGS 823). The research was focused on the practical use in aromatherapy to assure the same intensity of scents which are sprayed by a glass nebulizer. The prepared system for scent emission and control of its intensity was presented as well.

1. Introduction

Nowadays aromatherapy, which affects human senses and feelings, becomes more and more popular. It is believed that essential oil scents are helpful to people with dementia. In particular that therapy can reduce agitation, anxiety and insomnia as a result of relatively inexpensive treatment [1]. Another good example of aromatherapy application is reduction of appetite at the presence of peppermint scent that may lead to weight reduction [2]. It has been also shown that perception and learning skills of human beings can be improved by selected scents of essential oils. The experiments indicate that lavender or lemon aromas could be used during lessons and examinations to increase learning performance and student achievements, as well as reducing agitation during breaks [3]. Finally, scents are successfully used for increasing sales by influencing customer behavior. For example, a geranium scent improved brand evaluations and lavender affected both length of time and the amount of money spent in restaurants [4].

The mentioned examples show clearly that aromatherapy is a very influential factor for human behavior and feelings. Unfortunately, the effectiveness of aromatherapy is often not well recognized due to weak repeatability of scent emission and its individual reception by human beings. Therefore there is a demand for techniques that could monitor aroma intensity and control more precisely the process of scent emission. This paper presents briefly the prepared scent emitting device and explores possibilities of scents detection by two techniques that can be easily utilized in practice.

2. Techniques of essential Oil diffusion

There are two popular types of scent emission systems that are currently available on the market. The first one is based on spraying aromas, by hand or by an electronic device, in the given instants. This method uses a nebulizer to produce a mist of scent. The nebulizer produces tiny drops of essential oils by utilizing ultrasound vibrations or compressed air as the driving force. This solution is popular due to fast scent emission and low energy consumption.

Another commonly used method is based on heating (e.g., by flame of a candle) water with a few drops of essential oil. The scent vaporizes by a diffusion process. This method is very cheap but much more slower than the previous one. Additionally, higher temperature can lead to some disadvantageous chemical reactions within the essential oils that could destruct the final effect.

The first-mentioned method can be easily modified to be used in aromatherapy when repeatability of the emitted scent intensity is important. This result could be achieved by applying a selected resistance gas sensor to measure its response to the changes of ambient atmosphere and by a control unit that affects the scent emission intensity, e.g., by altering the air pressure or fan speed (Fig. 1). However, DC resistance measurements of the TGS sensor can be insufficient to detect low concentrations of the emitted scents. Therefore, we propose additional method to improve the efficiency of aroma detection. The proposed method is called fluctuation enhanced sensing (FES) and utilizes resistance fluctuations

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Fig. 1. Nebulizer for oil essential scents emission powered by compressed air (left) and the prepared prototype device (right) that can emit four different aromas.

of gas sensor which give additional information about their ambient atmosphere.

2.1. Scent emitting device

A new device was applied to emit essential oil scents. The device comprises four independent nebulizers powered by the same pump and electronics. The method of scent emission bases on mechanically spreading small oil drops by applying specially formed tiny glass pipes (Fig. 1) and an air pump. This setup produces low pressure, over the pipe filled with aroma oil stored at the flask bottom. The pressure produced by the applied air pump will affect the speed of aroma emission. The same effect is obtained by changing the speed of the fan used to spread aroma within the whole room. Both elements can be easily controlled by a cheap electronic circuit.

Another advantage of the proposed solution is that sprayed odor drops have very small dimensions (~1 μm) which means fast and efficient smell spreading. Additionally, the smaller molecules combine more easily with air molecules what results in longer aroma presence.

2.2. Resistance gas sensors

Measurements of scent intensity were carried out by applying Taguchi gas sensors (TGS) that are reliable and popular gas sensors available on the market. Such sensors (Fig. 2) change their DC resistance in the presence of different gases in their ambient atmosphere. The gas-sensitive layer (e.g., SnO_2) of these sensors is preheated to an elevated temperature. Such conditions increase the probability of gas molecule adsorption on the gas-sensitive layer surface. The layer comprises grains of different size. The adsorption processes change potential barriers between the grains; that results in a decrease of DC resistance. The same processes are responsible for fluctuations of potential barriers between the grains that are observed as sensor resistance fluctuations.

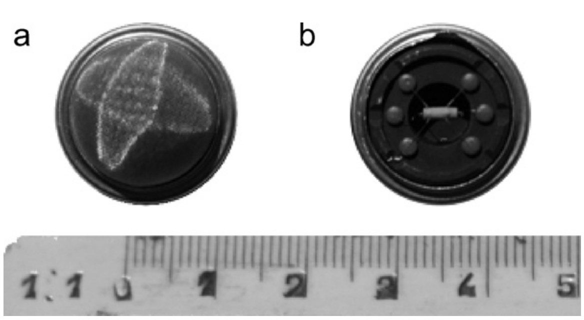

Fig. 2. Taguchi gas sensor (TGS) produced by Figaro company: (a) the purchased sensor type TGS 826, (b) uncovered gas sensitive layer covering a tube with an inside heater and outside contacts.

The applied gas sensors were optimized to detect air pollutants or hazardous and explosive gases but we can expect their reaction to various scents (e.g., aroma oil fragrance). It was assumed that during aromatherapy various air pollutants (e.g., cigarette smoke, fungus odours) are diminished by ventilating air in the therapy room. Otherwise, aromatherapy would not be effective due to unpredictable and often adverse effects caused by the mentioned pollutants.

The ambient atmosphere changes affect resistance fluctuations as well and can be utilized as a source of useful information, which can strongly improve the sensitivity and selectivity of gas detection [5–8]. Usually, the resistance fluctuations within a gas sensor can be observed as voltage fluctuations across the polarized sensor [5]. The observed fluctuations can be analyzed by the estimated power spectral density $S(f)$ using the fast Fourier transform (FFT algorithm) [9,10]. This algorithm can be implemented in a computer that controls the device. Other statistical functions or parameters of the observed fluctuations that could improve aroma detection are kurtosis, skewness or probability distribution.

2.3. Measurement setup

During measurements the gas sensor was placed inside a gas chamber which was filled through a pipe with air sucked in the vicinity of the scent-emitting device. Voltage fluctuations across the gas sensor, which was polarized by an adjustable DC voltage, were amplified by a low-noise voltage preamplifier. A cheap JFET transistor (2SK170) was used to provide such a preamplifier with a voltage gain in the range of $K = 200/800$ V/V [11,12]. Batteries were used to polarize the applied sensor and to supply voltage to the mentioned low-noise preamplifier. The DC voltage component across the gas sensor was measured at the output of a low-pass RC filter that comprised a capacitor C and a resistor R being a few orders greater than the sensor resistance R_s. Polarization of the gas sensor was adjusted by a potentiometer, connected to the sensor by a resistor $R_1 = 11$ kΩ of a value similar to the sensor resistance (Fig. 3). An additional capacitor at the potentiometer output was used to reduce outside interference and the noise component from the applied DC voltage source. The amplified AC voltage component $U(t)$ was measured by a Stanford SR760 spectrum analyzer and a parallel National Instruments PCI-4474 data acquisition card. The spectrum analyzer was used to estimate power spectrum and data acquisition card was used to record voltage samples for kurtosis estimation. The DC voltage across the sensor was mea-