https://doi.org/10.20965/jrm.2020.p0315

Paper:

Development of MEMS Tactile Sensation Device for Haptic Robot

Junji Sone*, **Yasuyoshi Matsumoto***, **Yoji Yasuda***,
Shoichi Hasegawa**, **and Katsumi Yamada***

*Tokyo Polytechnic University
1583 Iiyama, Atsugi, Kanagawa 243-0297, Japan
E-mail: sone@cs.t-kougei.ac.jp
**Precision and Intelligence Laboratory, Tokyo Institute of Technology
4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8503, Japan
[Received September 4, 2019; accepted December 23, 2019]

A tactile sensation device using micro-electro-mechanical system (MEMS) has been developed. This device is integrated with a haptic sensation robot for use as fingers. The tactile device must be miniaturized to enable attachment of the actuator mechanism to the fingers. Therefore, we used MEMS technology for this device. The device is composed of an interface part fabricated by 3D printing, pins, and MEMS cantilever-type actuators. It has the ability to stimulate the mechanoreceptors of the fingertips. The device and robot can display not only high-resolution images of the fingertips but also the repulsion force during finger operations such as tool holding and rotation. We have not yet achieved the final device because of fabrication problems. In this paper, we explain the details, progress of development, and results of trials on the prototype device.

Keywords: MEMS device, tactile sensation, haptic sensation robot

1. Introduction

Virtual reality (VR) technology has become popular for conducting visiting experiments, surgery, and games. For example, one of the main technologies of VR involve displays that can engage a user in a world of computer graphics and provide an immersive experience through the use of stereo 3D display. Humans have five senses, among which tactile and haptic sensations are very important for manipulation and recognition of the shapes and textures of objects. The tactile sensation and force feedback are important for surgical systems [1] and teleoperated tasks [2]. In our previous work, we succeeded in presenting a force profile similar to that of real cutting [3]. There are several products for Braille displays [a], and tactile devices have been researched [4] for such purposes. A tactile display requires high density and good response to realize teleoperation tasks and virtual reality that the Braille code embodies.

One of these tactile displays was realized using a magnetic microactuator based on a PDMS (polydimethylsiloxane) elastomer [5]. Although it could realize high density and high speed, its force was very less. Ion-conducting polymer gel film actuators can realize high-density and high-speed display under wet conditions [6]. Watanabe developed a hydraulic displacement amplification mechanism that could achieve a large displacement using a micro-electromechanical system (MEMS) actuator and flexible microchamber filled with an incompressible liquid [7]. The resolution was not sufficient, but because of the large displacement, a high Braille code display capability could be achieved. A shape memory alloy actuator is one possible solution [8, 9], but it does not have sufficient response speed for use in a tactile device. Paschew developed a high-resolution display using a smart hydrogel [10]. They used the smart hydrogel as an actuator with temperature as the drive source, but the response was not fast enough for the application. A similar polymer actuator was developed by Choi using a dielectric elastomer [11]. This actuator was soft, flexible, and thin. Ultrasound vibrators and vibrotactile devices can also generate artificial tactile sensation [12–15]. A quasi-tactile device was developed using an electro-tactile display. It is an interesting phenomenon that the tactile sensation changes with polarity [16]. In one device, material stiffness was represented using a smart fluid [17]. An air jet [18], suction force [19], and air pressure control have been used in some tactile displays [20, 21]. However, it is difficult to use these devices as wearable devices.

Kawasaki conducted research on a haptic device [22] that can generate haptic sensation for each finger. CyberGlove system can represent the forces on all fingers, and can be used over a wide area by a supported robotic system to improve reality. However, these systems cannot change the contact location on the fingers. Cutkovsky researched methods to change the contact point on the fingers to represent the forces accurately [23], but this was applied to only one finger. Yokokohji also developed a haptic system that can change the contact location on the

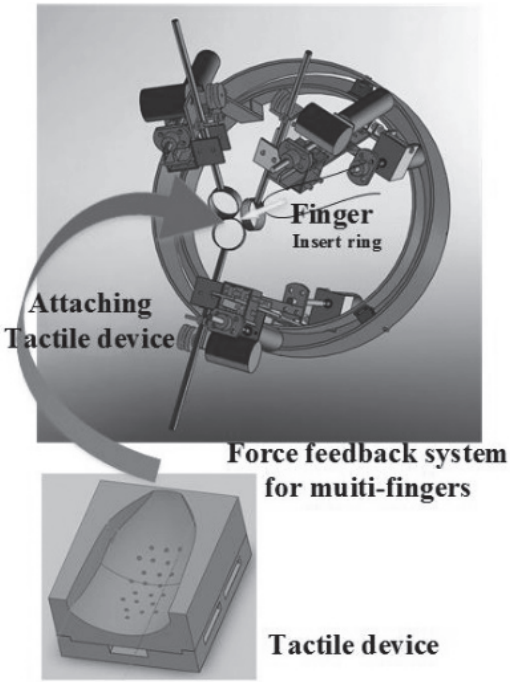


Fig. 1. Concept of our system [31].

