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후각 메카니즘을 모방한 냄새 센서의 개발 연구

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Development of Odorant Sensor System using Six Channel Lipid-Coated SAW Resonator Devices imitating the Olfactory Mechanizm

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Abstract

A sensitive surface acoustic wave (SAW) sensor for the detection of odorants has been constructed by depositing different phospholipids and fatty acids on the surface of the SAW device with the Langmuir-Blodgett technique. The characteristics of SAW device operating at 310 MHz deposited with phosphatidylcholine were analyzed. Amyl acetate, acetoin, menthone and other organic gases showed different affinities. The identification of odorants depending on the species of lipid used for coating is discussed in terms of the similarity of the normalized resonant frequency shift pattern. Using a number of different lipid-coated SAW devices, odorants could be identified by a neural-network pattern recognition with back-propagation algorithm.

Introduction

The authors have been studying on the odorant detection system using natural lipids modified AT-cut piezoelectric crystals. Theoretically, the sensitivity of piezoelectric detectors is directly proportional to the square of resonant frequency, and inversely proportional to the surface area. So, surface acoustic wave (SAW) resonators can be applied as chemical vapour sensors if appropriate adsorptive coatings are deposited on the surface. This sensor offers many attractive features to be used as chemical vapour sensors. In this study, aiming to develop a higher sensitive odorant detection system, a novel sensor system using an array of SAW devices incorporating LB film is being developed.

The olfactory receptor of odorants is not very well understood. Odorant molecules are mostly lipophilic and have therefore affinity to lipids. Kurihara et al. emphasized the importance of lipids in olfactory cells for odorant detection. They hypothesized that lipid layer acts in the detection of odorant in the olfactory cell even if lipid layer does not have specificity to odorants. And they summarized and concluded the pattern recognition mechanism of odor discrimination. Therefore based these assumptions, a sensitive SAW device for the detection of odorants has been constructed by depositing different phospholipids and fatty acids on the surface of device.

In this paper, we investigated the properties of SAW resonator as odorant sensor. An array of SAW resonators coated with six types of lipids were examined as chemical vapour sensors. The identification of odorants is discussed by comparing the behavior of the normalized resonant frequency shift pattern depending on the coated phospholipid. Using a number of different lipid-coated SAW devices, odorants could be identified by a neural-network pattern recognition with back-propagation algorithm.

Experimental

The SAW oscillators (SRU 310) fabricated on Y cut (cut angle = 36 degree) X propagating quartz using standard photolithographic techniques were obtained from Toshiba Co.. The device consisted of a two port resonator (Fig.1). The electrodes were metallized using aluminium. The interdigital transducer (IDT) consisted of 55 pairs with a half wavelength finger space of 5.1 μm. The Grating Reflector (GR) has 230 grooves with half wavelength finger. The space between the IDTs' was 65 μm, because the insertion loss is smallest at this distance. The resonant frequency is 310 MHz.

The quality of phospholipids was checked by measuring the isotherms using LB trough (Kuhn-type, Takahashi). The deposition of monolayers was performed by the method of Langmuir-Schaefer at a surface pressure of 15 mN/m. The speed of the filmlift was kept at 6 mm/min. The SAW device was set parallel to the surface of the LB trough and the lift moved up and down automatically. With this method, it was possible to cover the SAW device and to make it reproducible up to 40 monolayers of the X-type structure.

The schematic diagram of the experiment is shown in Fig. 2. The experiment apparatus was composed of lipid-coated SAW devices, vessel, gas permeater, Network/Spectrum analyzer, and microcomputer. The lipid-coated SAW devices were placed into a clean dry air for 3 h prior to measurement of odorants. The SAW resonator was fixed on top of a small vessel which has two valves. The volume of the vessel was 100 cm^3. After positioning the SAW device, the vessel was flooded with nitrogen gas until the resonant frequency reached a steady state. Subsequently, the nitrogen stream was stopped and the odorant was injected by a permeater (Ueshima, GASTEC PD-1B). The temperature and the odorant concentration of the gas stream were controlled by the permeator. The standard gas was generated based on the Lugg's method. The resonant frequency shifts were measured using six channel oscillation circuit and Network/Spectrum analyzer (Anritsu MS620J) on line with micro-computer (NEC 9800). The interval for the measurement of the resonant frequency was 30 sec. The identification of odorants was discussed by comparing the behavior of the normalized resonant frequency shift pattern depending on the coated phospholipid, and odorants were identified by a neural-network pattern recognition with back-propagation algorithm.

