FEASIBILITY OF A MICRO-FLUIDIC HEALTH CARE DEVICE MEASURING CONTENT OF SODIUM CHLORIDE

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Abstract: Feasibility of developing a new-type micro-fluidic health care device was investigated. Blood test and urinalysis are generally used for the health check. However, to check more simply and easily diseases, utilization of small quantity but easily collected other body fluids such as sputum, sweat, and tears were taken up. These body fluids contain sodium chloride, and it is considered that the content relates to the health conditions. Therefore, the method to easily detect the sodium chloride content was investigated, and it was found that the measurement of spectral transmittance in deep ultra violet light region was effective. It was clarified that the transmittance at wavelengths of 190-200 nm noticeably decreased relating to sodium chloride content and the absorption coefficient well corresponded to the content. Although the relationship between the sodium chloride content and the health condition have to be investigated in detail hereafter, the new device will be feasible for easily monitoring health conditions.

1 INTRODUCTION

Various bio-devices have been researched and developed for keeping human health and detecting illnesses and diseases. Blood test (Almeida, Glesse and Bonorino, 2011) (Chen, Fang, Qiu, He and Deng, 2009) (Edward, Kreig and Butler, 2009) (Noda, Suzuki, Kanno, Hanafusa, Yamamoto, Ijuin, Hori, Osumi and Kotera, 2010) (Ye and Li, 2011) and urinalyses (Chen, Fang, Shyu and Lin, 2006) (Koide, Ito and Karube, 2007) (Mori, Mori and Yamori, 2011) (Otero, Akinfiev, Palacios and Presedo, 2011) are generally carried out as a health examination or a disease check. However, everyone does not like to be taken the blood using a syringe, and feel ashamed to offer urine.

For this reason, it was aimed to use other body fluids which are easily and friendly collected even though only small quantities are collected. In concrete, sputum, tear, sweat and snivel were targeted. If small-size biosensors or devices for easily diagnosing illnesses were newly developed using micro-fluidic technology (Horiuchi, Watanabe, Hayashi and Kitamura, 2010) (Horiuchi, Otsuka, Ozaki, Ando and Hiraki, 2011), they would be effective from a view point of not only size saving and portability but also reduction of sample volume and painless collection of body fluids.

On the other hand, it is most important to search how to easily obtain information indicating health conditions. To conceive a bright idea, measurement of spectral transmittance in deep ultra violet (UV) wavelength region was investigated. Spectral transmittance in infrared wavelength region is often investigated to know organic materials or molecular groups contained in specimens. However, the deep UV region has not sufficiently been investigated.

It was fortunately found that the light transmittance changed at the wavelength of 190-200 nm, if the object fluid contained sodium chloride (NaCl). In this paper, how the spectral transmittance changes in the above deep UV region relating to the contents of NaCl in aqueous solution is reported. In addition, although only a few results have been obtained, it is clarified that similar spectral transmittance change is also observed for human sputum. Accordingly, if the contents of NaCl in some body fluids relate to the health, it will be feasible to develop a new health check device.

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2 SPECTRUM TRANSMITTANCE MEASURING DEVICE

To measure the spectrum transmittance in UV wavelength region using small quantities of aqueous solutions of NaCl or body fluids, a micro-reservoir of resist was fabricated on a quartz plate using optical lithography, as shown in Fig. 1. Negative resist SU-8 (MicroChem) composed of an epoxy resin was coated in 100-μm thick. The SU-8 is almost transparent for visible light but opaque for UV light, as shown in Fig. 2. The spectral transmittance was measured using a spectrophotometer (JASCO Corp., V-630) of which the measurable wavelength range was 190-1100 nm.

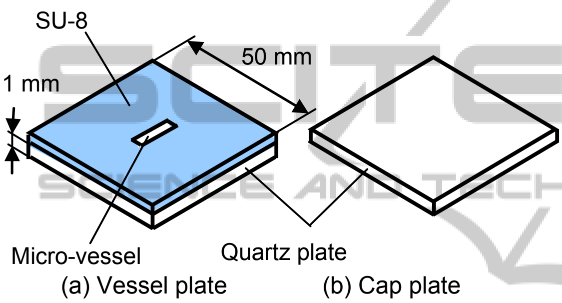

Figure 1: Device components for investigating spectral transmittances of body fluids.

