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Aroma-Chip based Olfactory Display

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Abstract

Physical implementation of controlled release, as in traditional audiovisual entities, is the prime hindrance in the development of olfactory display. Therefore, attention was focused on the use of functional high-polymers for the controlled release of aromatic fragrances.

Among functional high-polymers, temperature sensitive hydrogels were used in an attempt to control the release of aromatic fragrances, because the temperature stimuli for sensitive hydrogels can easily cause a reversible conversion action between sol and gel. Aromatic molecules become active in sol form, and are restrained when they are in gel form. Based on this principle, the measured quantity of aromatic fragrance emission indicated that the emission from gel was more controllable than that from a sol.

In addition, sensory evaluation of aroma intensity was performed among individuals using a Peltier-module with embedded olfactory display. Efficiency was evaluated by heating the module to emit the aroma and by cooling the module to stop the emission of aroma. As a result of evaluation, it was verified that hydrogels respond well and are effective for controlled release. Effective timed release was also demonstrated when used in conjunction with video display.

Keywords: Sol-Gel, Hydrogel, Phase Transition, Aroma-Chip, Olfactory Display

1 Instructions

Human beings acquire information from the external world through their sense of sight, hearing, smell, taste and touch. Moreover, the growth and popularization of various media such as television (TV) and personal computers (PC) have made it easy to acquire information from remote areas. However, these media are based on interaction with audiovisual (AV) information, and do not provide any information regarding fragrance and the atmosphere of a particular location.

Recently, several different studies have been conducted, and a variety of systems and displays that transmit odor have been proposed [1, 2]. For example, the ambient atmosphere in movie theaters has been successfully tested for the release of fragrance [3]. Different Internet sites provide services that transmit several different fragrances with a click; an aroma generator, which is connected to the PC beforehand, transfers a fragrance when specific links are clicked [4,5]. Olfactory displays developed in the past emphasized the display of multiple fragrances using one device; therefore, problems arose such as large device size, high cost, troublesome operation and complicated maintenance. Therefore, TVs and PCs providing AV content with aroma information have not yet been achieved.

In the present work we propose a developed aroma-chip based olfactory display system, which can be implemented very easily at home and is convenient to use.

2 Controlled Release of Aroma by Functional High-polymer

Since ancient times, aromatic fragrances have been used in religious practice, sterilization, and as antibiotics**.** Recently, aroma has been used for different purposes including aromatherapy, and aromachology. The use of aroma has spread and has reached as far as PC images.

Lately, aromas are synchronized and embedded in pictorial and sound content, and thus transfer olfactory information through displays.

Due to their physical properties, aromatic fragrances are roughly classified into liquid and solid (powder) aromatic fragrances. In general, liquid aromatic fragrances are largely used; however, liquid aromatic fragrances diffuse easily and therefore, do not provide a continuous effect. To overcome this hindrance, gelatinization, which utilizes a natural macromolecular material, is used to achieve controlled release of aroma, Gelatin, agar, konnyaku, carrageenans etc. are commonly used natural macromolecules. In nature, the characteristics of natural macromolecules are weak, as they can easily be deteriorated by a microbe. To solve this problem, gelatinization using various compositions was investigated. In particular, in next generation drug delivery system (DDS) studies, stimulation responsive hydrogel are used as one type of gelatinizing macromolecule. To realize the ideal concept of controlled release, discharge of flexible quantities of chemical in an appropriate place when stimulated by temperature, light, or pH etc. was investigated.

In this study, attention was paid to functional high-polymers which are also known as "intelligent materials", especially the temperature sensitive hydrogels, which can have reversible conversion action between sol and gel, and the controlled release of aromatic fragrances was evaluated.

2.1 Temperature Sensitive Hydrogel

As the temperature sensitive hydrogel maintains uniform and continuous speed for the spreading of drugs within the body, it is also used as a medical DDS. In this study, utilization of such physical-chemical properties was evaluated for the controlled release of aromatic fragrances by producing olfactory information.

