3C2.1

The 14th International Conference on Solid-State Sensors, Actuators and Microsystems, Lyon, France, June 10-14, 2007

TRANSDUCERS & EUROSENSORS '07

GLOVE TYPE OF WEARABLE TACTILE SENSOR PRODUCED BY ARTIFICIAL HOLLOW FIBER

Y. Hasegawa[1], M. Shikida[2], D. Ogura[1], and K. Sato[1]
[1]Department of Micro-Nano Systems Engineering, Nagoya University, Nagoya, JAPAN
[2]EcoTopia Science Institute, Nagoya University, Nagoya, JAPAN
(Tel: +81-52-789-5224; E-mail: hasegawa@kaz.mech.nagoya-u.ac.jp)

Abstract: We previously proposed an artificial hollow fiber, as a new MEMS material, for the development of a fabric tactile sensor. The artificial hollow fiber is fabricated by uniformly laminating metal and insulation layers onto the surface of an elastic hollow fiber. The fabric tactile sensor is made by weaving the modified hollow fibers into a cloth. The sensor can detect the contact force by measuring changes in capacitance at the points where the warp and weft fibers intersect, and can detect 2D contact force distribution by sequentially scanning the capacitance changes at all intersecting points. We investigated the dependence of sensor output on normal load and tension. The normal load and tension were independently applied to the fiber elements in order to determine the basic characteristics of the fabric sensor. We also developed two different glove-type wearable tactile sensors. One was made by patching the sensor onto an existing glove, and the other was made by directly weaving the hollow fibers into the yarn of the glove. In experiments with the patched sensor, we confirmed that it was able to detect contact force.

Keywords: tactile sensor, wearable, flexible, fabric

1. INTRODUCTION

Ubiquitous network systems are progressing rapidly in line with the miniaturization of computational and sensor chips. Flexibility of the sensor structure itself is required in tactile sensing devices if they are to be applied to wearable ubiquitous networks. Researchers have developed many types of tactile sensors, produced using microelectromechanical systems (MEMS) technologies, to achieve flexibility. However, they are generally fabricated on sheet substrates, such as PDMS and polyimide film [1-3], and can only bend along one axis. Therefore, the only curved surfaces they can be used on are cylindrical surfaces. N. Chen et al. recently proposed a novel fabrication process [4] that makes it possible to produce an arbitrary bendable structure by using photolithographic technology. However, it is difficult to directly combine this structure with fabric for clothes. We therefore proposed an artificial hollow fiber structure, as a new MEMS material [5], and we applied it to develop a fabric tactile sensor. The fabrication process of the fibers and the normal load characteristics were presented in the previous paper. This time, we investigated the effects of normal load and tension, which were applied to the fiber elements, to obtain the basic characteristics of the fabric sensor. We also developed two different wearable tactile sensor gloves by patching the sensor on, and by directly weaving the fibers into the yarn.

2. DESIGN AND PRINCIPLE

A schematic view of the fabric tactile sensor and its operation principle are illustrated in Fig. 1. The surface of a single elastic hollow fiber is covered with metal and insulation layers, as shown in Fig. 1(a). The sensor is produced by weaving the hollow fibers together (Fig. 1(b)). The applied contact force is detected by

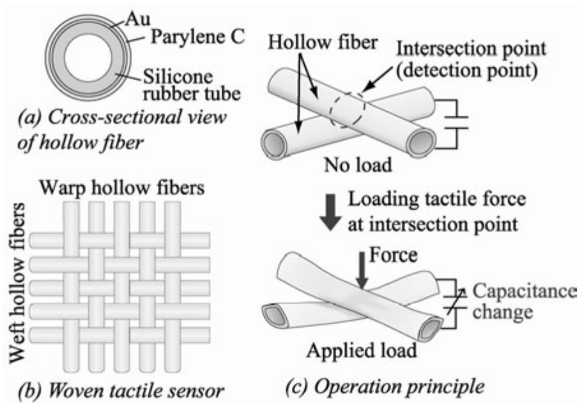
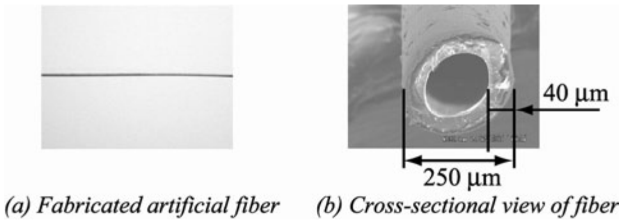


Fig. 1 Fabric tactile sensor made of artificial hollow fibers.

