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Photo induced memory devices using conducting polymer, poly(3-hexylthiophene) thin films

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Abstract

Photo induced memory devices have been fabricated utilizing conducting polymer, head-to-tail coupled poly(3-hexylthiophene), PHT. The PHT film with Au electrodes at the bottom was coated with ultra thin Al by the thickness of 1 nm on the top. A large increase of conductivity was observed upon light illumination. The increased photoconductivity lasted for several hours after turn off of illumination, indicating photo induced memory effect. The phenomenon is discussed in terms of the persistent photoconduction, which resulted from the electron trapping at Al donor sites in the depletion layer formed near the top of film.

Keywords: Conducting polymer; Poly(3-hexylthiophene); Light induced memory; Depletion layer; Memory devices

1. Introduction

Organic electronics devices like electro luminescenence (EL) displays, field effect transistors (FET) and solar cells have been interestedly and intensively studied, because of the lightweight, flexibility and low cost manufacturing process. For the fabrication of all organic electronic circuits, organic memory devices are required. A large number of studies on the improvement of EL and FET have been carried out, however, organic memory devices have not been studied so far. A cell consisting of polyethlenedioxythiophene (PEDOT) and polystyrene sulfonic acid has revealed a write-once, read-many-times (WORM) memory [1]. Bistable memory devices using organic materials of 2-amino-4,5-imidazoledicabonitrile (AIDCN) [2] have shown that the conductivity of the films switched on and off by the application of voltages at certain threshold. The reports have stimulated further interests to realize the rewritable organic memories. In this paper, a preliminary study on the light induced memory effect utilizing a persistent photoconduction in conducting polymers, poly(3-hexylthiophene), (PHT) film will be mentioned.

2. Experimentals

Three types of memory devices were prepared and their typical structures are shown in Fig. 1. The fabrication process of the cell, for example, shown in Fig. 1(A) was as follows. Au electrodes with the thickness of 25 nm were firstly deposited in vacuum on a glass substrate. The distance and the width of Au electrodes were 25 μm and 2 mm, respectively. Then PHT was spin-coated with 1400∼3400 rpm for several tens seconds. The thickness of the PHT films was 50–200 nm, which was tuned by using various concentrations of PHT in chloroform solution ranging 0.13–1.0 wt.%. Al with thickness of approximately 1 nm was deposited on it for memory cells. The other type cell with Al layer deposited on Au bottom electrodes is shown in Fig. 1(B). The cell with thin Al layer deposited on Au electrodes underneath PHT and top of PHT film was also prepared and shown in Fig. 1(C). The electrical characteristics of the cell were measured in vacuum using the Keithley 6517 source and measure unit. Light source was a monochromated light of 550 nm with the intensity of 50

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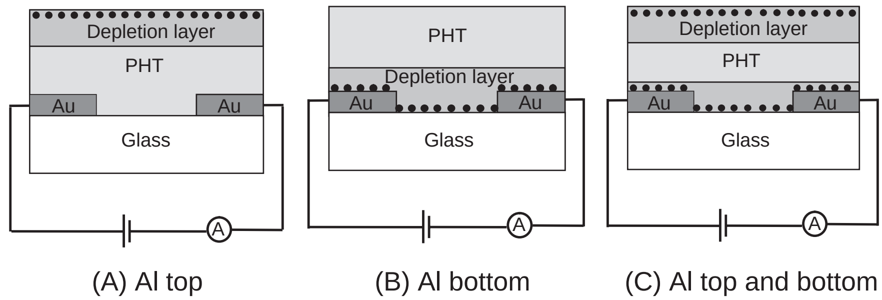

Fig. 1. Schematic drawing of the memory cells.

μW/cm^2 from the Xe lamp. The intensity of light was tuned by using neutral optical density filters.

3. Results and discussion

Fig. 2 shows the response of the resistances of PHT for the cell (A) of Fig. 1, as the function of Al thickness [3,4], which was obtained during deposition of Al. The resistance increased at the initial stage of Al deposition, followed by decrease above the thickness of 10 nm. The result indicates that the increase of resistance at the fist stage originates from the formation of depletion layer with much higher resistance. The depletion layer is generated by the compensation of p-type PHT by donated electrons from Al. The resistance of depletion layer is much higher than that of pristine PHT by several orders of magnitude. The decrease of resistance at the second stage originates from the building up of conductive path by Al particles at the top. The line in the inset shows the current path above the Al thickness of 20 nm. From the magnitude of the increased resistance at the first stage, the thickness of depletion layer was estimated to be 20–100 nm depending on time after deposition. It should be noted that the depletion layer plays the role of Schottky type junction, and shows a rectification with the combination of ohmic contact by Au electrode. Taking these results into consideration, the following experimental results can be accounted for.

3.1. Photo induced memory effects

A light of 550 nm with the intensity of 50 μW/cm^2 was illuminated onto the top of cells. The action spectrum of the photo-current showed similarity to the absorption spectra peaking at around 550 nm. Curves in Fig. 3 show the time response of current for the cell (C) with the film thickness of approximately 200 nm. The current increased slowly by the light illumination with the time constant of approximately 100 s and saturated in 1000–2000 s. The photo-induced current lasted for several hours after turn off of the light illumination as shown in Fig. 3. The life time of memory effect typically consisted of two components of approximately 20 s and 13 h. Similar photo induced memory effect was also observed in the cell (A) and (B). The characteristic of memory effect, such as the magnitude of photo-current and the time constant depended on samples. At the moment, (A) and (C) cells seem to show the large light responses.

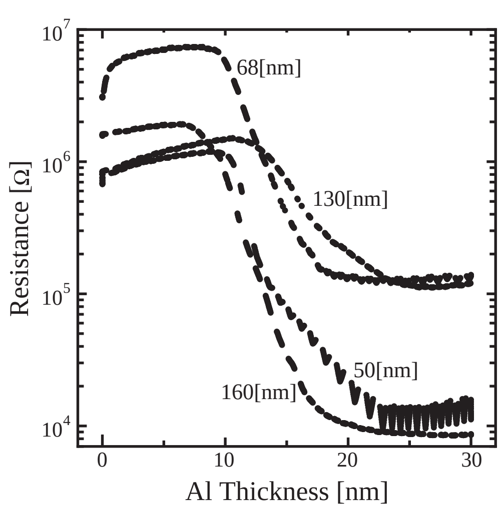

Fig. 2. Resistance change of the cell (A) as the function of Al thickness.

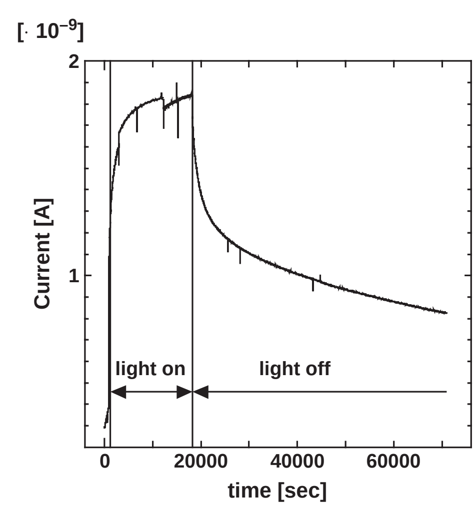

Fig. 3. Typical photo response of the current upon light on and off in the cell (C).