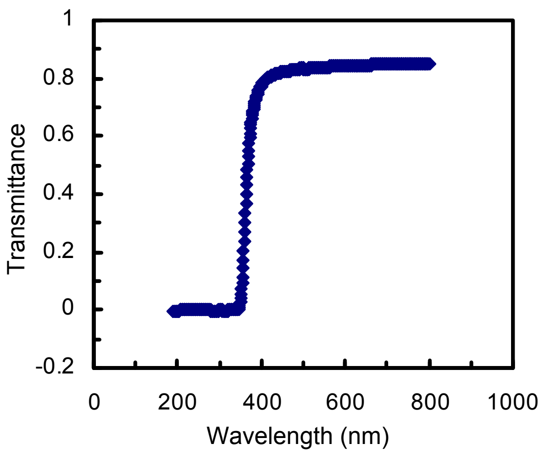

Figure 2: Spectral transmittance of SU-8.

Because SU-8 is a negative resist, exposed parts are hardened. Accordingly, if the resist is exposed except the masked central rectangular region, a concave reservoir is fabricated at the centre of the quartz plate. On the other hand, hardened SU-8 surrounding the concave reservoir is almost opaque for UV light. Accordingly, only the place where the concave reservoir is made becomes almost transparent for the deep UV light through the quartz substrate. Therefore, if the measurement light is widely irradiated including the micro-reservoir, only the light passing through the reservoir is distinguishably detected.

Light transmittance depends on the thickness of the fluids. However, if the fluids to be examined is infused in the reservoir and capped by another quartz plate, the thickness becomes almost equal to the SU-8 thickness coated on the former quartz plate. Therefore, the fluid thickness is controlled by adjusting the coated SU-8 thickness.

Two quartz plates with the fluid fused in the SU-8 reservoir were inserted in a specially prepared plastic case, and pressed each other by packing gauze so as the infused fluid did not leak out and kept the constant thickness. The spectral transmittance was measured comparing with the reference set which had the same-size micro-reservoir without infusing the fluid.

Because the irradiated light beam to specimens had a slim rectangular shape with a horizontal width of approximately 2 mm and a vertical length of approximately 10 mm, a horizontal slim rectangular micro-reservoir with a size of 2 by 15 mm was fabricated, as shown in Fig. 3. Accordingly, the light beam certainly crossed the micro-reservoir. Because the vertical width of the reservoir was 2 mm, effective size of the light detected by the photo sensor in the spectrophotometer was kept 2 mm square constant. Therefore, the fluid volume substantially used for the measurement of spectral transmittance was kept as little as approximately only 400 μℓ.

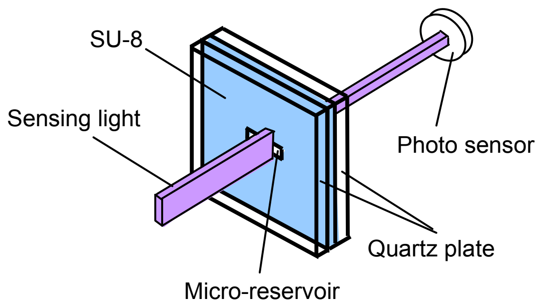

Figure 3: Shape of light beam passing through the micro-vessel fabricated by SU-8.

3 SPECTRAL TRANSMITTANCE MEASUREMENT OF SODIUM CHLORIDE

Using the devices, spectral transmittance of the aqueous solution of NaCl was evaluated, as shown in Fig. 4. The transmittance values for the wavelengths of 190-200 nm were largely changed depending on the contents of NaCl. On the other hand, when the wavelength was fixed at 190 and 195 nm, for example, the transmittance changed as shown in Fig.5.

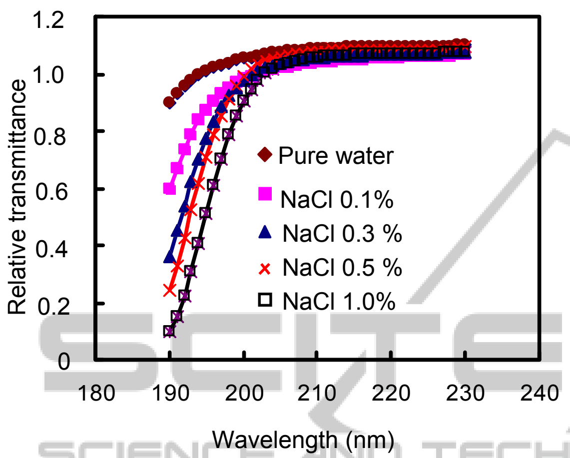

Figure 4: Spectral transmittances of aqueous solution of NaCl.