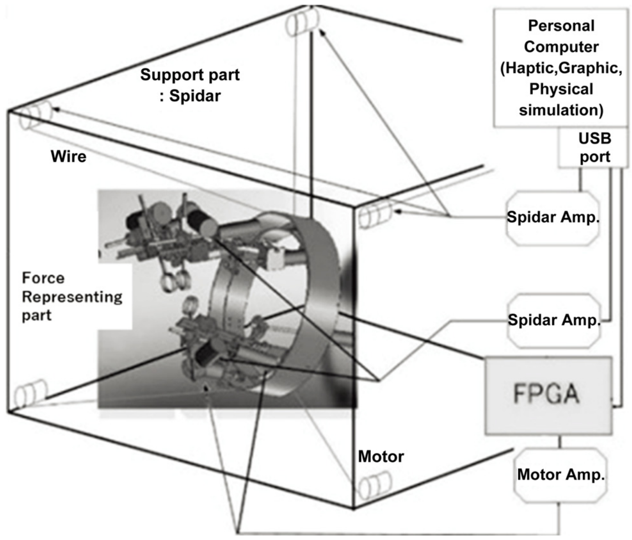


Fig. 2. Configuration of developed force display [31].

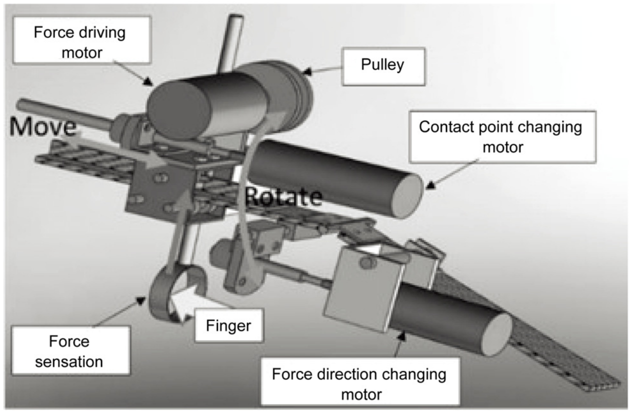


Fig. 3. Haptic sensation mechanism [31].

fingers [24]. FingGAR [25] can represent skin deformation, vibration, and pressure stimulation. However, it is not possible to change the contact location.

We aimed at developing a fusion system with tactile and haptic display that can represent actual touching shape information and force sensation of the fingers. Therefore, we selected MEMS [26–28] and 3D printing technologies for developing the tactile device. For haptic sensation display, we developed a haptic display that allows changing the contact location for multiple fingers (thumb, index, and middle fingers). This haptic display can move around a wide area, and is based on SPIDAR [29] haptic display technology [30]. In this paper, we explain the configuration of the haptic and tactile display as well as the development process and results of trials on the tactile display.

2. Concept of Tactile and Haptic Display

The system concept of tactile and haptic display was explained in a paper published in VRCAI2018 [31]. **Fig. 1** shows this concept. Haptic display represents the force of each manipulation and collision. The size of the tactile device is a little larger than that of each finger; this device is placed on the hook of the haptic display. Hence, we can represent the tactile and haptic sensations at the same time. **Fig. 2** shows the configuration of the haptic display. We used SPIDAR as the support mechanism for the force representing part. SPIDAR is a six degree-of-freedom haptic device, whose working area can be changed easily by altering the position of the motors. As it is driven by eight strings, it does not require a rigid frame from the force ground to the force representation point. It can measure the position and orientation of the force representing part and the support unit, because SPIDAR's motors apply a small force during standby (non-force representing) mode. We configure the haptic mechanism for the fingers and the force such that it can represent the thumb, index, and middle fingers. **Fig. 3** shows the haptic sensation mechanism for each finger. This mechanism has three motors. One is for force sensation, the second is for changing the contact location, and the third is for changing the direction of the force. **Fig. 4** shows the multi-finger force representation mechanism. There are three force sensation mechanisms. The multi-finger force representation mechanism can rotate with wrist rotation. Further, we used SPIDAR as the support mechanism for the force representing part. It can measure the position and rotation of the wrist part, and can also represent the force and torque applied to the wrist. **Fig. 5** shows the system configuration. We used Unity and SpringHead for the software development kit (SDK), a SPIDAR amplifier (SH-4 amplifier, MPS Co., Ltd.) for haptic motor control, and an FPGA motor controller (original development) for

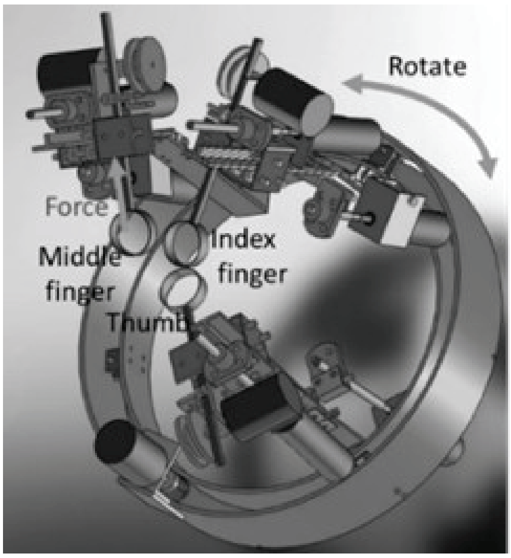


Fig. 4. Multi-finger force representation mechanism [31].