1-4244-0842-3/07/$20.00©2007 IEEE



(a) Fabricated artificial fiber (b) Cross-sectional view of fiber

Fig. 2 Photographs of fabricated artificial hollow fiber.

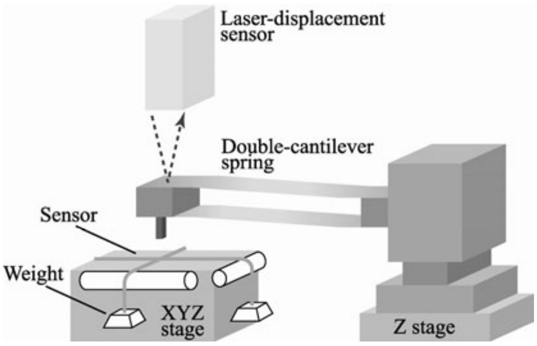


Fig. 3 Experimental setup.

measuring the change in capacitance between the warp and weft fibers at their intersection points. When a load is applied to an intersection point of the fabric tactile sensor, both the warp and weft fibers deform, as shown in Fig. 1(c). As a result, the capacitance between them increases as the applied load increases. Therefore, the sensor can detect the contact force by measuring this change in capacitance. This fabric tactile sensor has two advantages. First, it can detect 2D contact force distribution by sequentially scanning the capacitance changes at all intersection points. The resolution of the 2D contact force distribution is determined by the grid spacing between the warp and weft fibers, and it is easily controlled by combining these artificial hollow fibers with conventional cotton yarn. Second, the fabric tactile sensor can be fitted onto any arbitrary surface by directly weaving the artificial hollow fibers into fabric or by patching them onto fabric. Therefore, we can produce genuine wearable tactile sensors like the way we produce clothes and shoes.

3. FIBER CHARACTERISTICS

We used a commercially available silicone rubber tube as the material of the artificial hollow fiber. The outer and inner diameters were 250 and 170 µm. We first uniformly deposited a

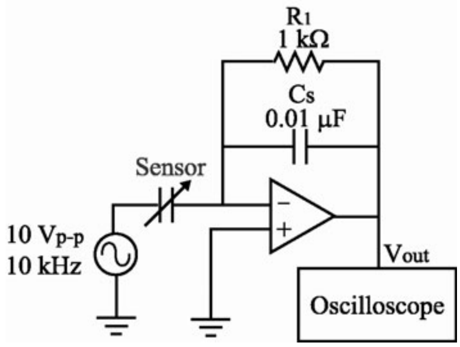


Fig. 4 Detection circuit of capacitance change between warp and weft fibers (during deformation).

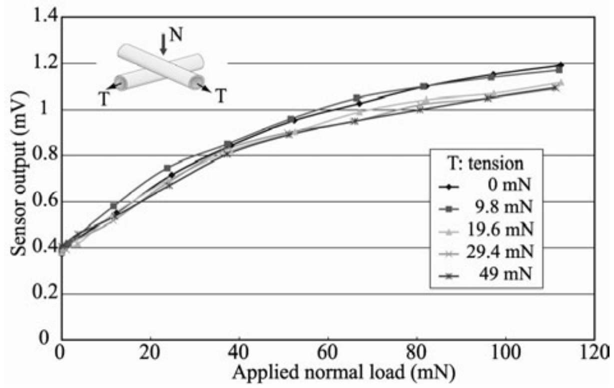
250-nm-thick Au film by sputtering it onto the tube surface. We then coated it with a 1-µm-thick film of evaporated Parylene C. Figures 2(a) and (b) show photographs of the fabricated artificial hollow fiber and the fiber cross section.

We investigated the dependence of sensor output on normal load and tension. The load and tension were applied to a pair of warp and weft fibers to obtain the basic characteristics of the fabric sensor. The dependences were measured by detecting the capacitance changes at the intersecting points of the fibers. The experimental setup is depicted in Fig. 3. We used a double cantilever beam spring mechanism to apply the normal load. The load was applied with a 1.5-mm-diameter pin that was attached to one end of the beam. The applied load was calculated from the deflection of the beam, and the deformation of the two hollow fibers was directly measured with a laser-displacement sensor. We used four different weights to apply tension to the two fibers, which were fixed to the stage at one end. A driving signal of 10 V_{p-p} at 10 kHz was used to detect the capacitance change between the two fibers (Fig. 4).