Based on the work of Kim et al. methoxy-poly(ethylene-glycol)-block-poly(caprola ctone) copolymers [MPEG-PCL] were used [6].

With a temperature sensitive hydrogel of this density ratio, the phase transition change of the sol-gel was shown by simple temperature stimulation after having mixed the hydrogel with liquid aromatic fragrances, as shown in Figure 1.

With regard to controlling aromatic release while in sol form, and determining what aromatic materials could be maintained in the gelatinous form, thermogravimetry (TG) was performed. Uniform weight change was not observed over time, because the initial weight ratio of MPEG-PCL was decreased so as not to evaporate when in the form of a sol.

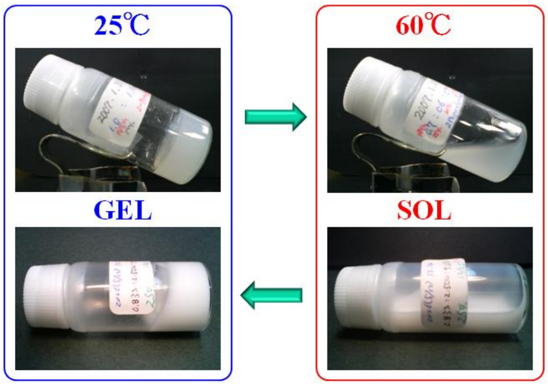

Fig 1.Temperature sensitive hydrogel

2.2 Controlled Release of Aromatic Fragrances

The physical-chemical properties of temperature sensitive hydrogel were utilized, and the controlled release of aromatic fragrances to produce olfactory information was evaluated.

As shown in Figure 2, the mixture ratio of vanilla (Hasegawa) to MPEG-PCL was from 5-50%.The aromatic fragrance generated was then used to conduct a sensory evaluation of the aroma intensity. A similar environment to that as in an average house was assumed to conduct the sensory evaluation of aroma intensity. Three non-smokers/non-rhinitis sufferers, with good olfactory perception, according to the conditions described on section 4.1, were used as participants. Nine tests were conducted at a rate of three per day for three consecutive days.

When the mixture ratio of aromatic fragrances was 5-15%, participants perceived aroma only when the Peltier module was hot. When the mixture ratio was from 20-50% all participants perceived the aroma even at room temperature. Moreover, even when the Peltier module was hot, 5% vanilla was perceived very weakly, and at 15% it was perceived very strongly. Therefore, 10% was assumed as an appropriate ratio for detection, and it was decided to use this quantity in further experiments.

MPEG-PCL (%)	Distilled Water (%)	Fragrance (Vanilla %)	Total
1.000g (30%)	2.167g (65%)	0.166g (5%)	3.333g
1.000g (30%)	2.000g (60%)	0.333g (10%)	3.333g
1.000g (30%)	1.834g (55%)	0.499g (15%)	3.333g
1.000g (30%)	1.667g (50%)	0.666g (20%)	3.333g
1.000g (30%)	1.500g (45%)	0.833g (25%)	3.333g
1.000g (30%)	1.334g (40%)	0.999g (30%)	3.333g
1.000g (30%)	1.166g (35%)	1.166g (35%)	3.333g
1.000g (30%)	0.999g (30%)	1.333g (40%)	3.333g
1.000g (30%)	0.833g (25%)	1.500g (45%)	3.333g
1.000g (30%)	0.666g (20%)	1.667g (50%)	3.333g

Figure 2.Ratio of aromatic fragrance in MPEG-PCL

3 Application for Olfactory Display

3.1 Structure of Experimental System

In this section, we describe the prototype activated aroma generator using the temperature sensitive hydrogel, as described in section 2.1, which is controlled by dual tone multi-frequency (DTMF) signals [7]. The prototype configuration is presented in Figure 3.