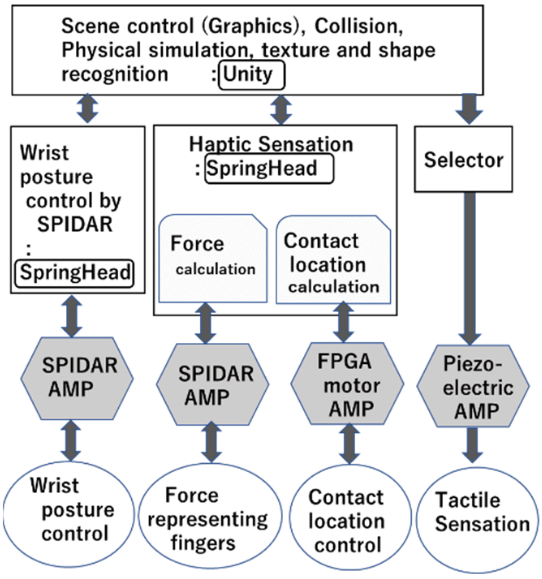


Fig. 5. System configuration.

contact location control of haptic sensation. Ten brushless servomotors are used in this system. We have not developed a tactile sensation control system. We will develop a tactile sensation control system in which the texture and shape feature recognition functions will be incorporated in the Unity application, and tactile signals will be sent to the selector and amplified by the piezoelectric amplifier to actuate the actuators of the tactile device. **Fig. 6** shows the arrangement used for the haptic experiment. Haptic sensation is generated when a finger collides with a virtual sphere or square object. The haptic force reflects the stiffness of the target object and collision speed. The posture of the wrist is reflected by outside the SPIDAR system motor encoder information and the calculated quaternion matrix.

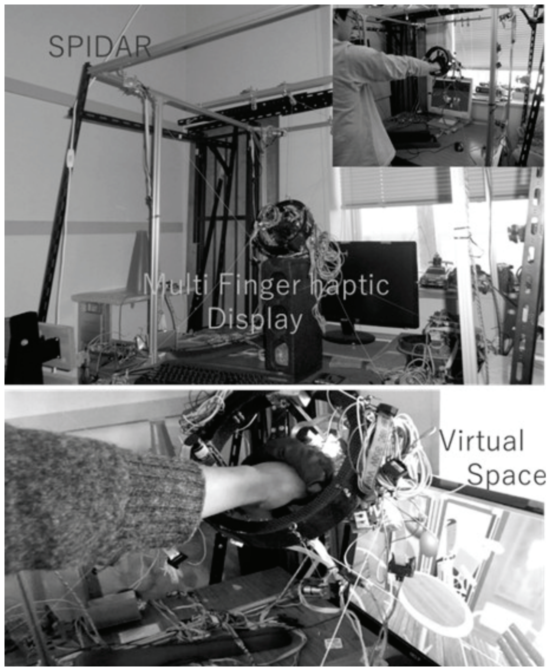


Fig. 6. Haptic experiment.

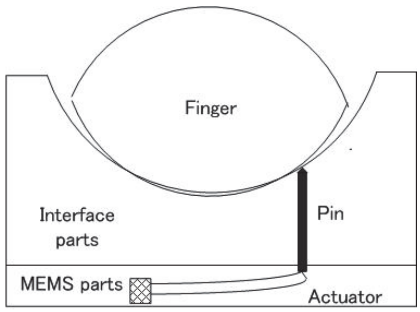


Fig. 7. Scheme of tactile device [31].

3. Development of Tactile Display

We explain below the development method and the result of trials on the tactile display.

3.1. Design of Tactile Display

Figure 7 shows the scheme of our tactile device. A finger contacts the interface parts, and tactile sensation is generated via pins. The pins must be placed with high density; carbon fiber reinforced plastic (CFRP) pins are used here, as in the work by Smithmaitrie [32]. The interface parts are fabricated by 3D printing (we used ABS resin). The stimulation targets were paciniform end-organs and Merkel cell neurite complexes. In this case, we needed to stimulate these mechanoreceptors by pressing to a 400 μm depth at the fingertips. Therefore, we designed cantilever type actuators to perform actuation to this depth. The deformation of a piezoelectric microactuator is small [33]; thus, we considered a method for obtaining a larger deformation. We selected the following arrangement. A cantilever composed of many tiles,

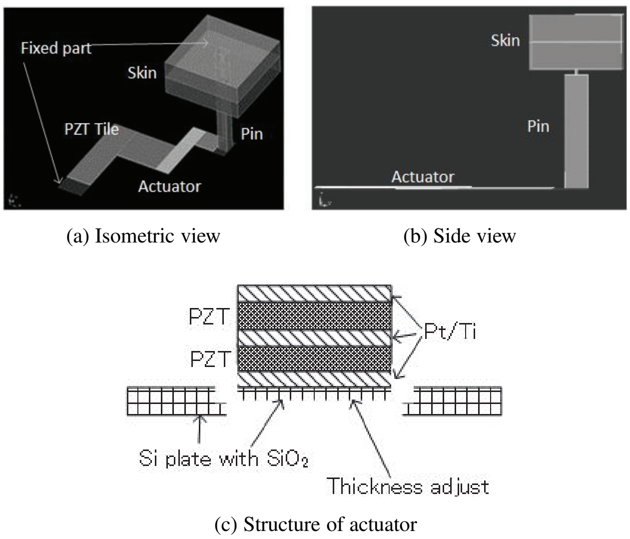


Fig. 8. Analysis model of cantilever, pin, and human skin [31].