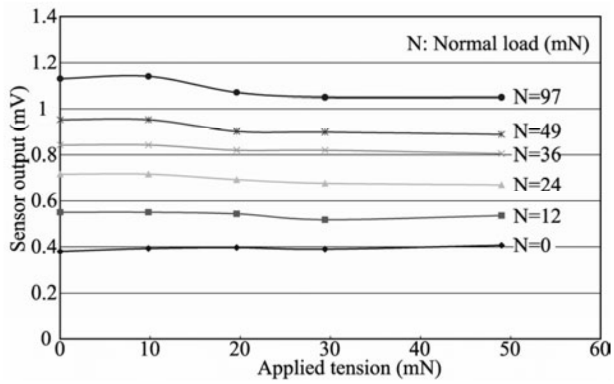
Figures 5(a) and 5(b) plot the respective dependences of sensor output on normal load and tension. The sensor output increases as the normal load increases. The variation of the output due to changes in the tension was less than 10% of the initial values. From these results, we found that the dependence of sensor output on tension was very small compared to the dependence on normal load in the range from 0 to 49 mN.

TRANSDUCERS & EUROSENSORS '07
The 14th International Conference on Solid-State Sensors, Actuators and Microsystems, Lyon, France, June 10-14, 2007

TRANSDUCERS & EUROSENSORS '07
The 14th International Conference on Solid-State Sensors, Actuators and Microsystems, Lyon, France, June 10-14, 2007



(a) Relationship between applied normal load and sensor output under tension.



(b) Relationship between applied tension and sensor output.

Fig. 5 Dependences of sensor output on normal load and tension

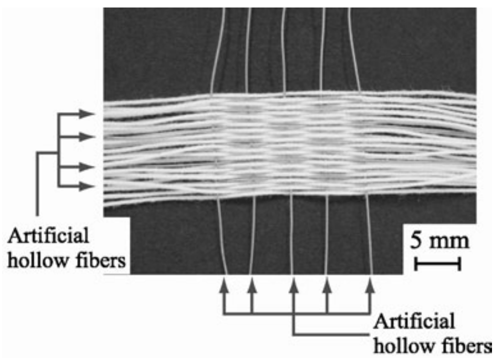


Fig. 6 Fabric tactile sensor formed by combining artificial hollow fibers and conventional cotton yarn.

4. FABRIC TACTILE SENSOR

We developed two different types of wearable tactile sensor gloves: a patched type, and a direct knit type.

Patched type

We first produced a rectangular-shaped fabric tactile sensor by combining the artificial hollow fibers and conventional cotton yarn (Fig. 6). The warp and weft intervals of the artificial hollow fibers were 2.0 mm and 4.5 mm, respectively. These values represent the space resolution of the contact 2D tactile force distribution. We then patched the sensor onto a commercial glove using cotton yarn, as shown in Fig. 7.

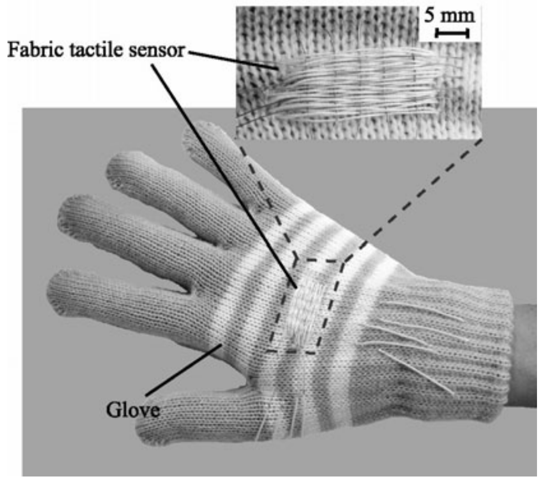


Fig. 7 Patched-type sensor formed by adding fabric tactile sensor to glove.

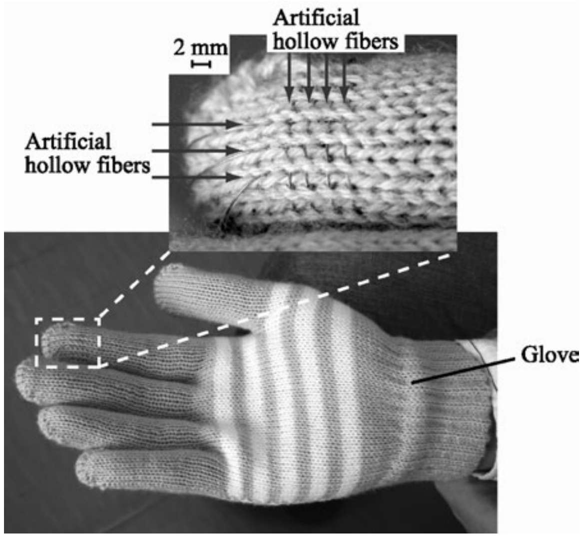


Fig. 8 Direct-knit type produced by weaving artificial hollow fibers into glove yarn.

