PS-10-6

Extended Abstracts of the 2013 International Conference on Solid State Devices and Materials, Fukuoka, 2013, pp344-345

Anti-Stiction Technique Using Elastomer Contact Structure in Woven Electronic Textiles

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Abstract

This paper presents an anti-stiction technique with the use of elastomer contact structure in woven electronic textiles (e-textiles). A coating of poly(3,4-ethylenedioxythiophene): poly(4-styrenesulfonate) (PEDOT:PSS) in form of a solid conductive film on a hemispherical silicone elastomer structure is employed in creating an electrical circuit embedded into the fabric of a woven e-textile, where the contact structure reduces contact area and capillary force generated by moisture in the air between weft and warp ribbons. In the case of contact between the contact structure and the ribbon coated with plain PEDOT:PSS, stiction do not occur as the relative humidity increases from 20% to 80%.

1. Introduction

In recent years, flexible electronic devices have gained significant attention in various fields of research. Among the recent applications for flexible devices, there are woven electronic textiles (e-textiles) developed in the area, that include not only information technology and communications, but also include life science and energy harvesting [1-3]. Woven e-textiles employ multi-functional fibers for making electrical circuit by the process of weaving. The interlaced fibers enable the device to function by means of their physical contacts with each other, by making the electric current to flow from power supply fiber to device integrated fiber.

It is often the case that poly(3,4-ethylenedioxythiophene): poly(4-styrenesulfonate) (PEDOT:PSS) a conductive polymer is used as electrode material in flexible devices because PEDOT:PSS films have a high flexibility. However, PEDOT:PSS is hydrophilic and so its film surface absorbs moisture in humid environment [4]. Therefore, it has been reported that the problem of high adhesion in contact area between weft and warp (interlaced) fiber ribbons coated with PEDOT:PSS occurs under high humidity environment due to meniscus/viscous effects [5]; this is referred to as “stiction.”

As we reported in previous studies, all polymer hemispherical contact structures realized on a polyethylene terephthalate (PET) ribbon cable were fabricated, and investigated the improvement in the stability and durability of the electrical contacts employed in flexible devices [6-8]. In this paper, we investigate anti-stiction properties of the contact structure. We then compare those with the case where there are no such contact structures made.

2. Fabrication of Elastomer Contact Structure

The detailed fabrication process flow is begun by coating onto 5 mm-width, 100 μm-thick PET ribbon cable with PEDOT:PSS (Nagase ChemteX Denatron PT-400MF) with the thickness of 1 μm because the PET ribbon surface is hydrophobic, following by highly conductive PEDOT:PSS (a mixture of H.C. Starck GmbH Clevios PH 1000 and 5 wt% ethylene glycol) with the thickness of 1 μm using die-coating method. Both PEDOT:PSS were thermally cured at 110 °C for 3 min. It is to be noted that the PEDOT:PSS a conductive polymer comes in its liquid form, which is then hardened by a subsequent heat treatment. Then a 1 μl drop of silicone emulsion (Shin-Etsu Chemical KM-2002T) was dropped on to the PEDOT:PSS coated cable using an automatic precision dispenser (Iwashita Engineering ACCURA 8DX). The viscosity of the emulsion used in this work about 5,500 mPa·s. The droplet took form of a hemispherical shape on the cable due to its high viscosity. After annealing the ribbon at 110 °C for 10 min, both the PEDOT:PSS were also coated onto the silicone structure using the dispenser, and then followed by another thermal curing at 110 C for 3 min individually. Figure 1 shows SEM images of the processed structure on plain PEDOT:PSS coated PET ribbon cable.

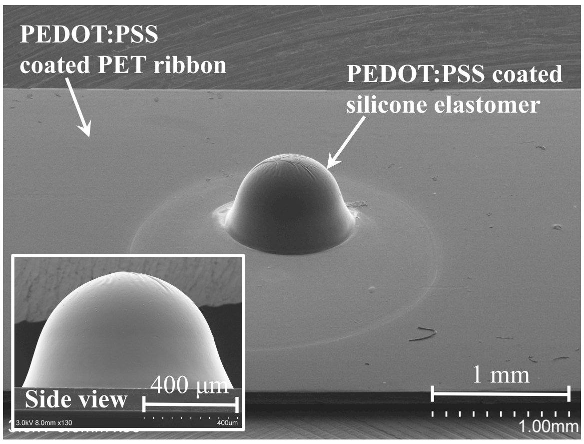

Fig. 1 SEM images of the PEDOT:PSS coated silicone elastomer contact structure realized on PET ribbon cable.