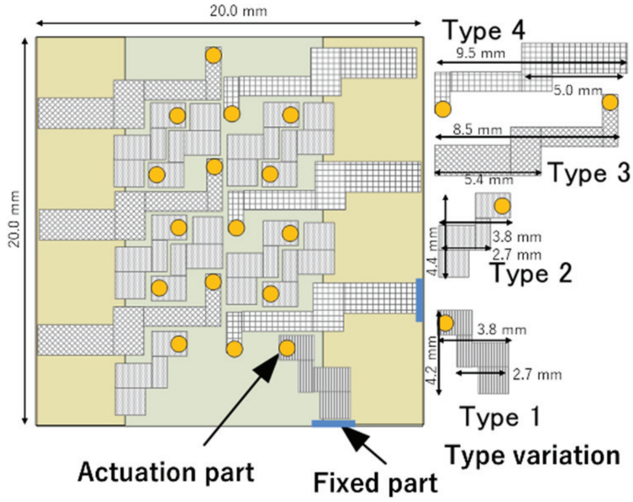


Fig. 9. Cantilever layout.

aligned in a perpendicular direction, was used to increase the length. A multilayer piezoelectric structure was used as a high-power drive. The distortion in the width direction of the cantilever was used to obtain a large deformation. The cantilevers were placed closely to establish high-density stimulation points. The piezoelectric material Pb(Zr,Ti)O_3 (PZT: lead zirconate titanate) was used for high-power actuation. The thickness of each layer was 3 μm.

Figure 8 shows the analysis model. The actuators comprise four connected tiles, and each tile has a PZT multilayer and Si base layer. Each PZT layer has Pt electrodes, and the drive and ground electrodes are placed alternately. The end of each actuator is connected to a CFRP pin, and the top of each pin is in contact with human skin. The top of each pin is a 0.5-mm square, which stimulates the fingertip.

Figure 9 shows the cantilever layout. We designed four types of cantilevers, as shown in the figure. To fabricate the compact device, we used a 20-mm square Si plate, which was the overall device dimension; this is similar to the width and length of a fingertip. One side of a cantilever actuator was fixed, and the other side was the actuation part, which is connected to a stimulus pin. The stimulus pins were aligned within 2.5 mm. We confirmed the stimulation performance using FEM analysis [34].

3.2. Fabrication of Tactile Display

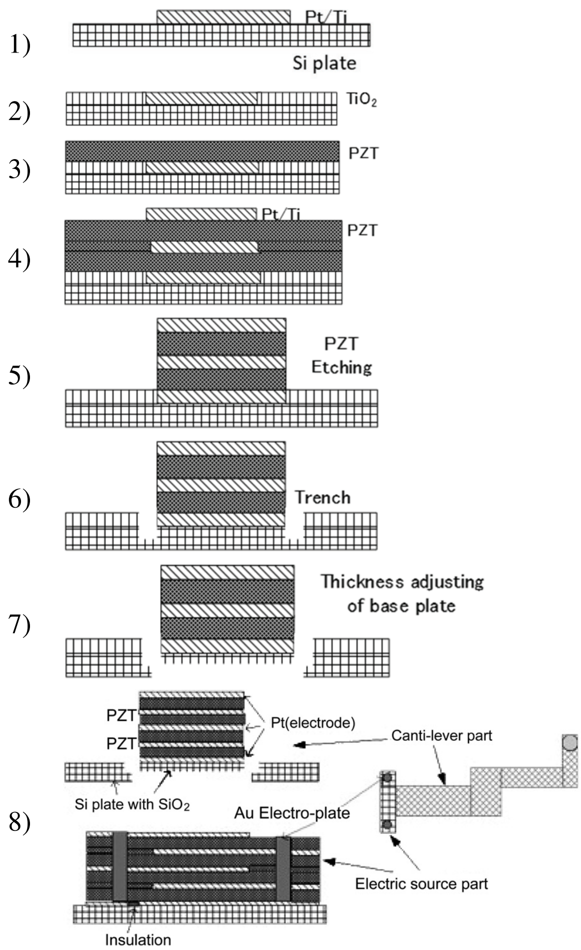
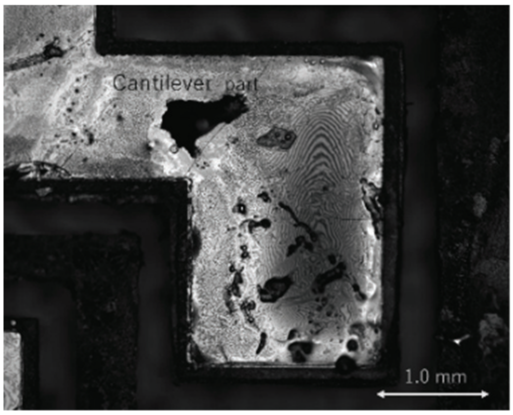
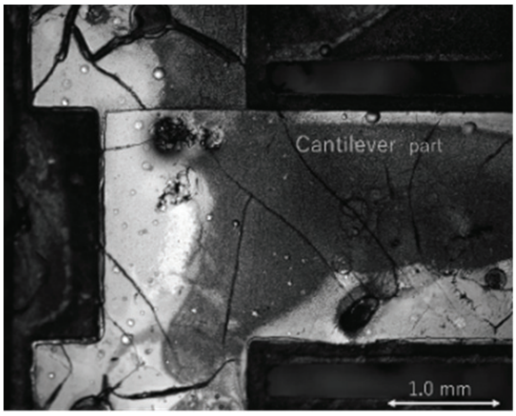


Fig. 10. Device fabrication process.

