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Cross-Talk Immunity of Gold-Nanoparticle Incorporated PEDOT:PSS Pressure Sensors with 2×2 Cross-Point Array Structure

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Abstract

The piezoresistive and cross-talk properties of gold nanoparticle (Au-NPs) incorporated PEDOT:PSS pressure sensors with 2×2 cross-point array structure have been investigated. With the Au-NPs incorporation, the PEDOT:PSS pressure sensors present a fast response and cross-talk immunity as compared with the pure PEDOT:PSS one. The improved piezoresistive response and cross-talk properties can be explained by the Au-NP assisted electron hopping and fast relaxation of PSS chain by the Au-NPs respectively, suitable for future high-density pressure sensing applications.

1. Introduction

Conductive polymers have been widely used in organic electronics after their discovery by Shirakawa et al. [1]. The properties of high flexibility, low-cost fabrication process, light weight, and easy tailoring are required to obtain the desired performance [2,3]. Among the conductive polymers, PEDOT:PSS has gained an outstanding position for pressure sensor applications owing to its high electrochemical and thermal stability, high conductivity, good optical properties, high transparency, and unique piezoresistive property [4,5]. Traditionally, there are three types of pressure sensors and the piezoresistive one attracts lots of attention because of the high sensitivity and low cost. Recently, the structure dependence on the piezoresistive characteristics of PEDOT:PSS pressure sensors has been examined [6]. However, the cross-talk effects of piezoresistive pressure sensors with cross-point array structure are rarely studied. In this work, we have investigated the piezoresistive and cross-talk characteristics of gold nanoparticles (Au-NPs) incorporated PEDOT:PSS pressure sensors with 2×2 cross-point array structure. The piezoresistive response of PEDOT:PSS incorporated with different size of Au-NPs is observed and the cross-talk effects for the 2×2 array structure has significantly improved by the Au-NPs incorporation. The superior cross-talk behavior can make the future high-density pressure sensing possible.

2. Experimental

The device structure with 1×1 and 2×2 cross-point electrodes is shown in Fig. 1(a) and (b) respectively. The flexible polyethylene terephthalate (PET) with transparent electrode, indium tin oxide (ITO), has been used as the top and bottom electrodes. Au-NPs with three different diameters (5, 10, 20 nm) have been mixed with PEDOT:PSS solution at a 1:0.3 volume ratio and spin coated on the patterned PET-ITO substrate. Fig. 2 shows the atomic force microscopy (AFM) topographic images of PEDOT:PSS films incorporated with different size of Au-NPs. An increased roughness of PEDOT:PSS film with the increased size of Au-NPs can be ascribed to the Au-NP incorporation. The piezoresistive properties were measured by JSV H1000 to apply the pressure and Keithley 2450 digital multi-meter to obtain the resistance value.

3. Results and Discussion

Fig. 3 presents the piezoresistive characteristics of PEDOT:PSS pressure sensors with and without Au-NP incorporation. The Au-NP incorporation can enlarge the sensing range to 8 kPa. Fig. 4(a) demonstrates the reversible testing of fabricated samples for at least 3 cycles. The testing proves the repeatability of these samples. Further, the PEDOT:PSS pressure sensors with Au-NPs incorporation show a faster response, i.e. negligible relaxation time after a 10-sec hold time, as displayed in Fig. 4(b). Fig. 5 shows the cross-talk effects of PEDOT:PSS pressure sensors incorporated with different size of Au-NPs by using a 2×2 cross-point array structure. The PEDOT:PSS pressure sensor suffers from a serious disturbance. For the Au-NP incorporated sample, the cross-talk effect can be significantly eliminated. The piezoresistive and disturbance characteristics improvement can be explained by the theoretical model illustrated in Fig. 6. The Au-NPs can assist the electron hoping between PEDOT grains and help the relaxation of PSS chains, leading to the superior piezoresistive and cross-talk properties.

