Evaluation Method of Fabrics by Visual and Tactile Texture Information using MEMS Combo Sensor

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***Abstract*—In this paper, we report texture measurement of the fabrics by a multimodal MEMS sensor. This sensor has sensitivity to both multi-axial force vector and light. Therefore, we can evaluate tactile texture by force measurement and visual texture by light measurement. This sensor has a possibility for texture measurement with both visual and tactile information in substitution for the human sensory test. In this work, various fabrics were chosen as the target object and evaluated by sensory test method using 10 test subjects. The dependences of the sensor output on reflection of probe light, reactive force, and frictional force by active approaching and touching of the sensor to the object surface were also evaluated. As a result, it is demonstrated that there is a good correlation between the results of the human sensory test and features of visual and tactile sensor output.**

***Keywords*— tactile sensor; optical sensor; texture measurement; multimodal sensing**

I. Introduction

In late years, texture design for fabric products has become highly important because it influences appearances and feels of the fabric[1]. Surface texture of the object is composed of multimodal sensation inspired by both tactile and visual senses [2,3]. Generally, texture of the object is characterized by a human sensory test using visual and tactile senses of the test subject[4], however, this method takes relatively high cost and long time and lacks quantitativity and reproducibility. We have proposed a measurement method of texture using MEMS combo sensor with sensitivity to force and light. In previous works, it was demonstrated that the sensor can detect normal and shear forces as the resistance change of strain gauge on the microcantilever structures fabricated by MEMS technologies[5] and detect light as the impedance change of Si semiconductor[6], respectively. Furthermore, we applied this sensor for measurement of texture including hardness, roughness, friction, and color of the object[7]. In this work, we have compared the sensor output to results of the human sensory test and confirmed availability of texture measurement using this sensor.

II. Structure of Multimodal MEMS Sensor

Fig.1 shows a measurement system for surface texture of the object using the proposed MEMS combo sensor and LED as probe light for visual measurement. The microcantilevers were fabricated on a Si-on-insulator (SOI) wafer by the surface MEMS process and embedded in polydimethylsiloxane (PDMS). Force vector (normal force and 2-axial shear forces) applied by touching to the object can be detected as the resistance changes of the strain gauge on the microcantilevers. On the other hand, reflected light from the object irradiated by LED probe light can be detected as the impedance change induced by the photoconductive effect in Si.

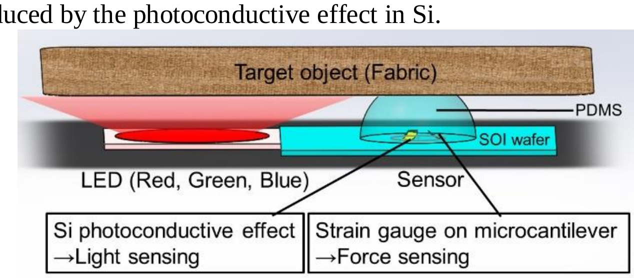

Fig. 1. A conceptual illustration of a measurement system for characterization of surface texture of the object using the optical and force combo sensor.

III. Experimental Method

A. Target Objects

Fig.2 shows a photograph of various kinds of fabrics as the target object for the texture evaluation experiment. We adopted 23 kinds of fabrics such as cotton, non-woven, satin, and others with various colors including yellow, blue, green, pink, and others as the target.

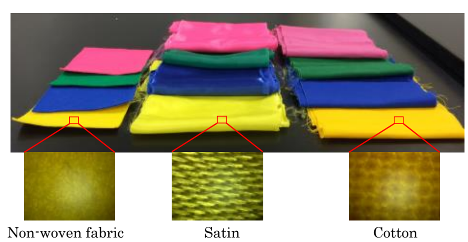

Fig. 2. Target objects (fabrics) for evaluation.

B. Human Sensory Test

The objects were evaluated by visual and tactile sensation of ten 20s male test subjects. The semantic differential (S-D) method with 7-level rating scales was employed for the sensory evaluation. Evaluation items were hardness, coolness, heaviness, grade, and likability.