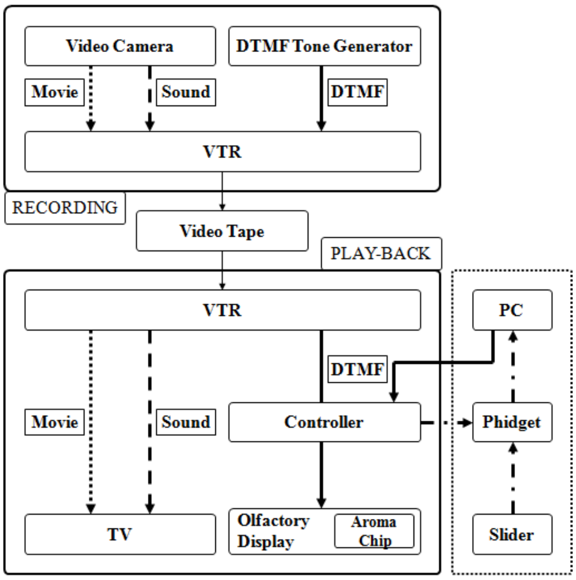

Fig 3.Configuration of prototype experimental system

The recorder side is composed of video camera, DTMF-tone generator, and a video tape recorder (VTR) to edit visual images. The reproduction side consists of a VTR, a controller, which controls the aroma generator instructions that are embedded as DTMF signals on the sound tracks of the VTR, and an olfactory display that controls release of the fragrances according to the aroma generator instruction signals.

The DTMF signals which are embedded on the controller are not only from the VTR sound tracks, but can also be input directly from the PC. These are the fundamental components of the olfactory display; however, to collect the sensory evaluation data from participants, a Phidget slider was prepared and combined with the prototype.

The operational information for the physical movement of the controller are collectively input into the PC via the Phidget slider.

3.2 Controller

The signal that controls the olfactory display is synchronized with the AV content, which was produced beforehand. The aromatic information (signal) is embedded as sound data in one of the unused sound channels. Therefore, there is no need to reconstruct the existing AV equipment, and the olfactory display can be added as a set-up box. Moreover, because the synchronized information is merely sound information, this information can be played back and recorded very easily, even in a home environment. The olfactory display controller uses DTMF signals.

Different signals can be used for different fragrances; for example, signals 1 to 9 would correspond to nine different fragrant sources. For example, at the place where the 2nd signal is recorded, the odor of the corresponding 2nd aroma-chip is released, The signal numbered "0" suspends the release of all fragrances. The signals used to release and suspend odors can be transmitted using one channel among 5 different channels, such as in 5.1 multi-channel systems. For the present experiment, a stereo channel was used to transmit odor control signals. These signals can be recorded on an empty sound track. At the time of playback, the DTMF signals recorded on the sound track do not provide any sound data output to the speaker, but instead they provide input to the olfactory display controller.

The olfactory display controller decodes the DTMF signals and directs the olfactory display with the specified fragrance numbers. Figure 3 shows the synchronizing of the olfactory information and Figure 4 shows a photograph of the prototype controller.

The controller is composed of a decoder (LC7385, Sanyo), which analyzes the DTMF signals, and a peripheral interface controller (PIC) microcomputer that accelerates the olfactory display, according to the analytical result send by the decoder.