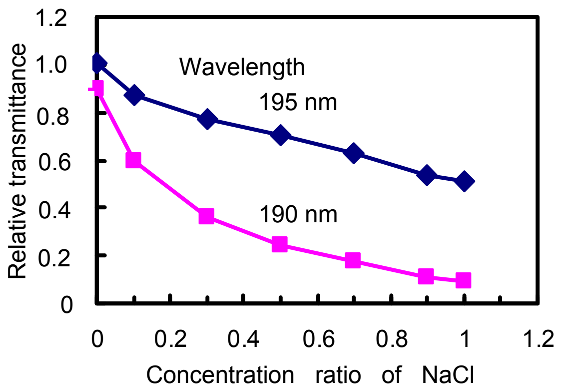

Figure 5: Change of light transmittance depending on the wavelength and concentration ratio of NaCl. Depth of the micro- reservoir was 100 μm.

It was found in the experiments there was another merit in this micro-reservoir that the infused fluids can clearly be observed by eyes, because SU-8 is transparent for visible light. Even if some air bubbles are occasionally mixed in the fluids infused in the reservoir, they can easily been detected and the specimen was omitted or infused again.

In the above experiment, the contents of NaCl were changed between the ranges of 0.1-0.9%. Because the weight percentage of physiological aqueous solution of NaCl is 0.9%, the transmittance changed for far thinner solutions. For this reason, the sensitivity would be sufficient to detect the slight change of NaCl content in the body fluids.

Influence of the fluid thickness or the depth of micro-reservoir was also investigated. Figure 6 shows the transmittance change depending on the micro-reservoir depth.

When a light beam passes through the fluid with a thickness of t, transmittance T and absorption coefficient α are calculated by eq. (1) and (2).

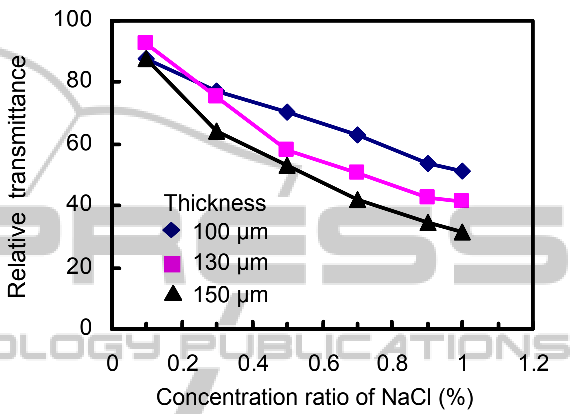

Figure 6: Change of light transmittance at the wavelength of 195 nm depending on the micro-reservoir depth and concentration ratio of NaCl.

$$T = e^{-\alpha t}. \tag{1}$$

$$\alpha = -\frac{\ln T}{t}. \tag{2}$$

Using these equations, absorption coefficient α was estimated. T and α depend on the wavelength and the weight percentage of NaCl. When the wavelength was fixed at 195 nm, relationship between $\ln T$ and t was obtained as shown in Fig. 7.

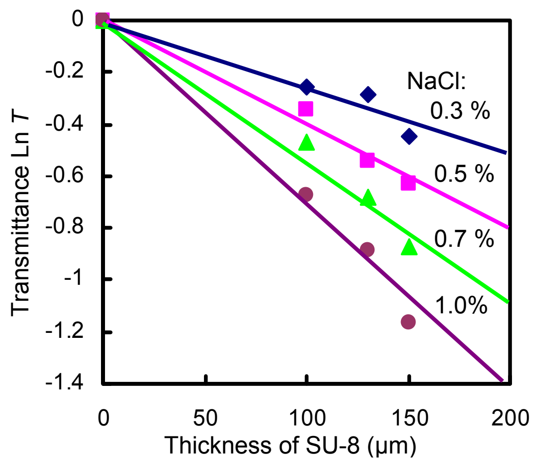

Figure 7: Relationship between transmittance T and micro-reservoir depth or the SU-8 thickness t at the wavelength of 195 nm.

Although the transmittance degraded much more at the wavelength of 190 nm, it was considered that the transmittance value should be appropriate to judge its change caused by the health conditions.

The NaCl content of physiological aqueous solution is 0.9%, and because almost half of the light with the wavelength of 195 nm transmits through it, transmittance change is most conspicuously detected using this wavelength.

Referring to the data shown in Fig. 7, α at the wavelength of 195 nm was calculated, as shown in Table 1.

Table 1: Calculated absorption coefficients for various concentrations of NaCl.

