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Soft-rubber-packaged PZT MEMS touch sensor optimized for human-machine interface applications

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Abstract

We proposed and developed soft–rubber-packaged PZT (Pb(Zr Ti)O_3) MEMS(Microelectromechanical systems) touch sensors. The sensor size is 5mm ×5mm ×1.1mm. The sensor generated an electric charge of 7.7pC under an applied force of 1N. Also, we optimized hardness of soft rubber package for humane touch force. The soft rubber with certain Durometer Hardness A of 35.6 is suitable for the sensors considering to sensitivity and durability. This touch sensor can be expected to be applied for human-machine interface such as smartphones, tablet PCs and wearable computers.

1. Introduction

With the spread of smartphones, tablet PCs, wearable computers [1], touch sensors that need the features of small size, high sensitivity and low power consumption are required. We research about PZT MEMS touch sensor because PZT MEMS sensors can meet these requirements. However, PZT MEMS sensor have a big problem in terms of durability because Si and PZT are brittle and can easily crack under the human touch force [2]. Therefore, it is desirable that the touch sensors have high sensitivity at a range of human touch force which is from 0 to several N [3], and have low sensitivity at over human touch force. This is because that low sensitivity means the deformation of PZT MEMS sensor is small, and durability is high against over human touch force.

In order to develop PZT MEMS touch sensors which have characteristics as above mentioned, we focused on soft-rubber-package and optimized the hardness of the soft-rubber-package for human touch sensor applications.

2. Sensor structure and fabrication

The proposed PZT MEMS touch sensor is a PZT cantilever in a soft-rubber package as shown in Fig.1 (a). The PZT MEMS cantilever consists of a 400 µm thick handling layer, 300 × 1100 × 10 µm silicon beam with a 300 × 600 × 1.86 µm PZT sensing film. The sensors are packaged in 1.1 mm height PDMS rubbers. When the packaged PZT sensor is touched, firstly the soft rubber is compressed, and secondly the PZT cantilever is bent in accordance with the compression of the soft rubber (Fig. 1 (b)). Then, the PZT cantilever generates electric charges.

The fabrication process of the PZT MEMS cantilever has been reported [4]. After the PZT MEMS cantilever was bonded on the package, the mixture of PDMS rubber (Toray Dowcorning Sylgard 184) and its curing agent with different mixture ratios including 5:1, 10:1, 20:1, and 40:1 was poured in the package with a thickness of 1.1 mm. Table I shows the durometer hardness (Type A) of the rubbers, which were measured with a durometer (Teclock, GS-719G). Finally, the PDMS was cured in an oven at a temperature of 60 °C, and the sensors were cut into pieces by using a dicing saw. Fig. 2 shows the soft-rubber-packaged PZT MEMS touch sensors. The PZT MEMS cantilever was packaged in transparent soft PDMS rubber. The sensor chip size is only 5 mm square.

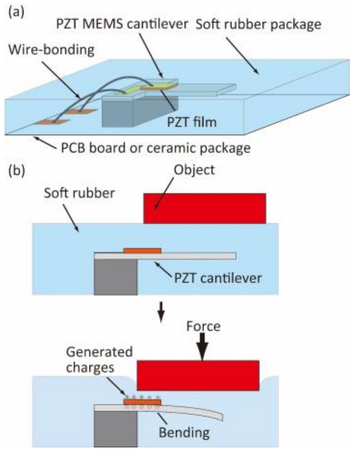

Fig. 1. (a)Structure of soft-rubber-packaged Pb(Zr, Ti) O_3 MEMS touch sensor. (b) Sensing mechanism of soft-rubber-packaged PZT MEMS force sensor

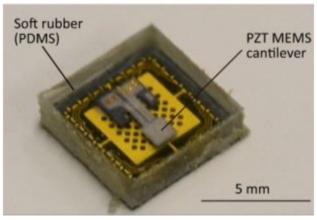

Fig. 2. Photograph of soft-rubber-packaged PZT MEMS force sensors

Table I. PDMS hardness with different mixture ratios of PDMS rubber to curing agents

mixture ratio PDMS:Curing agent	Durometer hardness (Type-A)
5:1	49.4
10:1	35.6
20:1	27.5
40:1	17.9

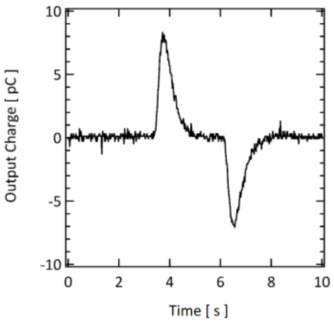

Fig. 3. Transient response of electric charge generation when the force is applied to the sensors. The magnitude of force is 1N and the PDMS mixture ratio is 10:1.

