Human Olfactory Interface for Odor Modulation Utilizing Gas Adsorption and Desorption: Evaluation of Separation Performance of Odorous Substances in Adsorption Process

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Abstract. This paper proposes a human olfactory interface that modulates airborne odors and enables the users to selectively sniff only the odors that they want. Air containing odors is collected and exposed onto plural types of adsorbents for separation and concentration of odorous substances contained in the odors. The desorbed substances from the adsorbents are mixed at different ratios from the original odors for modulation. This paper describes preliminary work on the evaluation of separation performance of odorous substances in adsorption process. As a provisional target, two kinds of odorous substances, 1-Nonanol and (−)-Carvone, were selected. 1-Nonanol smells like citronella oil and (−)-Carvone smells like spearmint. An odor generated by mixing these two substances smells a similar odor of (+)-Carvone which smells like sweet caraway. In order to separate each substance from the mixture, adsorbents were selected based on the molecular diameters and adsorption capability. Sensory tests with the triangle test were conducted to assess the separation capability of the selected adsorbents. An expected performance was not observed. More detail investigation including quantitative measurement with a gas chromatography will be needed for future work.

Keywords: Olfactory interface · Olfaction · Odor.

1 Introduction

Odors affect human psychological status and performance[1]. Taking preferable odors for individuals into their daily life has great potential to improve the

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quality of life. On the contrary, there are many variety of products to remove unfavorable odors, including air purifiers and refresher sprays. However, as far as the authors know, there are no attempts to dynamically modulate odors by adjusting the proportion of chemical substances contained in the odors.

This research aims to develop a human olfactory interface system that can modulate airborne odors so as to allow the users to selectively sniff only the odors that they want. The development of the proposed system is inspired by our previous research on an odor amplifier using an adsorbent [2]. Figure 1 shows a conceptual diagram of the proposed system. An airborne odor including multiple odorous substances is introduced into multiple types of adsorbents with different adsorption characteristics for separation. When presenting a modulated odor, the proportion of the odorous substances contained in the odor are changed by controlling the amount of desorbed odorous substances from each adsorbent. This paper describes preliminary work on the evaluation of the separation performance in the adsorption process.

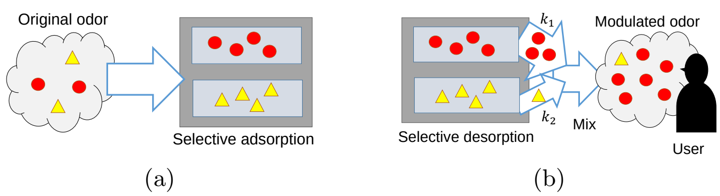

Fig. 1. Conceptual diagram of odor modulation. (a) Odorous substances in airborne odor are separated using multiple adsorbents with different adsorption characteristics. (b) Odor is modulated by adjusting each amounts of desorbed odorous substance.

2 Outline of Proposed System

The schematic diagram of the system is shown in Fig. 2. In the adsorption process of odorous substances, the airborne odor sucked using an air pump passes through all adsorbents as shown in Fig. 2(a). In the desorption process, the flow rate of clean air sent into each adsorbrent is adjusted with a solenoid valve as shown in Fig. 2(b) in order to modulate the original odor by changing the proportion of odorous substances contained in the odor.

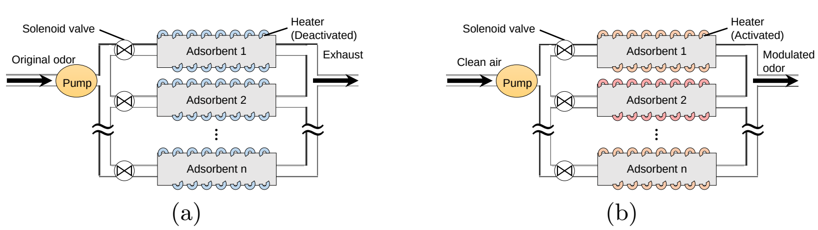

Fig. 2. Schematic diagram of the proposed system (a) in adsorption process to separate odorous substances and (b) in desorption process to presented a modulated odor.

3 Selection of Adsorbents

As a provisional target, two kinds of chemical substances, 1-Nonanol and (−)-Carvone, were selected. 1-Nonanol smells like citronella oil and (−)-Carvone smells like spearmint. An odor generated by mixing these two substances smells a similar odor of (+)-Carvone which smells like sweet caraway. In order to separate each substance from the mixture of 1-Nonanol and (−)-Carvone, we decided to use synthetic zeolites because of availability and affordability.