Direct knit type

We directly wove the artificial hollow fibers into the glove yarn, as shown in Fig. 8. The pitch of the fibers was 2.0 mm.

We experimentally evaluated the detection performance of the contact force on the patched-type glove. We inserted a plastic material inside the glove and then set the glove on the same stage used to evaluate the performance of

1-4244-0842-3/07/$20.00©2007 IEEE

the pair of fibers. The sensor output versus the applied load is shown in Fig. 9. The obtained results are as follows.

(1) The sensor output increased as the normal load increased, finally reaching 1.35 times the initial output.

(2) The initial value of the patched glove was 1.0 mV, which is the same value when the normal load of 65 mN was applied to a pair of fibers (see Fig. 5). We therefore shifted the origin of the graph to the point at the applied normal value of 65 mN at the axis of the normal load, as shown in Fig. 9. The shifted result almost fit the result obtained for the pair of fibers. We therefore presume that the almost 65-mN bias-load was applied at the intersection of the fibers by weaving them into the patch type textile. A more detailed study is necessary in order to understand the deformation behavior.

From these results, we concluded that the developed wearable tactile sensor glove can detect contact force by measuring the change in capacitance between the warp and weft fibers.

5. FUTURE WORK

Some of our future objectives are as follows.

(1) We need to develop electrical signal processing circuits that sequentially scan the detecting points to obtain 2D tactile force information.

(2) We need to analyze the deformation of cylindrical shapes as well as the capacitance change during load application by using a FEM.

(3) We also need to investigate the relationship between the applied load and the sensor output using the developed direct knit-type tactile sensor glove.

6. CONCLUSION

We developed two different glove-type wearable tactile sensors by patching hollow fibers on, and directly weaving them into knit fabric. The obtained results are summarized as follows.

(1) The sensor output increased with increasing normal load. The variation in the output due to the change in tension was less than 10% of the initial values. We found that the dependence of the output on tension was very small compared to the dependence on normal load in the range from 0 to 49 mN.

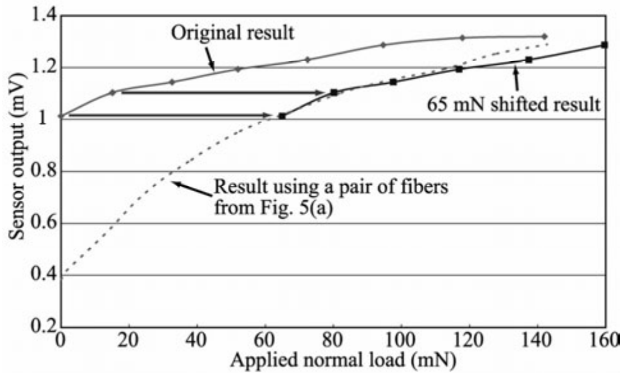


Fig. 9 Relationship between applied normal load and sensor output on patched-type fabric tactile sensor.

(2) The resolution of the developed tactile sensors was 2.0 mm. In experiments done using the patched-type tactile sensor, we confirmed that the sensor output increased as the normal load increased, finally becoming 1.35 times the initial output.

ACKNOWLEDGEMENTS

This work was supported by The 21st Century COE Program (Micro- and Nano- Mechatronics for Information-based Society) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

REFERENCES

[1] J. Engel et al. Polymer micromachined multimodal tactile sensors. Sensors and Actuators A: Physical. 2005. A117. pp. 50-61.

[2] E-S. Hwang et al. A polymer based flexible tactile sensor for normal and shear load detection. Proceedings of MEMS'06 conference. 2006. p. 714-717.

[3] H-K. Lee et al. A capacitive proximity sensor in dual implementation with tactile imaging capability on a single flexible platform for robot assistant applications. Proceedings of MEMS'06 conference. 2006. p. 606-609.

[4] N. Chen et al. Flexible skin with two-axis bending capability made using weaving by-lithography fabrication method. Proceedings of MEMS'06 conference. 2006. p. 330-333.

[5] Y. Hasegawa et al. Novel Type of Fabric Tactile Sensor made from Artificial Hollow Fiber. Proceedings of MEMS'07. 2007. p. 603-606.

TRANSDUCERS & EUROSENSORS '07
The 14th International Conference on Solid-State Sensors, Actuators and Microsystems, Lyon, France, June 10-14, 2007