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Sheet-like Ultrasonic Transducer and its Application for Tactile Display

シート状超音波振動子の開発と皮膚感覚ディスプレイへの応用

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1. Introduction

Recently, touchscreens have been widespread as computer interface. Using the touchscreen, operators can input easily and promptly by touching the screen directly. The touchscreens, however, have a problem in intuitive operation. For instance, sometimes the operators can not recognize completion of their operation, because those touchscreens cannot provide haptic feedback as mechanical buttons do. The problem means that the touchscreen without tactile feedback, is difficult to operate and may induce misoperation. With this background, importance of the tactile feedback has been focused. For the feedback, we have focused on roughness sensation. In our research, we proposed the tactile feedback by "roughness sensation" during rubbing motion. In our proposal, the touchscreen problem can be solved by a surface acoustic wave (SAW) tactile display[1-4].

To use the SAW tactile display principle together with a touchscreen of capacitance detection type, the SAW transducer will cover the touchscreen. In this case, the thickness of the transducer should be considered, because wider gap between the touchscreen and operators finger due to the transducer might cause unstable detection of the finger position as a touchscreen. Previously, a new transducer structure was considered to avoid the unstable detection. For the structure, a sheet-like ultrasonic transducer (SUT) was proposed[5].

In this report, fabrication of SUT and control of friction according to ultrasonic vibration are reported.

2. Tactile display

When we rub a solid object surface by our finger especially with roughness, mechanical vibration is generated on the surface of the finger. It is considered that mechanoreceptors in our finger skin detect the vibration as the roughness sensation. In our approach, to reproduce the sensation according to the rubbing motion on a rough surface, generation of the vibration seems to be effective. The tactile sensation was considered to be controlled by changing the frequency of the vibration according to the finger motion. The vibration is generated by controlled friction on an SAW transducer. Operating frequency of SAW transducer is higher than few MHz and is too high for human to perceive directly. Controlling friction with bursting SAW was applied to excite the artificial vibration. When display operator rubs the indication area of the SAW transducer through a slider, which consists of an aluminum film, kinetic friction can be experienced by the operator. When an AC driving voltage is applied to the IDT, the SAW is excited on the piezoelectric substrate surface. Under the wave excitation, the time while the slider contacts the transducer surface is reduced due to the high frequency vibration. As a result, averaged coefficient of friction between the slider and the surface of the transducer is reduced. This friction shift is applied for the tactile display. With repeating of the ON/OFF switching the ultrasonic vibration at regular intervals (utilizing bursting SAW), the shear force, namely friction, fluctuates. The fluctuation generates the vibration in the finger skin. Therefore, the vibration can be perceived roughness sensation like rubbing sandpapers. [1, 3]

3. Touchscreen application

Figure 1 illustrates concept of application of the tactile display. The sheet-like ultrasonic transducer covers a touchscreen, which is a comercial product and has a capacitance type finger position sensor. Thickness of the transducer should be thin so that the sensor can work stably. Also the transducer should be transparent.

During operation of the screen, we can operate as a touchscreen and also feel roughness under rubbing/dragging motion. The roughness sensation indication can play a roll of tactile feedback for the touchscreen.

4. Sheet-like ultrasonic transducer

For the SLT, the thickness of elastic media on which the ultrasonic wave propagates should be less than 1mm. Thinner media is preferable for the sensor of the touchscreen. In case the thickness is less than wavelength of the ultrsonic wave,

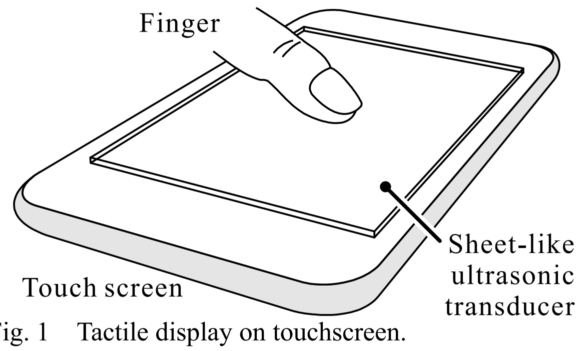

Fig. 1 Tactile display on touchscreen.