Zeolites are microporous crystalline aluminosilicates that adsorb surrounding molecules [3]. Each zeolite has a specific size pores and can only adsorb molecules smaller than the size of the pores. The adsorbed molecules on zeolites can be desorb by heating them. As a result of manual calculation by the authors, the effective diameters of 1-Nonanol and (−)-Carvone are 0.18–1.33 nm and 0.62–1.11 nm, respectively. We selected a pellet type of commercially available synthetic zeolites, Molecular Sieves 3A, which is sold by Nacalai Tesque, Inc. The effective diameter of adsorbable molecules on to Molecular Sieves 3A is less than 0.3 nm. Therefore, we estimated that Molecular Sieves 3A adsorbs only (−)-Carvone.

4 Evaluation of Separation Performance

To examine the separation in the adsorption process, a mixture gas was generated by bubbling the mixture of liquid phase of 15 mL each of 1-Nonanol and (−)-Carvone with air at a flow rate of 2.0 L/min. The mixture gas was introduced through 2.0 g of Molecular Sieve 3A contained in a polyethylene tube (ϕ 20 mm, length 50 mm). We expected that the exhaust through the adsorbent contains 1-Nonanol only.

Sensory tests with the triangle odor bag method were conducted to check if our expectation is correct. The method is commonly used in Japan for olfactory-related sensory evaluation including determination of odor detection threshold [4]. Subjects of the method are instructed to compare the smell in each odor bag and to pick a bag that is different from the other two bags. The probability of the subjects' selections is statistically checked using the binomial test compared with that of random choice. Although chemical analysis equipment such a gas chromatograph is able to accurately quantify the contents of the exhaust, we chose conducting sensory tests for the evaluation in this research because the execution is relatively easier for us.

If there is no difference between the adsorption rate of 1-Nonanol and that of (−)-Carvone onto Molecular Sieves 3A are same, the exhaust is the same as the diluted mixture gas at a rate. We conducted sensory tests in which participants were instructed to compare the exhaust gas with diluted mixture gases. The diluted mixture gas was generated by bubbling the diluted liquid mixtures of 1-Nonanol and (−)-Carvone with liquid paraffin at four volume concentration levels, 10%, 1%, 0.5% and 0.1%.

Three odor bags were prepared for each trial. One contains the exhaust through the adsorbent, and the others contain the diluted mixture gas at one of the four concentration levels. A subject did the comparison with the three odor bags at each concentration level, which means that a subject conducted four trials each. The order of presented concentration were adjusted among the subjects to reduce the order effect. 8 subjects (21–25 years old) participated.

The identification rate of the exhaust at each concentration level is shown with the blue dot in Fig. 3. The subject significantly distinguished the exhaust at all the concentration levels, which suggests that adsorption characteristic of Molecular Sieves 3A differs between 1-Nonanol and (−)-Carvone.

For further investigation, we conducted other sensory tests using either 1-Nonanol or (−)-Carvone with the same procedure as the sensory test using the mixture gas as described above. The number of the subjects who participated in the sensory test was also 8. Several subjects participated in multiple tests. The age range of the subjects were also 21–25 years old. The identification rates are also shown in Fig. 3 as red triangles and orange rhombuses. We performed the binomial test under each condition to see if the accuracy rate was significantly higher than when the odors were indistinguishable. The identification rates of 1-Nonanol and (−)-Carvone are similar, although we expected that the identification rates of (−)-Carvone are similar to those of the mixture gas.

As a result of the sensory tests, an expected separation performance was not observed. However, the separation performance has not been denied with the results. We will continue further investigation including well-designed sensory tests and quantitative measurement using a gas chromatography.

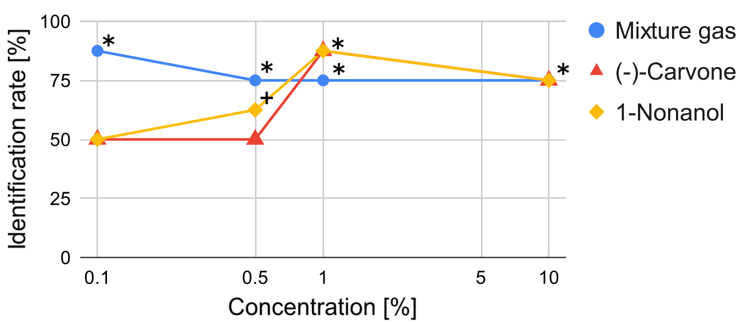

Fig. 3. Identification rates of the exhaust through adsorbent when comparing it with gas generated using diluted liquid substances. ($*$: $p < 0.05$, $+$: $p < 0.1$)

5 Conclusions

The authors have attempted to develop an olfactory interface that can modulate airborne odors. This paper describes the experiments to evaluate the separation performance of odorous substances in the adsorption process. An estimated separation performance was not confirmed with the provisional adsorbent selected by the authors. Further investigation including measurement using a experimental equipment to obtain quantitative evaluation should be needed for future work.

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