Concentration of NaCl (wt%)	SU-8 thickness (μm)	α	α (average)
0.1	100 130 150	0.001335 0.000596 0.000876	0.000935
0.3	100 130 150	0.00255 0.00221 0.00297	0.00258
0.5	100 130 150	0.00347 0.00419 0.00419	0.00395
0.7	100 130 150	0.00466 0.00527 0.00580	0.00524
0.9	100 130 150	0.00618 0.00657 0.00703	0.00659
1.0	100 130 150	0.00674 0.00685 0.00776	0.00712

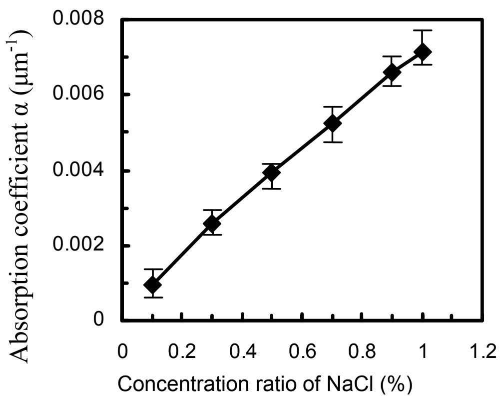

Figure 8: Relationship between absorption coefficient α and concentration ratio of sodium chloride. The error bars show each deviation range of three data shown in Table 1.

The average values of α is plotted, as shown in Fig. 8. Although the absorption coefficient α became almost linear, the inclination gradually decreased as the contents of NaCl increased.

4 SPECTRAL TRANSMITTANCE MEASUREMENT OF SPUTUM

Because it was verified that the spectral transmittance typically changed caused by the content of NaCl at wavelengths of deep UV region, spectral transmittance of sputum was investigated next. The same tools were used for the experiments, and micro-reservoirs of SU-8 with a thickness of 100 μm were prepared. Although the curvature tendency of the spectral transmittance curve slightly differed from that of NaCl aqueous solution, it was clarified that the transmittance also decreased in UV region for sputum, as shown in Fig. 9.

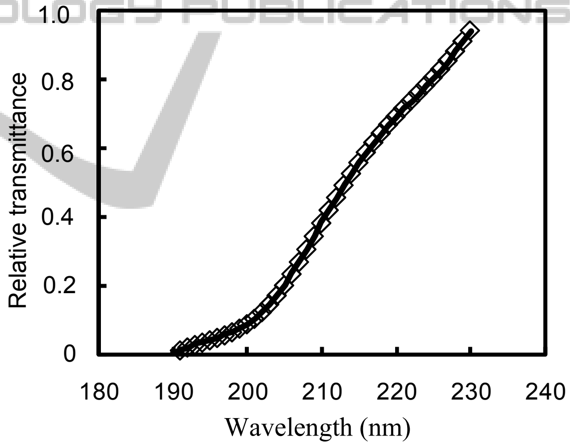

Figure 9: Spectral transmittance of sputum measured using the newly fabricated devices.

In the case of sputum, the transmittance decreased for a wider wavelength range comparing with that of the aqueous solution of NaCl. In other word, the transmittance decreased at the wavelengths of 190-230 nm. It probably depends on the fact that other materials are also contained in the sputum except NaCl.

However, the transmittance did not almost decrease in the wavelength region of 190-200 nm for potassium chloride (KCl). Although various contents in sputum may influence the transmittance change, it is supposed that the main content causing the transmittance decrease at the wavelength range of 190-200 nm is NaCl.

It was clarified that the spectral transmittances of

NaCl and sputum for deep UV light conspicuously decreased. Because the transmittance or the absorption depends on the concentration ratios of components, the variations of the transmittance curves or the absorption coefficients will become the detectors of the health. It will be feasible to obtain some health information from the transmittance curves or the absorption coefficient values, if a lot of practices are heaped up.

5 CONCLUSIONS

Fundamental research for developing a new micro-fluidic health care device was presented. It was clarified that the spectral transmittance for deep UV light with wavelengths of 190-200 nm noticeably changed depending on the content of NaCl. Utilizing these characteristics, health check or disease finding will be feasible using small quantity body fluids such as sputum. To obtain reliable spectral transmittance data, micro-reservoirs of thick resist SU-8 were fabricated on quartz plates using optical lithography, and test fluids were infused in the reservoirs. Because the infused fluids were capped by another quartz plate, and the fluid thickness was decided by the depth of the reservoir, the spectral transmittances were measured with very good repeatability. The transmittance became appropriate values when the micro-reservoir depth was 100-150 μm.

It is an important subject to clarify how the spectral transmittance curves and the absorption coefficients of body fluids change depending on health conditions, and it should be investigated hereafter. Accordingly, the distance to the goal is very long. However, a lead to develop a new micro-fluidic health care device was obtained.

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