Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 87 (2014) 1565 – 1568

Procedia Engineering

www.elsevier.com/locate/procedia

EUROSENSORS 2014, the XXVIII edition of the conference series

Water based PVA sacrificial material for low temperature MEMS fabrication and applications on e-textiles

K. Yang*, R. Torah, Y. Wei, S. Beeby, and J. Tudor

Electronics and Computer Science, University of Southampton, Southampton, SO17 1BJ, UK

Abstract

A sacrificial-layer approach enables the realisation of free-standing mechanical structures on textiles. This work presents a screen printable water based polyvinyl alcohol (PVA) sacrificial material, which, when printed and dried, provides a stable mechanical support for subsequent printed structural layers. The PVA support layer can be removed in water once all other processes are complete. The sacrificial paste is compatible with most textiles and is environmentally friendly due to a low release of volatile organic compounds (VOC). The process is demonstrated by fabricating a capacitively coupled cantilever on textile using screen printing. The resultant cantilever has a resonant frequency of 145 Hz that confirms the PVA sacrificial material has been entirely removed.

Peer-review under responsibility of the scientific committee of Eurosensors 2014

Keywords: e-textile; sacrifical material; polyvinyl alcohol (PVA); screen printing; cantilever

1. Introduction

Electronic textiles (e-textiles) have been used in various applications such as wearable computing, health monitoring, the automotive industry and the military [1-2]. Screen printing is a straightforward and cost effective fabrication method which allows significant design freedom in terms of pattern geometries. It is a well-established processing in the textile industry for patterning and coloration. It is also widely used for printing electronics on both rigid substrate and flexible polymer films. Printed Micro-Electro-Mechanical Systems (MEMS) is a new fabrication method capable of integrating electronic and mechanical functions into traditional textiles [3].

* Corresponding author. Tel.: +44 (0)2380596665; fax: +44 (0)23 80592901.
E-mail address: ky2@ecs.soton.ac.uk

Peer-review under responsibility of the scientific committee of Eurosensors 2014
doi:10.1016/j.proeng.2014.11.599

A sacrificial-layer approach enables the realisation of free-standing mechanical structures on textile which can be used in various sensing and actuation applications. Conventional silicon based MEMS sacrificial processes, for example, etch the sacrificial material using corrosive chemicals that are not compatible with textiles. We have reported a solvent based Trimethylolethane (TME) sacrificial material for smart fabric application in previous work [4]. However, the TME sacrificial layer needs removal at 160°C for 30 minutes which is not compatible with some delicate textiles.

Polyvinyl alcohol (PVA) is a water soluble polymer which forms a smooth thick film after the water and co-solvent evaporate from the PVA paste at an elevated temperature. The dried PVA layer can provide mechanical support for the subsequent printed layers. Once all the functional layers have been printed and dried, the PVA layer can then be removed by submersing the entire sample in water to release the free-standing structure. This is demonstrated with a cantilever structure with capacitive sensing that has one electrode on top of the structure layer and the other on top of the fabric interface layer to sense the movement of the cantilever. This type of the device can be used to monitor human motion [5].

2. Material and fabrication

2.1. Materials

The screen printable PVA sacrificial paste consists of PVA, water, co-solvent and surfactant. Colored pigment was also added as an indicator to monitor the removal progress of the sacrificial layer. The thickness of the sacrificial material is determined by the concentration of PVA and the number of printed layers. In this study, an average thickness of 75 µm was obtained after curing of 5 printed layers.

2.2. Fabrication

To demonstrate the use of the PVA sacrificial material, a capacitive cantilever was fabricated entirely by screen printing on standard polyester/cotton textile which is used for clothing. The cantilever is 15 mm x 10 mm and the electrode size is 14 mm x 8 mm. A DEK248 semi-automatic printer was used in this study and the printing steps are shown in Figure 1.