4. Conclusions

The Au-NPs incorporated PEDOT:PSS pressure sensors were fabricated and the piezoresistive and disturbance properties were studied by using the 2×2 cross-point array structure. It is observed that the Au-NPs can enhance the piezoresistive response and cross-talk behavior of PEDOT:PSS pressure sensors which can be ascribed to the Au-NP assisted electron hopping and fast relaxation of PSS chain by the Au-NPs respectively.

Acknowledgements

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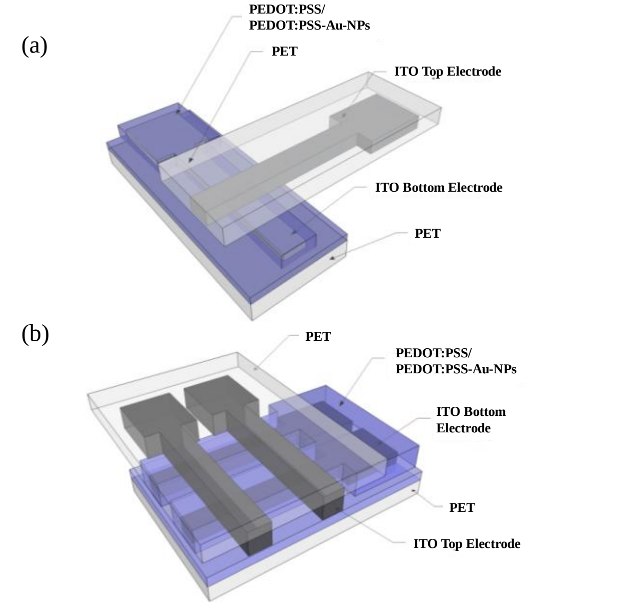

Fig. 1 Schematic diagram of fabricated PEDOT:PSS pressure sensors with (a) 1×1 cross-point structure and (b) 2×2 cross-point array structure.

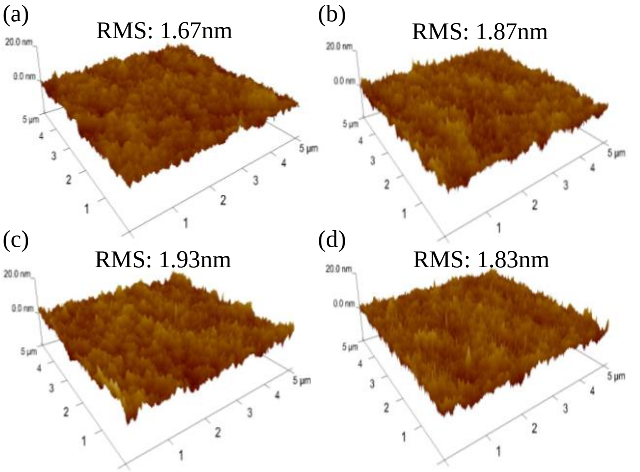

Fig. 2 AFM topographic images of (a) pure PEDOT:PSS film, and PEDOT:PSS incorporated with (b) 5-nm-in-diameter, (c) 10-nm-in-diameter, and (d) 20-nm-in-diameter Au-NPs.

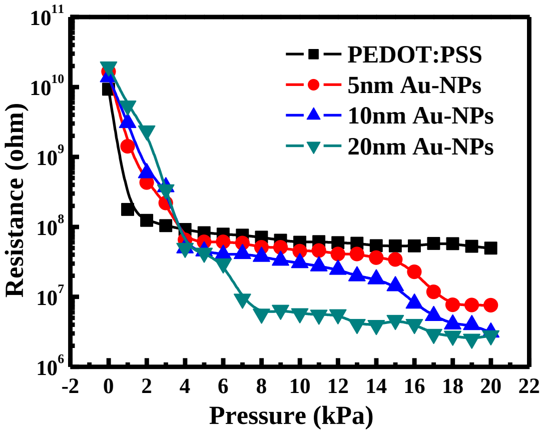

Fig. 3 Piezoresistive characteristics of PEDOT:PSS pressure sensors incorporated with different size of Au-NPs.