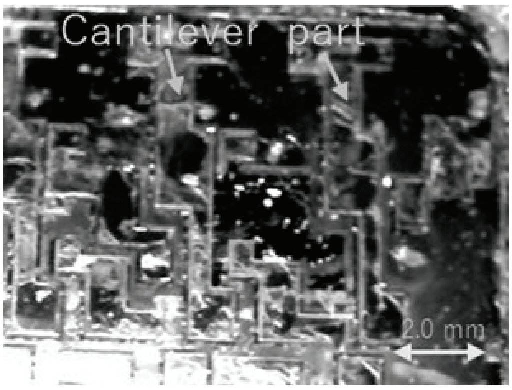
Figure 10 shows the tactile display fabrication process. 1) A base electrode of a Pt/Ti (GND) layer is formed by sputtering and patterning. 2) GND and source electrodes are separated by a TiO_2 insulator layer formed by sputtering. 3) A 3 μm PZT layer is formed by the sol-gel method, 75 repetitions of spin coating with baking (180°C, 350°C) and 15 repetitions of rapid thermal annealing (680°C, heating rate is 30°C/s, oxygen atmosphere). We used the same conditions, material, facility, and sputtering conditions of the electrode as in Moriyama's research [35]. We observed that our PZT layer has the same crystal orientation, P-E hysteresis loop, and displacement-voltage characteristics as in the results presented in this paper. A 12% PZT-E1 solution (Mitsubishi Materials) is used. 4) A Pt/Ti layer electrode is formed by sputtering and patterning. Processes 3) and 4) are repeated as required.



(a) Actuation part

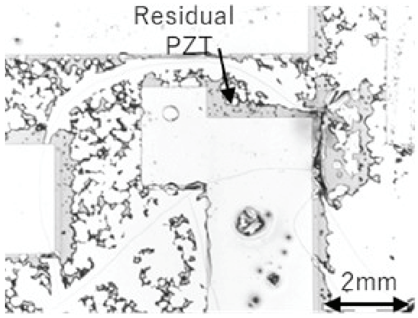


(b) Base part

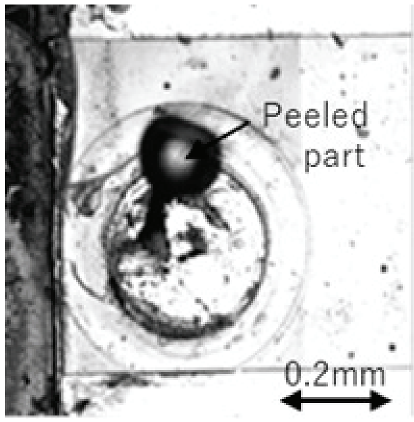


(c) Wide area view of cantilevers

Fig. 11. Device fabrication result.



(a) Wet etching result



(b) Wire bonding result

Fig. 12. Wet etching of PZT and wire bonding result.

5) The outer side of the PZT layers of the cantilever is etched by buffered hydrofluoric acid (BHF) and nitric acid. 6) The base Si plate is etched by deep RIE (reactive ion etching) to form the outline of the cantilever shape. 7) The thickness of the cantilever is adjusted to 50 μm by deep RIE from the back side. 8) Alternate electrode holes are filled with Au by electroplating. Each electrode is connected to each power source by wire bonding. This development process was explained in a previous paper [36, 37].

Figure 11 shows the fabricated device. **Fig. 11(a)** shows the actuation part of the cantilever. **Fig. 11(b)** shows the electrode part of the cantilever (before Au electroplating). **Fig. 11(c)** shows a wide-field view of the cantilevers. After releasing the cantilever from the base plate, slight deformation was observed. In this result, the surface on the electrode was not smooth, and several cracks were observed. **Fig. 12(a)** shows the residual PZT after etching. **Fig. 12(b)** shows the Au electrode layer peeled by wire bonding. The adhesion force between the lower layer of the Pt electrode and the Au layer was insufficient because of the residual PZT, and the perforated Au electrode was peeled by wire bonding; hence, the electric wiring failed. We infer that the wet etching of the PZT layer must be improved.

3.3. Performance of Tactile Display

We built a tactile device with four layers of PZT. **Fig. 13** shows the actuation measurement setup of the cantilevers before wire bonding. Electric power was supplied through the contact probes, and deformation was measured with a laser displacement sensor (Keyence LK-030). We used a digital multimeter to digitize the measurement results of the laser displacement sensor. If 80 V is applied to the actuator, the output voltage of the sensor changes by 28 mV. This would mean a 28 μm deformation, because the sensor output sensitivity is 1 μm/V (**Fig. 14**). This device has four layers of PZT. Piezoelectric simulation result shows that the deformation of the five layers of PZT cantilever was 400 μm at 100 V [34]. This deformation is smaller than the expected value. This variation is caused by the

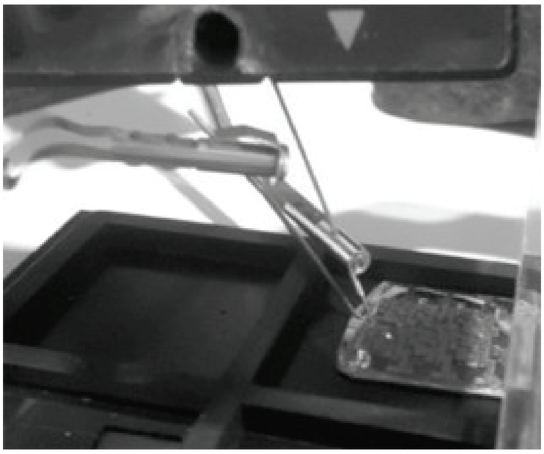


Fig. 13. Actuation measurement setting.

