Texture Characterization Including Warm/cool Sensation by Force, Light, and Temperature Sensitive MEMS Sensor

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SUMMARY

In this paper, texture measurements including tactile, visual, and warm/cool sensations by multimodal MEMS sensor have been reported. This MEMS sensor has force sensitivity by NiCr strain gauge film on the microcantilever and light sensitivity by the photoconductive effect in Si. In addition, it can be used for measurement of thermal properties which give warm/cool sensation, because resistance of NiCr and impedance of Si also depend on temperature. The impedance and resistance changes after contacting with target objects (copper, acrylic, and wood pieces) are correlated with their thermal conductivity. Furthermore, touch force and reflected light from the object can be detected as resistance and impedance change, respectively. Therefore, it has been demonstrated that texture features including warm/cool sensation can be characterized by a single MEMS sensor.

INTRODUCTION

Recently, texture designs have become more important for high-value-added products, such as automobiles and clothes. The texture obtained by touching the object strongly depends on warm/cool sensation generated by thermal properties [1]. In our previous work, we have proposed the tactile and visual texture characterization by a single force and light sensitive MEMS sensor using strain gauge film on the microcantilevers and photoconductive effect in the Si substrate [2]. Meanwhile, the resistance of the strain gauge film and conductivity in the Si have also temperature dependence. Therefore, in this work, the thermal dependence of the sensor outputs has been characterized and the possibility of texture measurement including warm/cool sensation by this sensor has been explored.

RESULTS AND DISCUSSION

Figure 1 shows a photograph and a conceptual schematic of the proposed multimodal MEMS sensor. This MEMS sensor has three microcantilevers which are embedded in PDMS. Figure 2 shows resistance change rate of the NiCr strain gauge on the microcantilever and impedance through Si substrate at 5 MHz as a function of temperature. It is found that both resistance and impedance depend on temperature. The impedance change induced by temperature drop, ΔT is quite larger than the resistance change.

Figures 3 and 4 show time dependences of impedance and resistance changes, after target objects contact with the sensor surface. The sensor was warmed to 40°C by a film heater beneath sensing point, simulating human body temperature. Copper, wood, and acrylic pieces were employed as the target objects because they have different thermal conductivity and specific heat. The impedance and resistance changes reflect temperature change caused by heat transfer from the sensor surface to the object after contact. Change rates of impedance and resistance are small by contacting with a wood piece with low thermal conductivity and capacity. On the other hand, change rates of impedance and resistance contacting with a copper piece is larger than that contacting with the other objects. Since copper has higher thermal conductivity than the other objects, the temperature change of the sensor caused by heat transfer to the object is larger. Therefore, it is demonstrated that target objects can be classified by warm/cool sensation. Furthermore, in Fig. 4, resistance falls just after contacting (~ 0.2 s). This resistance reduction is caused by applied touch force by contact. It is considered that the texture feature including both mechanical and thermal properties of the target object can be obtained by this sensor.

Figure 5 shows impedance change rate as a function of the distance between the sensor and a target object (copper), with and without probe light from white LED installed next to the sensor. The impedance is almost constant without probe light, but increases with distance near contacting, because of heat transfer by radiation. On the other hand, the impedance with probe light strongly depends on the distance. Because carrier density in the Si decreases with decrease of light intensity reflected by the object, impedance increases with increasing the distance. Therefore, the proposed sensor can detect reflected light including visual property of the object, such as color and reflectivity.

Word count: 642

REFERENCES

Figure 1. (a) A photograph of the multimodal MEMS Sensor and (b) a conceptual diagram of multimodal sensing of force, light, and temperature.

Figure 2. Relative resistance and impedance changes of sensor as a function of temperature change ($T_0 = 40^\circ$C).

Figure 3. Time dependence of relative impedance changes of the sensor after target objects contact with the sensor surface.

Figure 4. Time dependence of relative resistance changes of the strain gauge after target objects contact with the sensor surface.

Figure 5. Relative impedance changes of the sensor as a function of distance between the sensor surface and a target object.