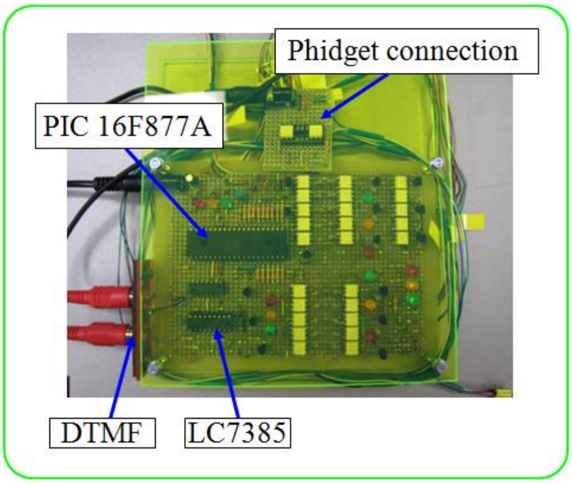

Fig 4.Controller

3.3 Olfactory Display

The olfactory display consists of three different components; the Peltier module, which helps to direct the action of the reversible conversion between electrical energy and heat; the heat-sink (Comon), which helps to output heat; and the rain-pipe (National), which works as a guard for the aroma-chip.

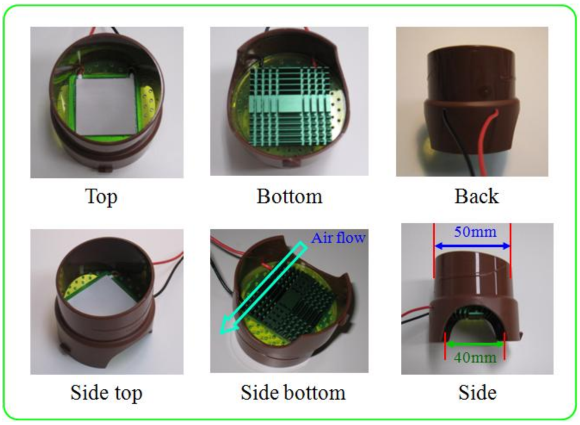

Fig 5.Olfactory Display

As shown in Figure 5, the olfactory display proposed in this research does not have any mechanical mechanism, and thus, is very stable and does not produce any operational sound.

3.4 Aroma-Chip

A micro-cover-glass 18×18×0.17 mm type (Matsunami 2) aroma chip was used. 0.1 g of the aromatic mixture of temperature sensitive hydrogel was placed in a micro-syringe (15×15 mm) and was homogeneously applied with a similar thickness to that of the micro-cover-glass. Figure 6 presents a photograph of the prototype aroma-chip.

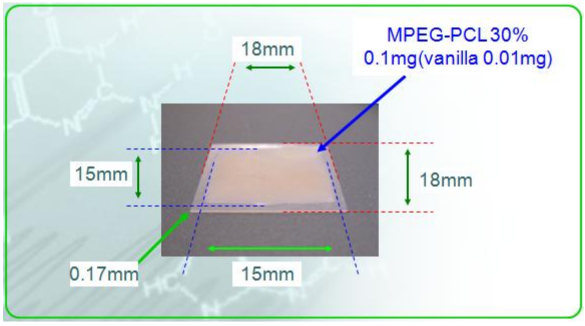

Fig 6.Aroma-Chip

The aroma-chip is presented in Figure 7, showing an example of the reversible conversion action between sol and gel for olfactory display.

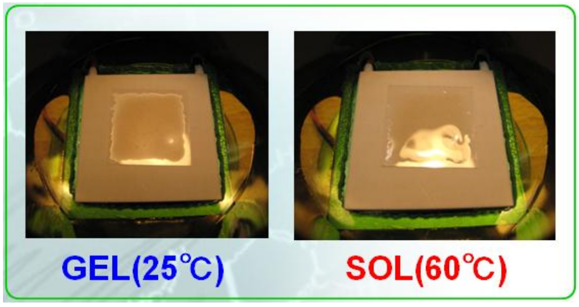

Fig 7.Gel-sol-gel phase transition

The gel state can be maintained at 25 °C. As current is applied to the Peltier device and the aroma-chip side is adjusted to 60 °C, the gel state is then changed into the sol state.

4 Evaluating Experiment

4.1 Environment of Experiment

The evaluation experiment was conducted in a room with air conditioning facilities, and the room temperature and humidity was maintained at 22 °C and 26%, respectively. Performance of the prototype system was evaluated and, photograph of the experimental environment is presented in Figure 8.