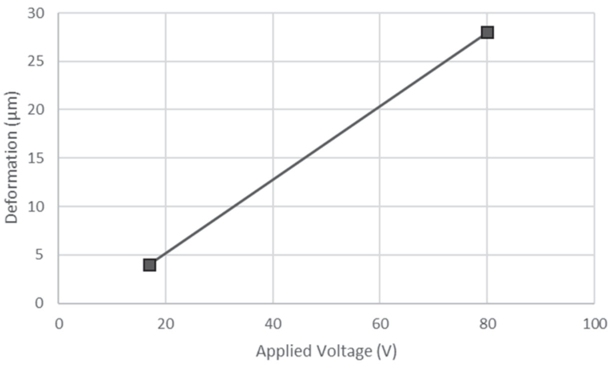


Fig. 14. Actuation measurement result.

rough surface of the PZT layer and the presence of several cracks in the Pt electrode layer. Therefore, it is necessary to improve the fabrication method of the PZT layers.

4. Conclusions

We considered a tactile device integrated with a haptic device. Our main aim was to use MEMS technology in the tactile device. We designed the device structure based on the result of FEM analysis of the deformation. We attempted to build a prototype device. The fabrication of five layers of PZT with 3 μm thickness was difficult, because the large number of processes leads to a greater probability of processing errors, which is reflected in the film quality. We attempted the sputtering deposition of PZT films, but it also requires accurate process control to form the high-quality film. Wet etching fabrication of thick PZT without residual PZT is also needed. We also found the Si plate to be weak for the high-density actuator layout, necessitating the bonding of a reinforcement plate to the device plate. Based on these trial results, we will investigate more suitable processes and improve the device structure.

Acknowledgements

A part of this work was supported by the "Nanotechnology Platform" of the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, at the Center for Integrated NanoTechnology Support, Tohoku University and JSPS KAKENHI Grant Number 15K12089 and 17K00285. This work was a research activity of "Research and development of educational and communicational robot system" approved by the Council for Promotion of Universal Future Society project at MEXT, Japan, and Color Science and Art project of Tokyo Polytechnic University. We thank Prof. Shuji Tanaka, Prof. Kentaro Totsu, Prof. Shinya Yoshida, Prof. Hideki Hirano, and Dr. Masaaki Moriyama (Tohoku University) for the discussions on this research topic.

References:

[1] A. M. Okamura, L. N. Verner, C. E. Reiley, and M. Mahvash, "Haptics for Robot-Assisted Minimally Invasive Surgery," Robotics Research, Vol.66, pp. 361-372, 2011.

[2] M. K. O'Malley and R. O. Ambrose, "Haptic feedback applications for Robonaut," Industrial Robot, Vol.30, No.6, pp. 531-542, 2003.

[3] J. Sone, K. Ogiwara, Y. Kume, Y. Tokuyama, and M. Isobe, "Force Profile study of Virtual Cutting," Proc. of 13th Int. Conf. on Artificial Reality and Telexistence, pp. 143-147, 2003.

[4] H. Ishizuka and N. Miki, "Review MEMS-based tactile displays," Displays, Vol.37, pp. 25-32, 2015.

[5] J. Streque, A. Talbi, P. Pernod, and V. Preobrazhensky, "New magnetic microactuator design based on PDMS elastomer and MEMS technologies for tactile display," IEEE Trans. Haptics, Vol.3, No.2, pp. 88-97, 2010.

[6] M. Konyo, S. Tadokoro, and T. Takamori, "Artificial tactile feel display using soft gel actuators," Proc. of the 2000 IEEE Int. Conf. on Robotics and Automation, pp. 3416-3422, 2000.

[7] J. Watanabe, H. Ishikawa, X. Aroutte, Y. Matsumoto, and N. Miki, "Demonstration of vibrational braille code display using large displacement micro-electromechanical system actuators," Japan. J. Appl. Phys., Vol.51, 06FL11, 2012.

[8] F. Zhao, K. Fukuyama, and H. Sawada, "Compact Braille display using SMA wire array," Proc. of the 18th IEEE Int. Symp. on Robot and Human Interactive Communication, pp. 28-33, 2009.

[9] T. Coles, N. John, D. Gould, and D. Caldwell, "Haptic palpation for the femoral pulse in virtual interventional radiology," Proc. of the 2009 2nd Int. Conf. on Advances in Computer-Human Interactions, pp. 193-198, 2009.

[10] G. Paschew and A. Richter, "High-resolution tactile display operated by an integrated Smart Hydrogel actuator array," Proc. SPIE – The Int. Society for Optical Engineering, Vol.7642, 764234, 2010.

[11] H. S. Lee, D. H. Lee, D. G. Kim, U. K. Kim, C. H. Lee, N. N. Linh, N. C. Toan, J. C. Koo, H. Moon, A. D. Nam, J. Han, and H. R. Choi, "Tactile display with rigid coupling," Proc. of Electroactive Polymer Actuators and Devices (EAPAD), 83400E, 2012.

[12] T. Maeno, K. Otokawa, and M. Konyo, "Tactile display of surface texture by use of amplitude modulation of ultrasonic vibration," Proc. of 2006 IEEE Ultrasonics Symp., pp. 62-65, 2006.

