論 文
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6채널 압전소자를 이용한 냄새인식에 관한 연구

A Study on the Identification of Odorants using Six Channel Piezoelectric Crystals

權 寧 守* · 張 尙 睦** · 朴 玉 順*** · 崔 龍 成§
(Young-Soo Kwon · Sang-Mok Chang · Ok-Soon Park · Yong-Sung Choi)

Abstract - At-cut quartz crystal has been applied as chemical vapour sensors. The responses of quartz crystal at 9 MHz coated with phosphatidylglycerol(PG), phosphatidylinositol(PI), phosphatidylethanolamine(PE), phosphatidylserine(PS), and lipid A(LA) are determined for amyl acetate, acetoin, menthone and other organic gases which showed different affinities for each lipid. The identification of odorants depending on the species of lipid used for coating is discussed in terms of the normalized resonant frequency shift pattern.

Key Words : · Vapour Sensor, Piezoelectric Crystal, Lipid, Odorant Sensor, At-cut Quartz Crystal Pattern Recognition

1. Introduction

Since Sauerbrey[1] reported the empirical equation for the relationship between the frequency shift of quartz resonator and the mass of substance deposited on its surface, much attention has been paid to piezoelectric crystal detectors as simple, sensitive and reliable detectors[2, 3].

$$\Delta F = -2.3\times 10^6 F^2 \Delta m A^{-1} \quad (1)$$

where ΔF is the frequency change due to deposited mass(Hz), F is the original resonant frequency of the piezoelectric crystal(MHz), m is the mass of the substance deposited on the surface(g), and A is the area coated(cm^2).

Piezoelectric crystal resonators have been applied to both gases and liquid phase analyses. After King's proposal[2] that the coated pi-

*正 會 員 : 東亞大 工大 電氣工學科 助教授 · 工博
**正 會 員 : 東亞大 工大 化學工學科 助教授 · 工博
***正 會 員 : 東亞大 大學院 化學工學科 碩士課程
§正 會 員 : 東亞大 大學院 電氣工學科 碩士課程
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ezoelectric crystal can be used for vapour detection, extensive researches on gas sensors using piezoelectric crystals have been performed[3]. However, the majority of the devices reported were intended to detect a specific odorant with a selective coating film, unlike the olfaction system, which has diversity to detect all kinds of odorants. Recently, the importance of recognizing the kind of odorants from output patterns of an array of sensors has been suggested with a view to mimicking olfaction[4].

The olfactory reception of odorants is not well understood. Nomura et al.[5] emphasized the importance of lipid in olfactory cells for odorant detection. They hypothesized that lipid layers act in the detection of odorant in olfactory cell even if lipid itself does not have a specificity to odorants. They concluded the pattern recognition mechanism of odor discrimination from these hypotheses. Based on these results, we investigated the responses of six types of lipid-coated quartz crystal resonators as chemical vapour sensors. The identification of odorants is discussed by comparing the behaviors of their normalized resonance frequency shift patterns, which are dependent on the phospholipid used.

2. Experimentals

2.1 Materials

Phosphatidylglycerol(*PG*), phosphatidylserine (*PS*), posphatidylinositol(*PI*), phosphatidylethanolamine(*PE*), and lipid *A*(*LA*) were used as sensitive films. the odorants, amyl acetate, acetoin and menthone as well as methanol, ethanol, propanol, and butanol were measured. Lipids were obtained from Sigma Chemical Company. Others were obtained from Wako pure chemical industries Ltd. All chemicals used in this study were of analytical grade.

2.2 Apparatus

The schematic diagram of the experimental system is shown in Fig. 1. The lipid-coated *AT*-cut quartz crystal resonators were placed in a vessel which has two valves for nitrogen gas inlet

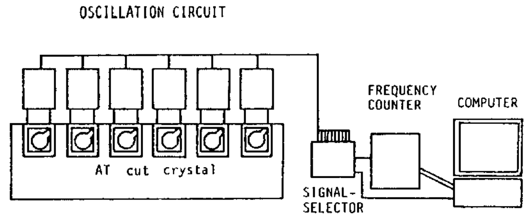

Fig. 1 Schematic diagram of experimental system

and outlet. The volume of the vessel is 10ml. The electrodes were deposited with the thickness of 200 Å of chromium, and 2000 Å of gold in turn by vacuum vapour deposition(ULVAL EBH-6) on the both sides of quartz crystal, using self-made mask. The surface area of electrode was 0.5cm^2. The resonant frequency was measured using six channel frequency counter combined line with micro-computer(NEC PC-9800). Standard gases of odorants were generated by putting a sampling tube in the tube holder and flowing nitrogen as a carrier gas. The concentration of a standard gas was controlled by changing the diameter and length of a sampling tube, flow rate of nitrogen, and temperature. The resonant frequency was measured at an interval of about 30 second.

The coating material was diluted with chloroform(5mg/ml). And a thin film was coated and formed by solvent evaporation.

The coated film led to a frequency shift of about 230KHz. The device was placed in clean, dry air for about 3 hour prior to measurement. After positioning the lipid-coated quartz crystal, 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-1B9).

3. Results and Discussion

Fig. 2 shows the response profiles for *PG* and *PE* coated *AT*-cut resonators obtained from consecutive exposures to 67ppm of *n*-amyl acetate. The response is quite typical, and changed linearly with consecutive exposures to *n*-amyl acetate.