3. Evaluation by Contact Experiments

To confirm the anti-stiction properties of the contact structure in e-textile applications, contact experiments were conducted. Figure 2 shows a schematic diagram of the experimental apparatus (Stable Micro Systems TA.XT plus Texture Analyser) used to measure resistance with the contact load. The apparatus situated in a chamber with the relative humidity (RH) controlled by water evaporation combined with an inlet flow rate of dry air. The RH was increased from 20% to 80%. A 10 cm-long PET ribbon coated with plain PEDOT:PSS bearing the contact structure was fixed at the bottom stage as the warp; and another ribbon without the structure was fixed at the top fixture serving as the weft. The top fixture was designed for a rapid up/down movement with a preset frequency. For comparison, we also measured the resistance between two PET ribbons, both coated with plain PEDOT:PSS without any structure on them.

Figure 3 shows measured resistances between weft and warp with contact structure. It was formed a stable contact at a mere 25 mN of load until RH 60% by reason that a contact with projecting hemispherical structure. In addition, stiction did not occur until at least RH 80%. On the other hand, in the case of contact between two PET ribbons, both coated with plain PEDOT:PSS, it took about 1.3 N of load to form a stable contact under high RH (Fig. 4). It is believed that the PEDOT:PSS film is softened by absorption of moisture from the air. Furthermore stiction occurred between the ribbons under RH 80%, and detachment of the stuck ribbon required about 0.2 N of delamination load. This is the reason that a large liquid meniscus forms between the two ribbons, because apparent contact area between the ribbons is larger than the area between the ribbon and the contact structure.

4. Conclusions

The properties of the contact structure made of PEDOT:PSS and silicone elastomer for the prevention of stiction generated by moisture in the air have been investigated. From the results of the contact experiments, it was confirmed that stiction can be prevented by using the contact structure even if RH increased to 80%.

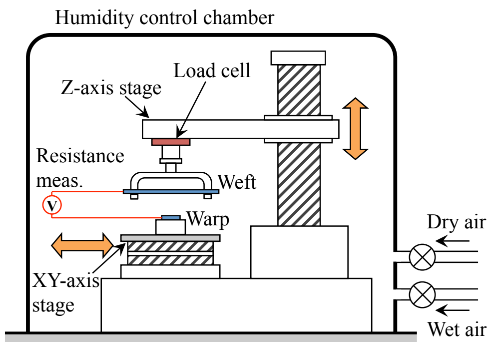

Fig. 2 Schematic diagram of the experimental apparatus situated in a humidity control chamber for measuring the electrical contact resistance between the two ribbon fiber cables.

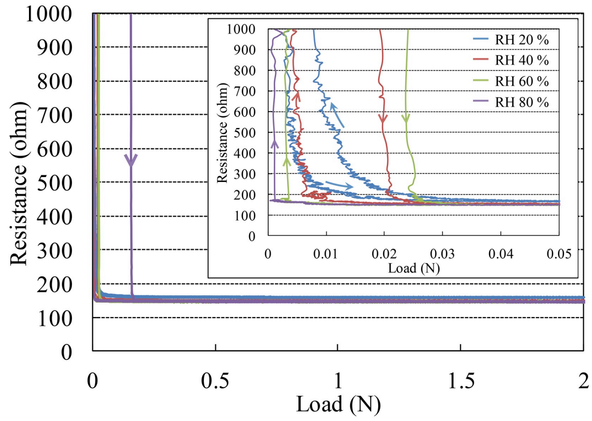

Fig. 3 Measured resistances between weft and warp with contact structure as a function of contact load at RH between 20% and 80%. In the inset, a magnified view of the load in the 0-0.05 N range is shown.

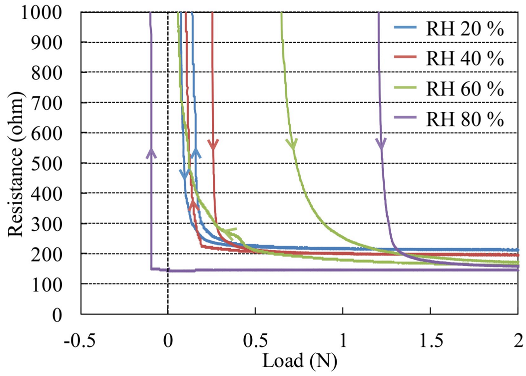

Fig. 4 Measured resistance between weft and warp without contact structure as a function of contact load at RH between 20% and 80%.

Acknowledgements

This work is supported by New Energy and Industrial Technology Development Organization (NEDO).

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