[13] S. Asano, S. Okamoto, Y. Matuura, H. Nagano, and Y. Yamada, "Vibrotactile displayapproach that modify roughness sensations of real texture," Proc. of the 21st IEEE Int. Symp. on Robot and Human Interactive Communication, pp. 1001-1006, 2012.

[14] P. Strohmeier and K. Hornbæk, "Generating Haptic Textures with a Vibrotactile Actuator," Proc. of the 2017 CHI Conf. on Human Factors in Computing Systems (CHI '17), pp. 4994-5005, 2017.

[15] Y. Rekik, E. Vezzoli, L. Grisoni, and F. Giraud, "Localized Haptic Texture: A Rendering Technique based on Taxels for High Density Tactile Feedback," Proc. of the 2017 CHI Conf. on Human Factors in Computing Systems (CHI '17), pp. 5006-5015, 2017.

[16] H. Kajimoto, "Electro-tactile display with real-time impedance feedback using pulse width modulation," IEEE Trans. Haptics, Vol.5, No.2, pp. 184-188, 2012.

[17] C. H. Lee and M. G. Jang, "Virtual surface characteristics of a tactile display using magneto-rheological fluids," Sensors, Vol.11, No.3, pp. 2845-2856, 2011.

[18] Y. Kim, I. Oakley, and J. Ryu, "Design and psychophysical evaluation of pneumatic tactile display," Proc. of SICE-ICASE Int. Joint Conf. 2006, pp. 1933-1988, 2006.

[19] T. Hachisu and M. Fukumoto, "VacuumTouch: attractive force feedback interface for haptic interactive surface using air suction," Proc. of the 2014 CHI Conf. on Human Factors in Computing Systems (CHI '14), pp. 411-420, 2014.

[20] X. Wu, S. H. Kim, H. Zhu, C. H. Ji, and G. Mark, "A refreshable braille cell based on pneumatic microbubble actuators," J. Microelectromech. Syst., Vol.21, No.4, pp. 908-916, 2012.

[21] L. Santos-Carreras, K. Leuenberger, P. Retornaz, R. Gassert, and H. Bleuler, "Design and psychophysical evaluation of a tactile pulse display for teleoperated artery palpation," Proc. of the 2010 IEEE/RSJ Int. Conf. on Intelligent Robots and System, pp. 5060-5066, 2010.

[22] H. Kawasaki, J. Takai, Y. Tanaka, M. Carafeddine, and T. Mouri, "Control of multi-fingered haptic interface opposite to human hand," Proc. of Int. Conf. on Intelligent Robotics and Systems, Las Vegas, USA, 2003, pp. 2709-2712, 2003.

[23] K. J. Kuchenbecker, W. R. Provancher, G. Niemeyer, and M. R. Cutkosky, "Haptic display of contact location," Haptic Interfaces for Virtual Environment and Teleoperator Systems, pp. 40-47, 2004.

[24] Y. Yokokohji, N. Muramori, Y. Sato, T. Kikura, and T. Yoshikawa, "Design and path planning of an encountered-type haptic display for multiple fingertip contacts based on the observation of human grasping behavior," IEEE Int. Conf. on Robotics and Automation, pp. 1986-1991, 2004.

[25] V. Yem and H. Kajimoto, "Wearable Tactile Device using Mechanical and Electrical Stimulation for Fingertip Interaction with Virtual World," IEEEVR2017, pp. 99-104, 2017.

[26] T. Okuda and S. Kidoaki, "Development of Time-Programmed, Dual-Release System Using Multilayered Fiber Mesh Sheet by Sequential Electrospinning," J. Robot. Mechatron., Vol.22, No.5, pp. 579-586, 2010.

[27] S. Yoshioka, A. Nagano, D. Hay, I. Tabata, T. Isaka, M. Iemitsu, and S. Fukashiro, "New Method of Evaluating Muscular Strength of Lower Limb Using MEMS Acceleration and Gyro Sensors," J. Robot. Mechatron., Vol.25, No.1, pp. 153-161, 2013.

[28] T. Tanaka, T. Takahashi, M. Suzuki, and S. Aoyagi, "Development of Minimally Invasive Microneedle Made of Tungsten – Sharpening Through Electrochemical Etching and Hole Processing for Drawing up Liquid Using Excimer Laser –," J. Robot. Mechatron., Vol.25, No.4, pp. 755-761, 2013.

[29] M. Sato, "Development of string-based force display: Spidar," Proc. of the 8th Int. Conf. on Virtual Systems and Multi Media (VSMM 2002), pp. 1034-1039, 2002.

[30] J. Sone, R. Tamura, K. Yamada, J. Chen, S. Hasegawa, K. Akahane, M. Sato, and K. Konno, "Mechanism Improvement in Multi-finger Haptic Display – Addition of Rotational Mechanism and Improvement of Thumb Trajectory –," Proc. of ASIAGRAPH 2010 in Shanghai, 2010.

[31] J. Sone, Y. Matsumoto, R. Sekiya, K. Ooizumi, Y. Yasuda, Y. Hoshi, and S. Hasegawa, "Fusion of Tactile and Force display – Concept and each display development –," Proc. of the 16th ACM SIGGRAPH Int. Conf. on Virtual Reality Continuum and its Applications in Industry (VRCAI 2018), 2018.

[32] P. Smithmaitrie, J. Kanjantoe, and P. Tandayya, "Touching force response of the piezoelectric Braille cell," Disabil. Rehabil., Assist. Technol., Vol.3, No.14, pp. 360-365, 2008.