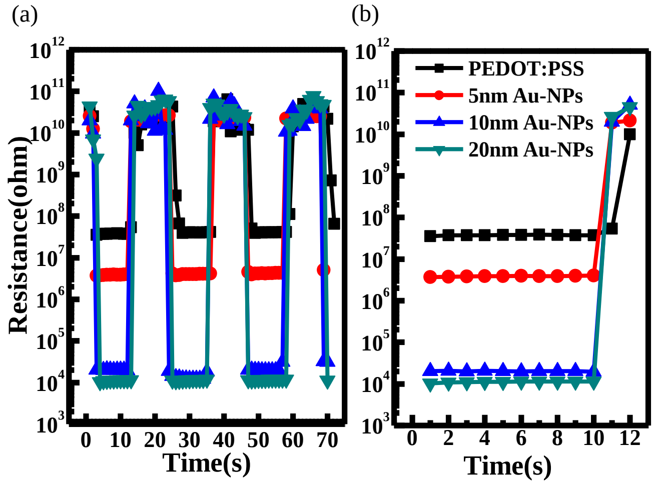

Fig. 4 (a) Reversible testing and (b) time-response of fabricated PEDOT:PSS pressure sensors incorporated with different size of Au-NPs.

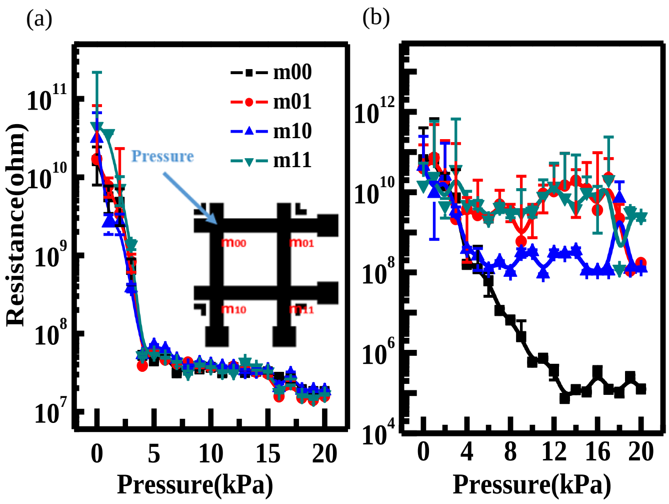

Fig. 5 Cross-talk effects of 2×2 cross-point pressure sensor array with (a) pure PEDOT:PSS and (b) PEDOT:PSS with 20-nm-in-diameter Au-NPs. The pressure was applied at m00 point.

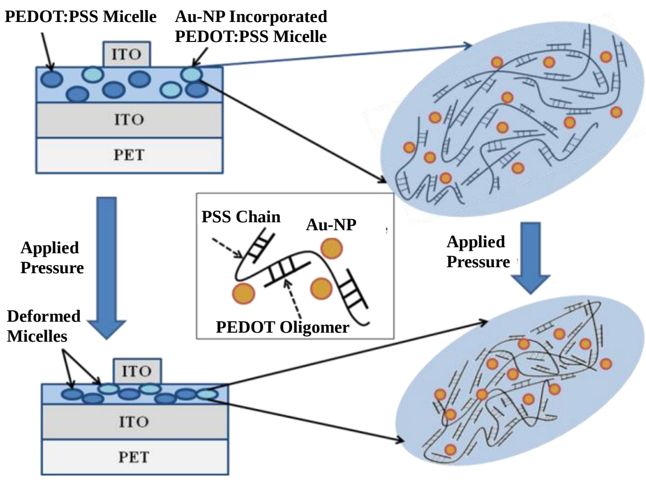

Fig. 6 Schematic diagram and theoretical model to explain the piezoresistive mechanism of PEDOT:PSS film with Au-NPs incorporation.