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C. Tactie Sensing

Fig. 3 shows a schematic illustration of the measurement method for tactile sensing. Two types of dynamic measurement for exploring tactile texture of the object were employed. The first one is an indentation and pull-up test which the object is indented onto the sensor surface with depth of 200 μm and then pulled up using a z-axis stage. The second one is a sliding test which the sensor is moved 100 μm/s horizontally after indenting the object into the sensor surface with normal force of 0.5 N.

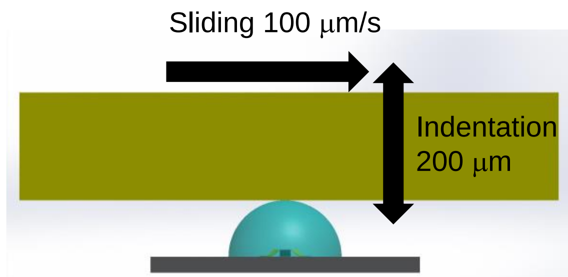

Fig. 3. A schematic illustration of the measurement method for the tactile texture.

D. Visual Sensing

Fig. 4 shows a schematic illustration of measurement system for visual texture of the object. The object was irradiated with probe light from a full-color LED installed at a lateral position to the sensor. The sensor was 10 mm away from the object and the LED. The LED can emit light in a wavelength of 470 nm (blue), 525 nm (green), and 621 nm (red). The impedance of the sensor depends on the surface reflectance including the color, roughness, and glossiness of the object.

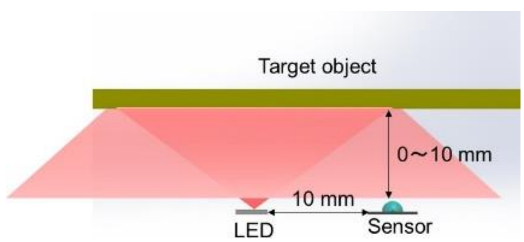

Fig. 4. A schematic illustration of measurement system for visual texture

IV. RESULTS AND DISCCUSION

A. Sensory Test

Fig. 5 shows a result of visual and tactile sensory evaluation for non-woven fabrics with yellow, blue, pink, and green colors. It is found that the human sense for texture is influenced by the color of even the same fabric. This result suggests that simultaneously visual and tactile sensing is necessary for texture evaluation of fabrics.

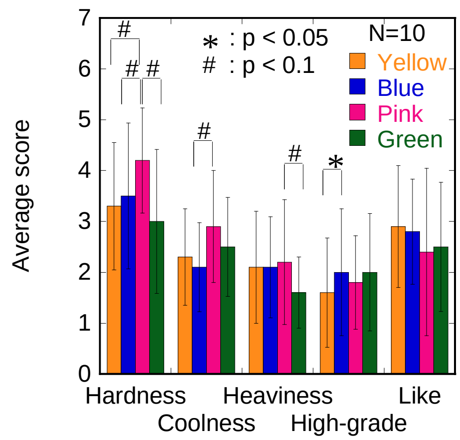

Fig. 5. Average score of each evaluation item in sensory test of non-woven fabric with different colors (Error bar : standard deviation).

B. Tactile Sensing

Figs. 6 and 7 show relative resistance changes of the strain gauge on the microcantilever of the sensor as functions of indentation depth to the objects and time when the sensor is slid on the objects surface, respectively. These results show that dependence of resistance of the strain gauge on the color is little, whereas the resistance change depends heavily on the kind of fabric.

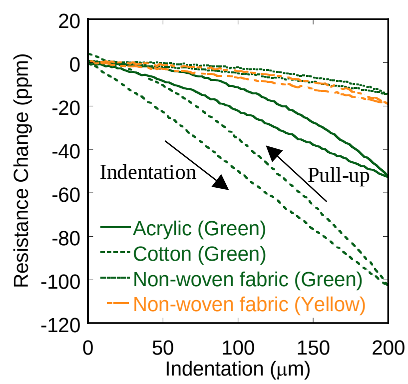

Fig. 6. Relative resistance changes of strain gauge on the microcantilever of the sensor as a function of indentation depth.