[33] S. Soulimane, M. A. Nigassa, B. Bouazza, and H. Camon, "Microactuator modeling to develop a new template for the Braille," Proc. of 15th Int. Conf. on Thermal Mechanical and Multi-Physics and Experiments in Microelectronics and Microsystem, pp. 1-3, 2014.

[34] T. Adachi, Y. Matsumoto, Y. Hoshi, and J. Sone, "Feasible Design of Wearable Tactile Sensation Device," Int. J. of Science and Research Methodology, Vol.4, No.4, pp. 349-359, 2016.

[35] M. Moriyama, Y. Kawai, S. Tanaka, and M. Esashi, "Low-Voltage-Driven Thin Film PZT Stacked Actuator for RF-MEMS Switches," IEEJ Trans. on Sensors and Micromachines, Vol.132, No.9, pp. 282-287, 2012.

[36] J. Sone, Y. Matsumoto, Y. Yamada, and Y. Hoshi, "Trial Development of Tactile Display Technology Using MEMS Technology," Proc. of JSME Annual Conf. on Robotics and Mechatronics (Robomec), 1A1-M05, 2017.

[37] J. Sone, Y. Matsumoto, S. Kutsuzawa, Y. Yasuda, and Y. Hoshi, "Study of piezo-electric film deposition by DC sputtering with two sputtering sources-2," Proc. of the 9th Symp. on Micro-Nano Science and Technology, 2018.

Supporting Online Materials:

[a] Braille Technology, "American Foundation for the Blind." http://www.afb.org/info/living-with-vision-loss/using-technology/assistive-technology/braille-technology/1235 [Accessed November 26, 2016]

Name:
Junji Sone

Affiliation:
Professor, Tokyo Polytechnic University

Address:
1583 Iiyama, Atsugi, Kanagawa 243-0297, Japan

Brief Biographical History:

1985- Research Scientist, Toshiba Manufacturing Engineering Laboratory
1992- Visiting Researcher, Keio University
2011- Professor, Tokyo Polytechnic University

Main Works:

- J. Sone, M. Murakami, and A. Tatami, "Fundamental Study for a Graphite-Based Microelectromechanical System," Micromachines, Vol.9, No.2, p. 64, 2018.
- J. Sone, K. Yamada, A. Asami, and J. Chen, "Sub-Micrometer Size Structure Fabrication Using a Conductive Polymer," Micromachines, Vol.6, No.1, pp. 96-109, 2015.

Membership in Academic Societies:

- The Japan Society of Mechanical Engineers (JSME)
- The Institute of Electrical Engineering of Japan (IEEJ)
- The Japan Society for Precision Engineering (JSPE)

Name:
Yasuyoshi Matsumoto

Affiliation:
Graduate School of Engineering, Tokyo Polytechnic University

Address:
1583 Iiyama, Atsugi, Kanagawa 243-0297, Japan

Brief Biographical History:

2015- Graduate School of Engineering, Tokyo Polytechnic University

Main Works:

- Y. Matsumoto, T. Adachi, Y. Hoshi, and J. Sone, "Feasible Design and Simulation of Tactile Sensation Device using MEMS Technology," Trans. of the Virtual Reality Society of Japan, Vol.22, No.2, pp. 279-285, 2017.

Membership in Academic Societies:

- The Virtual Reality Society of Japan (VRSJ)

Name:
Yoji Yasuda

Affiliation:
Assistant Professor, Tokyo Polytechnic University

Address:
1583 Iiyama, Atsugi, Kanagawa 243-0297, Japan

Brief Biographical History:
2013- Vocational Training Instructor, Human Resources Development Division of Kanagawa Prefecture
2017- Assistant Professor, Tokyo Polytechnic University

Main Works:
- "Reactive sputter deposition of WO3 films by using two deposition methods," J. Vac. Sci. Tech. A, Vol.37, 031514, 2019.

Membership in Academic Societies:
- The Japan Society of Applied Physics (JSAP)
- The Japan Society of Vacuum and Surface Science (JVSS)

Name:
Katsumi Yamada

Affiliation:
Professor, Department of Life Science and Sustainable Chemistry, Tokyo Polytechnic University

Address:
1583 Iiyama, Atsugi, Kanagawa 243-0297, Japan

Brief Biographical History:
1995- Tokyo Polytechnic University
2002-2003 Visiting Scientist, University of Florida

Main Works:
- "Micro-nano 3D printing of electronically conductive polymers as a new process for achieving higher electronic conductivities," Microsystem Technologies, Vol.25, No.5, pp. 2051-2057, 2019.

Membership in Academic Societies:
- The Electrochemical Society (ECS)
- The Optical Society of America (OSA)
- The Society of Photography and Imaging of Japan (SPIJ), Vice President

Name:
Shoichi Hasegawa

Affiliation:
Laboratory for Future Interdisciplinary Science and Technology, Tokyo Institute of Technology

Address:
4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8503, Japan

Brief Biographical History:
2006 Received Doctor of Engineering in Computational Intelligence and Systems Science from Tokyo Institute of Technology
2007-2010 Associate Professor, The University of Electro-Communications
2010- Associate Professor, Tokyo Institute of Technology

Main Works:
- Haptic renderings, real-time simulations, interactive characters, soft and entertainment robotics, and virtual reality

Membership in Academic Societies:
- The Virtual Reality Society of Japan (VRSJ)
- The Institute of Electrical and Electronics Engineers (IEEE) Technical Committee on Haptics (TCH)