A Phidget slider (Figure 9) was used while evaluating the individual sensory intensity of the aroma, by manipulating the slider (up and down) in accordance with the following conditions.

The slider was operated only if the aroma was detected. The slider was moved up and down according to the intensity of the aroma intensity. If the intensity of the aroma is detected, then the slider is maintained in the same position. If the intensity of the aroma is detected as being weak, then the position of the slider is lowered. According to the intensity of the aroma, the participants manipulate the position of the slider. If the intensity of aroma is detected as strong, it is not necessary to move the slider to the extreme position. If the aroma intensity is not detected at all, the slider position is moved to the extreme low position.

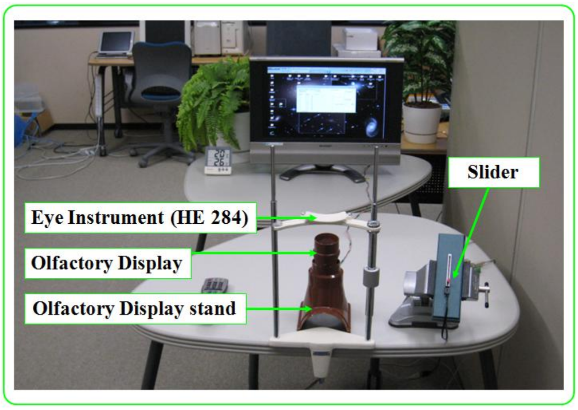

Fig 8.Environmental experiment

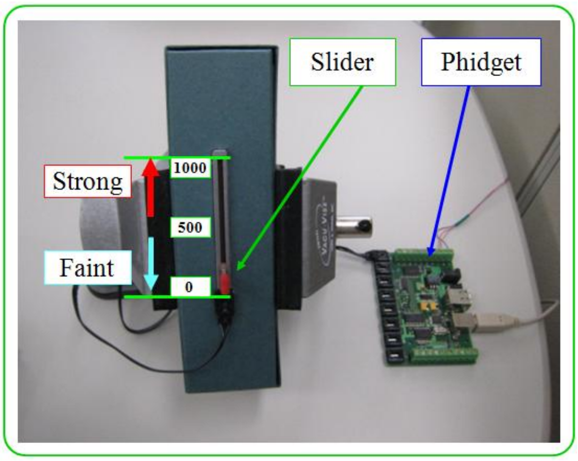

Fig 9.Slider for sensory evaluation

The output value of the slider changes continuously from 0 to 1000 and the data changes used by the controller to heat and cool the Peltier are recorded on the PC via the Phidget. (refer to Figures 3 and 4).

The absolute value obtained from the movement of slider for the sensory evaluation test of aroma intensity does not have any particular significance. Rather, relative transition values from individuals have significance. For the efficiency test of the prototype system, each of the participants were told to operate the slider after a "START" instruction, and were told to stop the operation after a "STOP" instruction. The curve in Figure 10 shows the change of temperature for the Peltier device, which was used in the evaluation experiment. The horizontal axis shows time in seconds, and the vertical axis represents the temperature (°C).

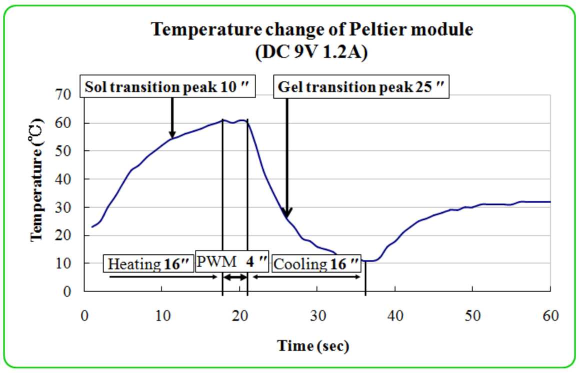

Fig 10.Temperature change of the peltier module

As shown in Figure 10, the temperature of the Peltier device was raised up to 60 °C in 16 seconds, and then pulse width modulation (PWM) was implemented for four seconds. After the temperature was made constant, the temperature of the Peltier device was lowered to 10 °C in 16 seconds to solidify the temperature sensitive hydrogel. The rise in temperature after 36 seconds shown in Figure 10 was after stopping the Peltier device and was caused by the room temperature.