1) Interface layer: an UV curable interface paste (Fabink-UV-IF1004, Smart Fabric Inks Ltd) was printed on the textile and cured in a UV cabinet (UV Light Technology Ltd) for 60 seconds.
2) Bottom electrode: a flexible silver paste (DuPont 5043) was printed and cured at 120 °C in a box oven for 10 minutes.
3) Sacrificial layer: The PVA sacrificial layer was printed and cured at 100 °C for 3 minutes.
4) Structure layer: ElectraPolymers EFV4/4965 was printed and UV cured for 60 seconds.
5) Top electrode: DuPont 5043 was printed and cured at 120 °C for 10 minutes.
6) Sacrificial layer removal: The sample was placed in hot water bath (90 °C) until there was no residue left and then dried at 100 °C for 10 minutes to evaporate the water from the textile. The pigment in the sacrificial paste enables the complete removal of the material to be visually confirmed.

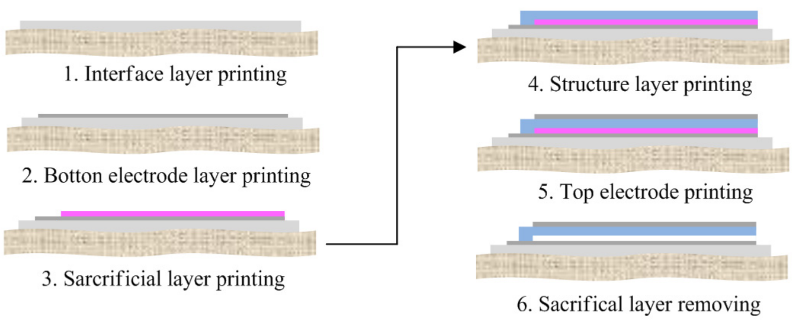

Fig.1. Fabrication process for printed MEMS on textile

The time to remove the sacrificial layer depends on the water temperature and the surrounding structure geometry. It can vary from a few minutes to a couple of hours. Increasing the water temperature increases the rate of dissolution of the printed PVA layer. An ideal temperature range to remove the sacrificial layer is between 80 and 100 °C. The completed capacitive cantilever before and after removing the sacrificial layer is shown in Fig. 2. It shows that the sacrificial layer has been completely removed and therefore a free-standing cantilever has been successfully obtained. The removal results have been confirmed by examining the cross-section of the released cantilever using a scanning electron microscope (SEM) of which the micrographs are shown in Fig.3.

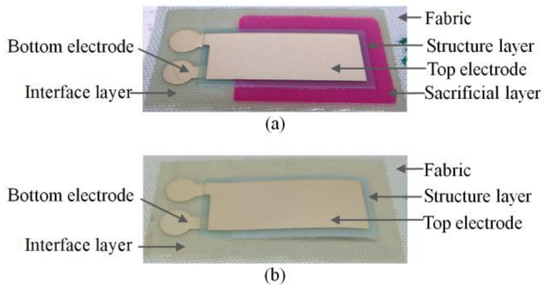

Fig.2. Overview of completed capacitive cantilever before (a) and after (b) removing the sacrificial layer