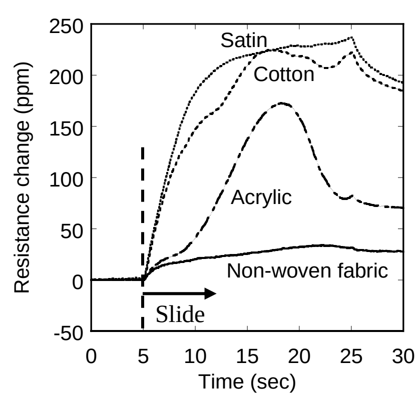

Fig. 7. Relative resistance changes of strain gauge on the microcantilever of the sensor as a function of time when the sensor is slid on the objects.

C. Visual Sensing

Figs. 8 and 9 show relative impedance changes of the sensor when non-woven fabrics of various colors and various kinds of fabrics are irradiated with red, green, and blue color probe lights, respectively. It is found that the impedance change in the case of each color of probe light depends on the color of the fabric. In addition, the impedance change also depends on a kind of fabric of the same color.

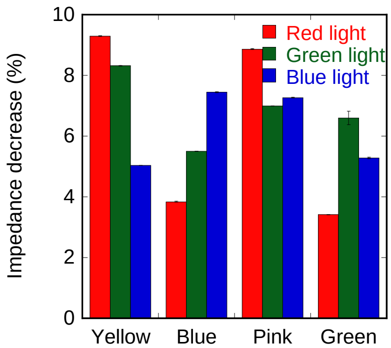

Fig. 8. Relative impedance decreases of the sensor when non-woven fabrics of various colors is irradiated with red, green, and blue color probe lights.

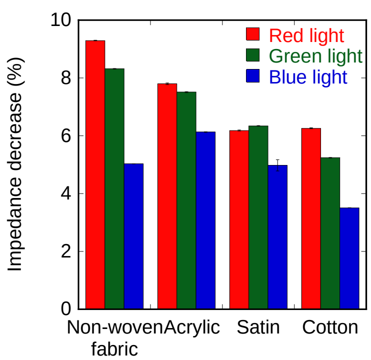

Fig. 9. Relative impedance change of the sensor when various kinds of fabrics of the same color (yellow) are irradiated with red, green, and blue color probe lights.

D. Comparison between Sensory Test and Sensor Output

Fig. 10 shows a 3-dimensional plot of average score for coolness by sensory test, the impedance decrease with blue light intensity, and the maximum resistance change induced by indentation. A colored area in Fig. 10 is obtained by the multiple linear regression analysis. Coolness is obviously correlated with both visual and tactile feature of the sensor output, where correlation coefficients are - 0.59, - 0.77 respectively. Therefore, it is considered that the texture of the fabrics can be evaluated by sensor outputs including visual and tactile information detected by proposed MEMS combo sensor similar to visual and tactile sensory test by human.

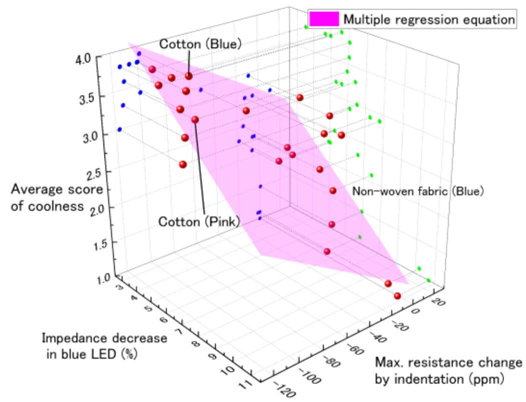

Fig. 10. A 3-dimensional plot of average score for coolness induce by sensory test, the impedance decrease with blue light intensity, and the maximum resistance change induced by indentation.

V. CONCLUSION

A measurement method of texture of various fabrics has been investigated in this work using the MEMS tactile and optical combo sensor and compared with visual and tactile the sensory test by human. It is demonstrated by sensory test that visual and tactile sensing is both crucial for evaluation of texture features of fabrics including colors and touch sense. In this work, it is demonstrated that visual and tactile features of the object can be measured by the proposed MEMS combo sensor which can detect both force and light. Therefore, it is considered that we can evaluate the texture of fabrics using the proposed sensor with reproducibility and quantitativity.

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