The peak for the phase transition of the temperature sensitive hydrogel into sol and back into gel is 54 °C, and 26 °C respectively. Therefore, if cooling passes 26 °C, the phase transition to sol does not occur again, as long as the temperature does not rise to 54 °C again. A rise in temperature to below 54 °C does not influence the state of the hydrogel, because below this point the gel state is maintained.

4.2 Evaluation of System's Efficiency

In this experiment, the performance evaluation of controlled release using temperature sensitive hydrogel and sensory evaluation of aroma intensity were conducted. The appearance of the experiment is presented in Figure 11.

To design experimental conditions similar for all participants, as shown in Figure 8 and 11, the distance between the nose and olfactory display were arranged to be around 100 mm. To avoid participants from moving their head and to maintain a constant distance a face fixation machine stand (Eye Instrument HE 284, Hadaya) was used. To avoid the identification of the temperature sensitive hydrogel, we asked all participants to close their eyes while performing the test. Moreover, the Peltier device temperature was not controlled by playing the edited videotape, but by directly sending DTMF signals from the PC to the controller.

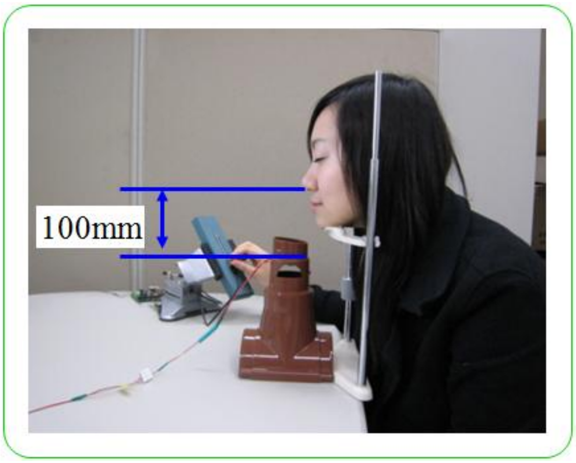

Fig 11.Estimation of odor from the aroma-chip

The procedure for the experiment was as follows. 1) Instructions regarding the experiment are given, 2) The intensity of aroma is evaluated by moving the slider up or down in accordance with the detected odor (for one minute), 3) conduct a questionnaire, and 4) sensory evaluation was conducted through interview. The Peltier device was designed to start heating after five seconds from the test start time. Other changes in temperature of the Peltier device are according to Figure 10. To avoid the problem of aroma infiltration, enough ventilation was used to freshen the test atmosphere after each test. In addition, all instruments used in the experiment were washed with ethanol and the aroma-chip was also changed for all participants.

Among the 17 participants of the experiment, two participants felt zero presence of aroma. On the other hand, two participants felt the presence of aroma from the beginning to the end. Therefore, the data of these four participants was eliminated, and only the data of 13 participants was used for the evaluation. Out of 13 participants, six of them were male and seven were female, nine were in their 20s and four were in their 30s. As previously described, the absolute value obtained from the movement of slider does not have any particular significance; therefore, the data was normalized according to Eq. 1.

$$I_{(t)norm} = I_{(t)}/I_{max} \times 100 \qquad (1)$$

Here, $I_{(t)norm}$ is the normalized sensory evaluation value at time t, I(t) is the operation value of the slider at time t, and I_{max} is the maximum value of the slider manipulated by the participants. The slider transition output value for each participant after normalization is shown in Figure 12. In Figure 13 shows the average normalized value for all the participants.