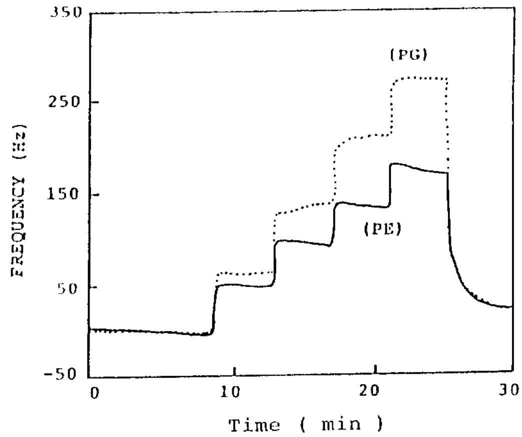

Fig. 2 Typical response of lipids coated AT-cut exposed to consecutive pulses of 67ppm n-Amyl acetate

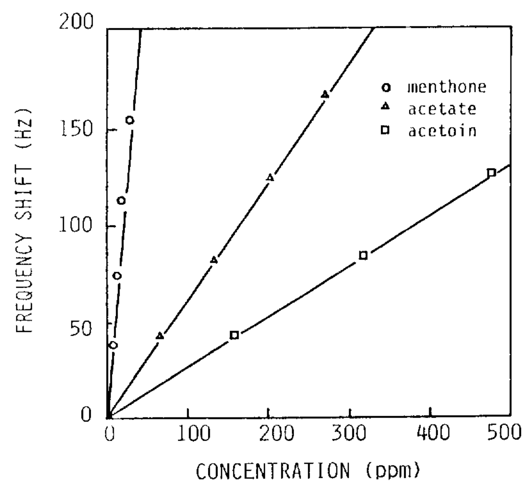

Fig. 3 The correlation between odorants concentration and resonant frequency shifts for phosphatidylethanolamine coated AT-cut resonator

Fig. 3 shows the correlation between resonant frequency shift and odorant concentration for a PE-coated AT-cut resonator. The results demonstrate that the lowest concentration among individual odorants required to give a measurable frequency change is different respectively. The sensitivity represents the slope obtained from a linear least squares fit of four sets of responses. The values are about 1ppm and 5.3Hz ppm^{-1} for menthone, 7ppm and 0.6Hz ppm^{-1} for amyl acetate, 15ppm ad 0.27Hz ppm^{-1} for acetoin, respectively. There are good qualitative correlations between these results and olfactory threshold values in biological cells as observed by Nomura et al.[5]

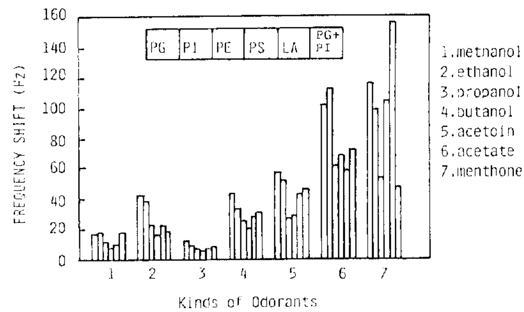

Fig. 4 The normalized patterns of resonant frequency shifts to respective PG : phosphatidylglycerol, PI : phosphatidylinositol, PE : phosphatidylethanolamine, PS : phosphatidylserine, LA : lipid A.

It is considered that these results reflected the equilibrium between the lipid membrane and the gas phase. Thes results show that there is an affinity difference of odorants to phospholipids.

The correlations between resonant frequency shift and odorants concentration for other lipid-coated AT-cut quartz crystal were also investigated. The responses were different from each other. Therefore, the frequency shift for each odorant of the different lipids was represented in the pattern. The patterns cannot be compared directly with each other due to the different vapour concentrations. It is necessary to normalize for the comparing Therefore, we normlized the response so that the sum of each response is one. [6]

$$P(i, j)=\Delta F(i, j)/\sum_j \Delta F(i, j) \tag{2}$$

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

The results after normalization procedure were shown in Fig. 4. The pattern itself is specific and represents a pronounced pattern for each odorant. The normalized pattern can be used for the identification of odorants.

From these results, it follows that a multichannel lipid-coated AT-cut quartz crystal can monitor different odorants. Using a number of different lipids for coating of surfaces of quartz crystals, odorants can be identified by a computerized pattern recognition algorithm. This approach can open a wide field for the detection of odorants.

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저 자 소 개

권영수(權寧守)

1950년 1월 17일생. 1973년 영남대 공대 전기공학과 졸업. 1983~88년 일본 동경공업대학 대학원 전기·전자 공학과 졸업(공박). 1990년 동경공업 대학 객원연구원 현재 동아대 공대 전기공학과 조교수.

장상목(張尙睦)

1959년 4월 16일생. 1982년 서울대학교 공대 화학공학과 졸업. 1984년 한국과학기술원 화학공학과 졸업. 1991년 일본동경공업대학 대학원 전자화학 전공졸업(공박). 현재 동아대학교 화학공학과 조교수.

박옥순(朴玉順)

1957년 7월 15일생. 1991년 부산공업대학 화학공학과 졸업. 현재 동아대학교 대학원 화학공학과 석사과정 재학중.

최용성(崔龍成)

1967년 11월 14일생. 1991년 동아대학교 공대 전기공학과 졸업. 현재 동아대학교 대학원 전기공학과 석사과정 재학중.