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Extended Abstracts of the 2014 International Conference on Solid State Devices and Materials, Tsukuba, 2014, pp882-883

Heat protection circuit with polymer PTC for flexible electronics

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Abstract

We have successfully fabricated flexible thermal protection circuit with polymer positive temperature coefficient (PTC). A resistivity of this PTC was dramatically changed from 7×10^3 Ωcm to 6×10^9 Ωcm when heated from 26°C to 31°C. This PTC shows good repeatability over than 50 times. In addition, we connected this PTC to an organic TFT. We can control the ON current from 70 μA to 100 nA.

1. Introduction

Flexible electronics have attracted much attention since their mechanical flexibility and durability are suitable for realizing a next-generation electronics such as robotic sensory arrays [1], e-paper [2] and organic solar cell [3]. Recently, these flexible electronics has been expected to use bio-medical applications; flexible electrodes for detecting bio signal [4,5], balloon catheter [6] and ultra-sensitive pressure sensor [7]. In these applications, it is important to measure the temperature of devices to protect human body from heat damage.

There are many kinds of temperature sensors such as thermocouples [8] and resistive temperature detectors (RTDs) [9]. Change of these sensors is very small, so we have to need highly accurate and complex electronic circuits to readout change of temperature. In addition, a protection circuit is also needed to integrate devices.

In this study, we fabricate the polymer based temperature sensor. Our temperature sensor shows 6 orders of magnitude change in resistivity near the temperature of a human skin. This temperature sensor also can be used as protection circuits for large change of resistivity, which allows us to control the current of organic TFTs by integrating our temperature sensor.

2. Fabrication process

The optical microscope image of the polymer PTC and optical microscope image and cross-sectional image of the temperature sensor based on polymer PTC are shown in Figure 1. This polymer PTC was fabricated by mixing a polymer which has low melting temperature around 30°C and 25wt% graphite.

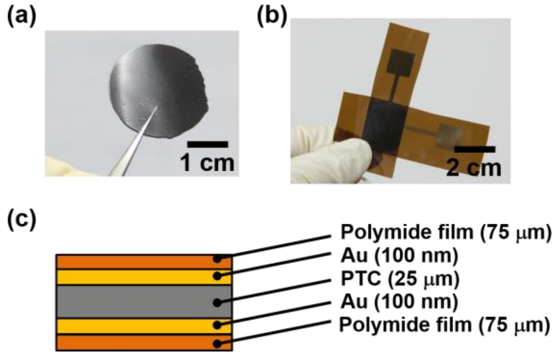

Fig. 1 (a) The optical image of polymer PTC. (b) The optical image of the temperature sensor. (c)The cross-sectional image of the temperature sensor.

After fabricating polymer PTC, we sandwiched the polymer PTC between two electrodes and pressed 1 hour. The thickness of polymer PTC is 25 μm and total thickness of temperature sensor is less than 200 μm.

3. Results

Figure 2 shows the temperature dependency of the resistivity of temperature sensor. A resistivity of this PTC was dramatically changed from 7×10^3 Ωcm to 6×10^9 Ωcm when heated from 26°C to 31°C. Over 31°C, the resistivity is almost constant.

We also checked the repeatability of our sensors. Figure 3 shows the repeatability test result. Over 50 cycles test, we achieved almost same resistivity change behavior.

In addition, we integrated the polymer PTC and organic transistor. Figure 4 shows the temperature dependency of transfer curve. Black line shows the transfer curve of only organic transistor. We change the measurement temperature from 26°C to 32.5°C. The On current of organic transistor was gradually reduced from 70 μA to 100 nA as temperature increased. This is because the resistance of the polymer PTC was increased as temperature increased.

In summary, we confirmed our PTC was worked as heat protection circuit by itself.