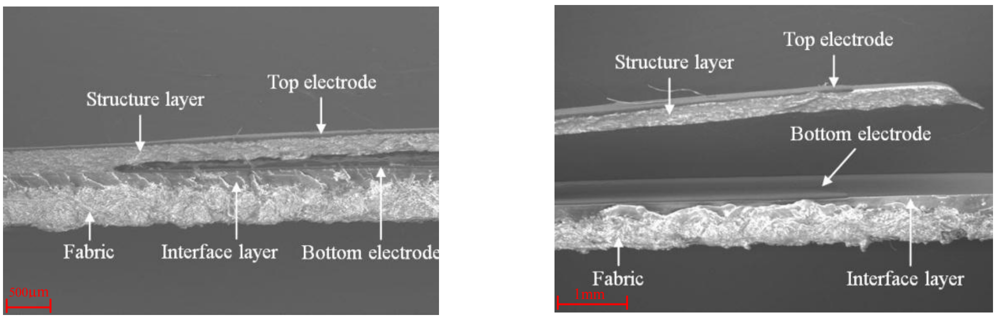

Fig.3. SEM at different positions along the capacitive cantilever

3. Testing results and discussion

The cantilever was tested on an electromechanical shaker and the resultant displacement of the printed cantilever was measured using a laser displacement meter (KEYENCE LC-2450) with the laser spot at the free end of the cantilever. Fig. 4 shows the displacement of the cantilever versus frequency with a vibration acceleration of 19.62 m/s^2 indicating a resonant frequency of 145 Hz. The sensitivity of the cantilever was measured at its resonant frequency at different accelerations ranging from 0.1 m/s^2 to 3 m/s^2 with an interval of 0.1 m/s^2. Fig. 5 shows the displacement increases linearly as the acceleration is increased. The sensitivity of the cantilever is approximately 46 $\mu m/ms^{-2}$.

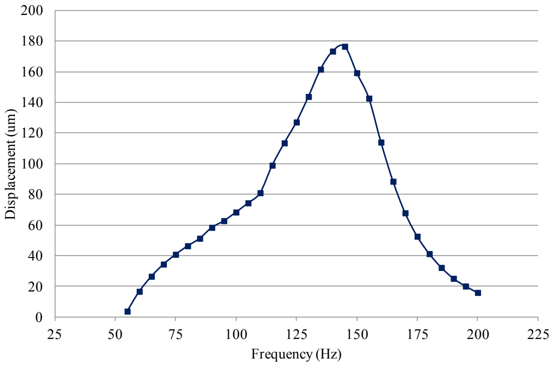

Fig. 5. Displacement of different vibration frequencies

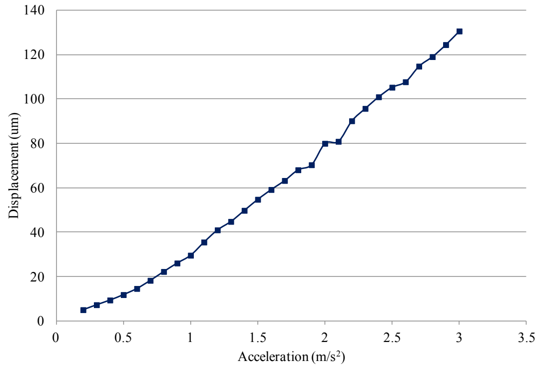

Fig. 4. Displacement at 145 Hz under different acceleration frequencies

4. Conclusions

This work has demonstrated the application of the PVA sacrificial paste on textile through an example of capacitive MEMS cantilever. The water based sacrificial material is screen printable and the processing temperature for both drying and removal of the sacrificial layer are up to 100°C which provides good compatibility with most textiles. The PVA sacrificial approach provides an environmentally friendly fabrication method due to the low release of VOC. A capacitive cantilever with a resonant frequency of 145 Hz has been fabricated entirely using screen printing method. In future work, we are going to reduce the device size, use improved structural materials and optimise device geometry in order to improve performance and make the structure unobtrusive which is an important consideration for the feel and appearance of the textile.

Acknowledgements

This work was funded by the EU FP7 (MICROFLEX project, Grant number CP-IP 211335-2). The authors would like to thank Klopman International for supplying the fabric and Smart Fabric Inks Ltd for supplying the interface paste.

References

[1] S. Park, S. Jayaraman, Enhancing the quality of life through wearable technology, IEEE Eng. Med. Biol. Mag., 2003; 22(3):41-48.
[2] L. Castano, A. Flatau, Smart fabric sensors and e-textile technologies: a review, Smart Mater. Struct., 23 (2014), 053001 (27p).
[3] MICROFLEX project, http://microflex.ecs.soton.ac.uk/, (accessed on 18 March 2014).
[4] Y. Wei, R. Torah, K. Yang, S. Beeby and J. Tudor, Screen printing of a capacitive cantilever-based motion sensor on fabric using a novel sacrificial layer process for smart fabric applications, Meas. Sci. Technol., 24 (2013), 075104 (11p).
[5] E. Szelitzky, J. Kuklyte, D. Mândru, and N. O'Connor, Low Cost Angular Displacement Sensors for Biomechanical Applications - A Review, Journal of Biomedical Engineering and Technology, 2014, 2 (2): 21-28.