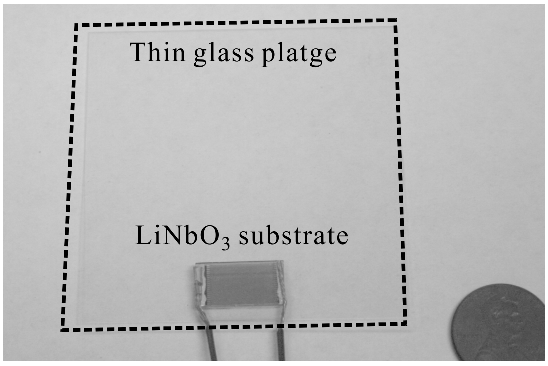

Fig. 2 Sheet-like ultrasonic transducer.

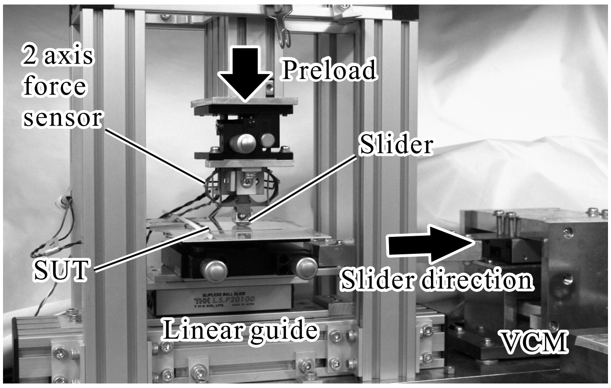

Fig. 3 Friction measurement.

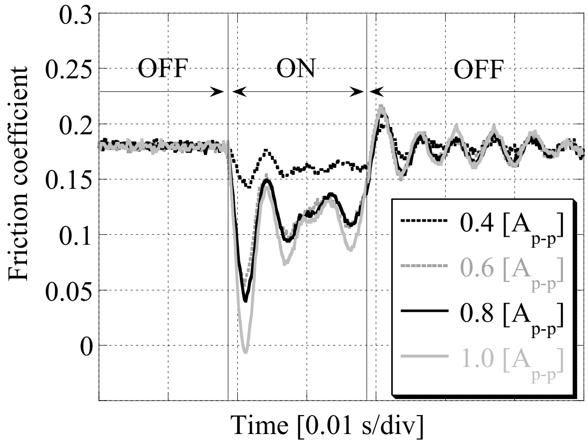

Fig. 4 Measurement result of friction.

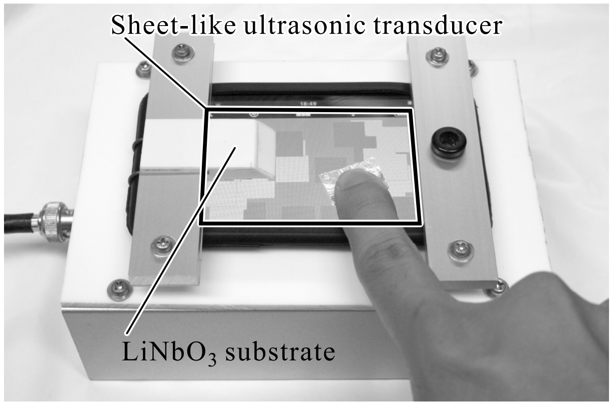

Fig. 5 SLT on a touchscreen.

vibration mode is not Rayleigh wave but another mode like Lamb wave. If normal vibration amplitude is acquired, tactile display principle is available.

Comparing attenuation of ultrasonic wave among silica glass and organic transparent materials, 0.3 mm thickness silica glass substrate was selected as the media on which the ultrasonic wave propagates[5]. To excite ultrasonic vibration at the frequency of several MHz, a $LiNbO_3$ substrate with an interdigital transducer (IDT) was coupled on the media.

Figure 2 is a photograph of the fabricated sheet-like ultrasonic transducer. To evaluate the friction between the media and the slider, measurement experimental apparatus shown in Fig. 3 was prepared. Pre-load to the slider and friction force were measured by a sensor simultaneously. The measurement results with the change of applied current to the IDT are plotted on Fig. 4. It can be seen that friction coefficient was reduced by the wave and reduction ratio was proportional to vibration amplitude. This reduction showed feasibility of the tactile display principle.

5. Touchscreen application

The developed SUT was installed on a comercial product touchscreen as shown in Fig. 5. Driving voltage to the IDT was switched by a pulse signal from a controller. The controller decided the duty ratio and frequency of the signal according to the finger position and rubbing speed. As a result, roughness was indicated successfully during dragging operation by the authors.

6. Conclusion

As an application of surface acoustic wave tactile display, touchscreen with tactile feedback was proposed. To realize the application, a sheet-like ultrasonic transducer was developed. Friction between the slider and the transucer was measured. The result showed the feasibility of the tactile display principle. Roughness sensation was indicated successfully.

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