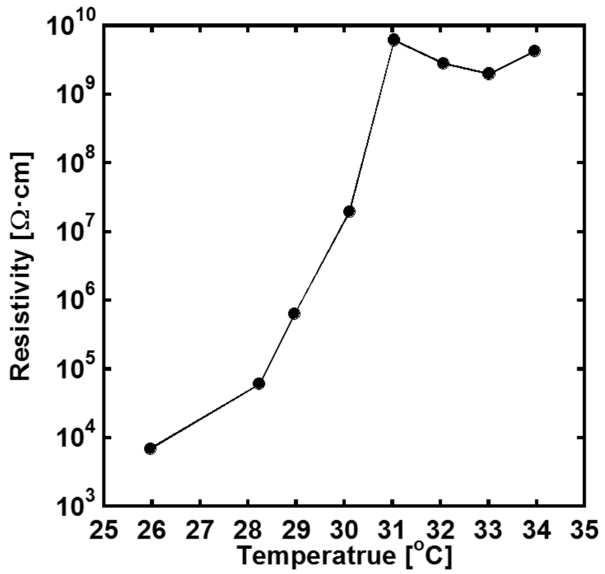

Fig. 2 Resistivity versus temperature curve.

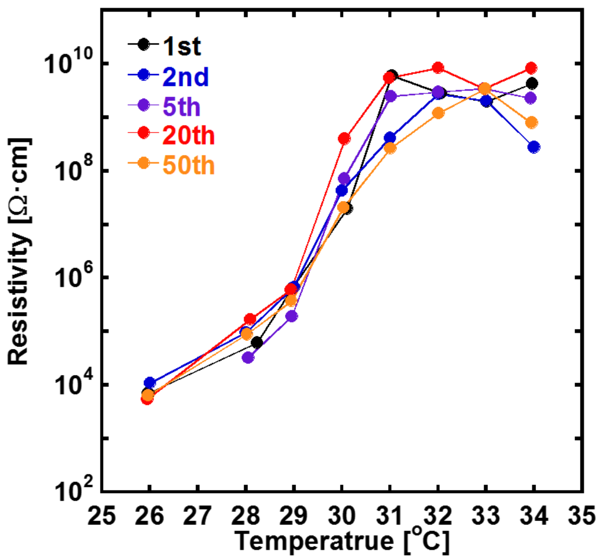

Fig. 3 Cycle test results. The resistivity change is almost same over 50 cycles.

4. Conclusions

In this study, we fabricated graphite micro-particle filled polymer composite temperature sensor which respond to around body temperature. A resistivity of this PTC was dramatically changed about 6 order magnitude from 26°C to 31°C. And also it shows good repeatability over than 50 times. Furthermore, we demonstrated this PTC as a heat protection circuit to be integrated with organic TFT. This PTC shows the good heat protection circuit characteristics by itself.

In the future, this technology will be expected to apply the flexible electronics as heat protection circuits.

5. Acknowledgements

This work was supported by the Someya BioHarmonized ERATO grant.

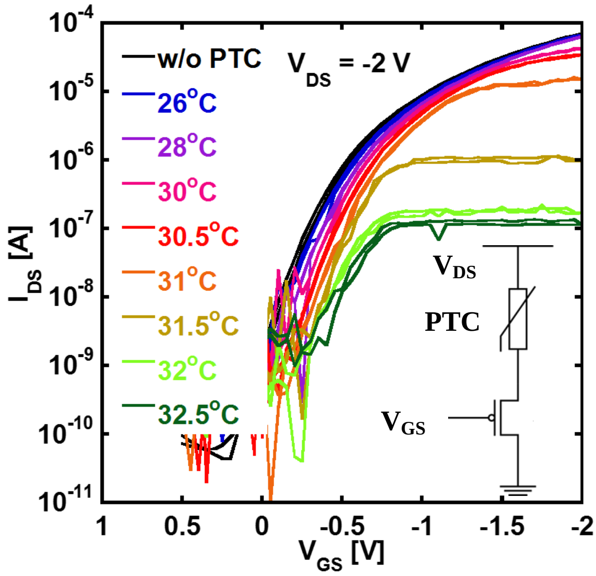

Fig. 4 Temperature dependency of transfer curve of integrated organic transistor and polymer PTC. Black line shows the transfer curve of only organic transistor. The transfer curves were measured from 26°C to 32.5°C.

6. References

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