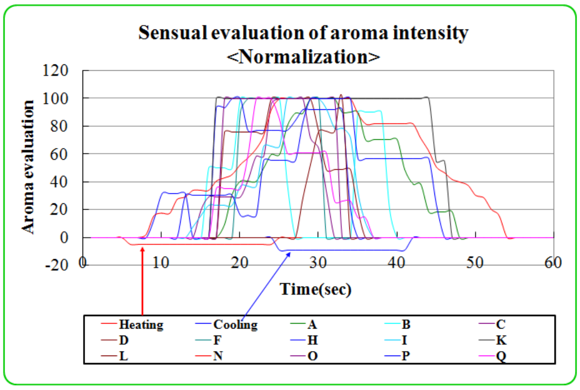

Fig 12.Sensory evaluation of aroma intensity (normalized)

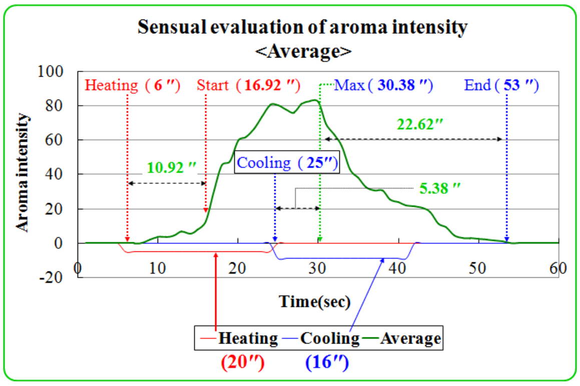

Fig 13.Sensory evaluation of aroma intensity (average)

As shown in Figure 13, it was confirmed that on average, after 10.92 seconds of the heating process, participants rapidly start to perceive the aroma. Therefore, if the time is reduced by 10 seconds from the time taken by the Peltier module to rise to the temperature of 54 °C, and if the source of aroma is 100 mm away from the participants, then the participants can sense the aroma within an average of 0.92 seconds. On the other hand, on average it will take 22.62 seconds to become aroma insensitive.

5 Conclusion and Future Work

In recent years, research on communication and information technologies are rapidly progressing, in order to achieve highly ambient environments. Moreover, multi-sensory communication research including the five senses has risen.

However, research related to the sense of smell, and tests of senses that acknowledge the receptor organs of humans as well as technology are still in the beginning phase. Light has three primary colors; taste has its own primary flavor, but unfortunately smell does not have any primary odor. Therefore, developing an olfactory display which can transmit multiple smells is a rigid task. To date, all developed olfactory displays have been based on an aroma-chip replacement method.

The complexity of exchanging the aroma source is the main hindrance in developing olfactory displays. Moreover, for the realization of an olfactory display, appropriate amounts of mixtures of different fragrances have to be prepared. Although the exchange of the aroma source is complex, different approaches are largely in use, for example, cartridge methods such as liquid, sponge, or gel, are used for different materials that require intense exchange. Other methods proposed include an aroma enclosed in a microcapsule, and a slurry type aroma printed on paper, and can thus can be distributed very easily. [As a result, the complexity in these changing aroma sources was reduced to an extent, but still suffers from mechanical problems of the aroma controlled release mechanism.

Therefore, in this research, we emphasized a chemical container of fine polymer and a card type aroma-chip, in which emanation and cessation of the aroma signals can be controlled very easily. Results based on the evaluation of the efficiency of the prototype shows that the olfactory display developed in this research is effective and useful.

The olfactory display proposed on this research, has inherited the advantages of the traditional card-type method. Moreover, by using a Peltier module to control the temperature, all previous complex mechanical mechanisms were eliminated. With this approach, the miniaturization and low cost of the aroma-generating device was achieved. In addition, operation of the system was soundless (substantially silent).

In the near future, we hope olfactory display will be accessible to a large number of people in a ubiquitous way, so that it may be a useful device for everyone. Further research is planned to accomplish this vision.

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