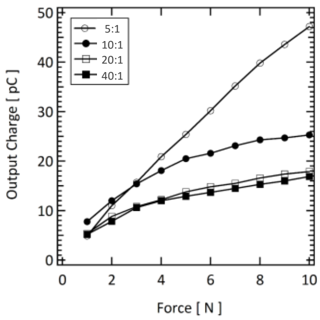

Fig. 4. Relationship between applied forces and generated electric charges

3. Experiments and results

We conducted experiments in order to investigate the relationship between the sensitivity of the touch sensor and hardness of PDMS rubber. The surface of touch sensor was push by a force gauge (Aikoh Engineering, Model FTN1-13A). The applied force could be varied from 1 to 10 N by using a positioning stage with a force gauge. The generated charge was converted to voltage with a charge amplifier and the output voltage was measured by oscilloscope. Fig. 3 shows the transient response of electric charge generation when the force was applied at 1 N and the PDMS mixture ratio was 10:1. The generated charge was 7.7 pC under the condition.

Fig. 4 shows the generated charge of touch sensors which were packaged by PDMS rubber with different mixture ratio when applied force was changed from 0 to 10N. The sensitivity become better when harder PDMS was used. Actually, the PDMS itself was deformed to a large degree when the rubber was soft. However, the sensor material of silicon and PZT film was harder than rubber, and the PZT film did not bend in accordance with the deformation of the PDMS. When the PDMS was hard, the PZT film and silicon cantilever were bent along with the PDMS, which resulted in high sensitivity. Also, the sensor with mixture ration of 10:1 was found to be optimal for human interface sensors to detect human touch of around several N because it had a linear sensitivity below 5 N and the bending was small over 5 N, which leads to high durability of the sensors against a large applied force. The resultant sensitivity curve of the PZT force sensor was almost linear, and the sensitivity was 3.15 pF/N under a force ranging from 0 to 5 N, as shown on the curve for a PDMS mixture ratio of 10:1 in Fig. 4.

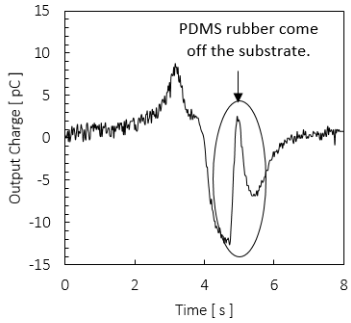

Fig. 5. Transient response of electric charge generation when the force is applied to the sensors. The magnitude of force is 114N and the PDMS mixture ratio is 10:1.

Fig. 5 shows the transient response of electric charge generation when the force was applied at 114 N and the PDMS mixture ratio was 10:1. Then, the shape of output signal changed and the touch sensor was broken.

4. Conclusions

We developed soft–rubber--packaged PZT MEMS touch sensors to achieve small, highly sensitivity, high durability with low power consumption. Also, we revealed the influence of hardness of PDMS rubber on the sensitivity of the touch sensor. The sensor with a Durometer Hardness A of 35.6 and a force sensitivity of 3.15 pF/N was found to be optimal for human interface sensors to detect human touch of around several N. Also, the sensor with mixture ration of 10:1 was not broken until applied force reached 114N which value is enough large to use for human-machine interface applications. In conclusion, to reduce the shock of the large force on the hard silicon and PZT films, PZT sensors with soft rubber of a certain hardness will be preferable when both durability to human input or force sensitivity are considered.

Acknowledgements

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References

[1] N. Lane, E. Miluzzo, L. Hong L, D. Peebles, T. Choudhury and A. Campbell, A survey of mobile phone sensing *IEEE Commun. Mag.* **48** (2010)140.

[2] T. Kobayashi T, R. Maeda R and T. Itoh, J. Micromech. Microeng. **18** (2008) 115007.

[3] ANSI/HFS 1988, American National Standard for Human Factors Engineering of Visual Display Terminal Workstations. Standard No. 100-1988, Human Factors Society, Santa Monica, CA.

[4] T. Kobayashi T, M. Ichiki, J. Tsaur, R. Maeda, Thin Solid Films **489** (2005) 74.