Results and disscusion

Applying the Langmuir-Blodgett technique it was possible to deposit optimum number of layers which was found to be between 10 and 20. The change of frequency property was shown in Fig. 3. The frequency decreases continuously whereby the insertion loss due to the dissipation of energy increases with the number of monolayers deposited. If the number of monolayers reached a critical value (between 20 and 30 in dependening on the surface pressure and molecular weight of the deposited material) the loss became so high that the frequency characteristics changes tremendously. Therefore, one has to deposit an optimal number of layers for the detection of odorants, which lies between 10 and 20.

The correlation between resonant frequency shift and concentration of odorants for lipid-coated SAW devices were investigated. The responses were different from each other. Therefore, the frequency shift for each odorant of the different lipids was represented in pattern. The pattern cannot be compared directly with each other due to the different vapor concentration. Normalization is necessary for comparison. Therefore, we normalized the response as follow.

$$P(i,j) = \Delta F(i,j) / \sum_{j} \Delta F(i,j)$$

where P is the pattern factor, i is the kind of odorant, j is the kind of lipid

On the basis of monolayer properties of phospholipids and fatty acid, an explanation is given for different odorant affinity. The normalized resonant frequency shift patterns of odorants were specfic and represents a pronounced pattern for each odorant (Fig. 4). The normalized resonant frequency shift patterns from a number of different lipid-coated SAW devices, were recognized using three layers neural-network mechanism and back-propagation algorithm (Fig. 5).

From these results, it follows that a lipid coated SAW resonator can monitor different odorants. Using a number of different lipids for coating of surfaces of SAW resonators, odorants can be identified by a computerized pattern recognition algorithm. This approach could open a wide field for the detection of odorants.

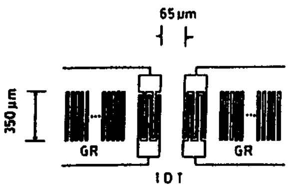

Fig.1 Two-port SAW resonator device
55 pairs and 230 grooves with
5.1um pitch.

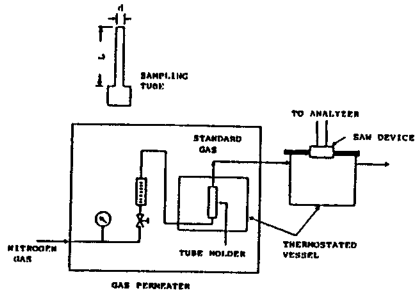

Fig.2 Schematic diagram of flow experimental system.

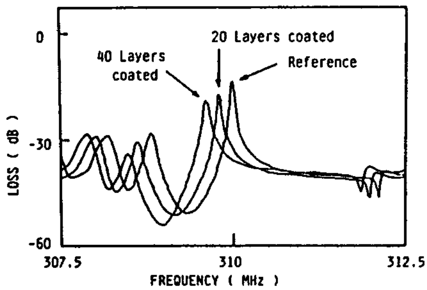

Fig.3 Typical insertion loss versus frequency

for two-port SAW resonator

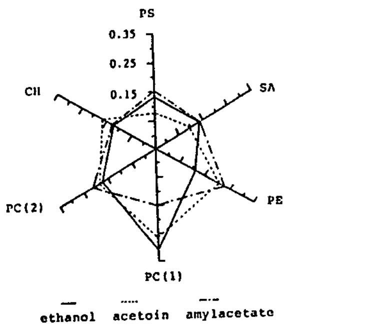

Fig.4 The normalized patterns of resonant frequency shifts to respective various odorants; phosphatidylserine, stearic acid, phosphatidylcholine, phosphatidylethanolamine, cholesterol

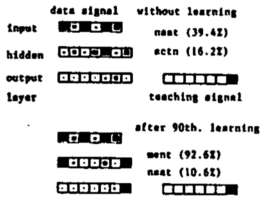

Fig.5 Schematic diagram of learning processes in the neural-network pattern recognition.