Biaxially stretchable a-IGZO TFT on PI/PDMS

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Keywords: Amorphous indium-gallium-zinc-oxide (a-IGZO), Thin-film transistor (TFT), Polydimethylsiloxane (PDMS)

ABSTRACT

We demonstrate stretchable amorphous indium-gallium-zinc-oxide (a-IGZO) thin-film transistors (TFTs) on polyimide (PI)/polydimethylsiloxane (PDMS). TFTs/PI island on the stretchable PDMS substrate maintain their electrical characteristics even after being stretched up to 20% strain. TFTs on PI/PDMS substrate exhibit robust electrical performances for stretchable devices.

1 Introduction

Recently, stretchable electronic devices have received a lot of attention in the next-generation display area [1]–[4]. Stretchable electronic devices can be used for wearable displays and sensors. Many studies have been conducted to realize a stretchable display [5]–[7].

Among many types of thin-film transistors (TFTs), amorphous indium-gallium-zinc-oxide (a-IGZO) TFTs are the subject of intensive research due to various merits such as amorphous structure, high mobility, high bandgap energy, on/off ratio, and compatibility with plastic substrates [8]–[10]. Because of these advantages, a-IGZO TFTs are also receiving a lot of attention in the stretchable electronic device area.

Although there are a lot of materials available in stretchable or flexible displays, the most commonly used materials are polyimide (PI) and polydimethylsiloxane (PDMS). PI has lots of merits such as high thermal stability, excellent mechanical strength, high heat resistance, and low coefficient of thermal expansion [11]. For stretchable devices, PDMS is the most well-known stretchable substrate. PDMS has advantages for stretchable devices, such as low cost, simple fabrication, and transparency [12], [13].

In this work, we fabricated coplanar structured a-IGZO TFT on PI/PDMS to utilize as a stretchable substrate. The fabricated TFTs were transferred to the PDMS substrate and then stretched up to 20 %. The electrical characteristics of TFTs maintained even stretched to 20% compared to the initial state. In summary, we demonstrated oxide TFTs using PI/PDMS substrates for stretchable devices.

2 Experiment

A mixture of water-based graphene-oxide (GO) solution and carbon-nanotube (CNT) solution was spray-coated on carrier glass and was followed by baking in the vacuum oven at 290 °C. Then PI solution was spin-coated to

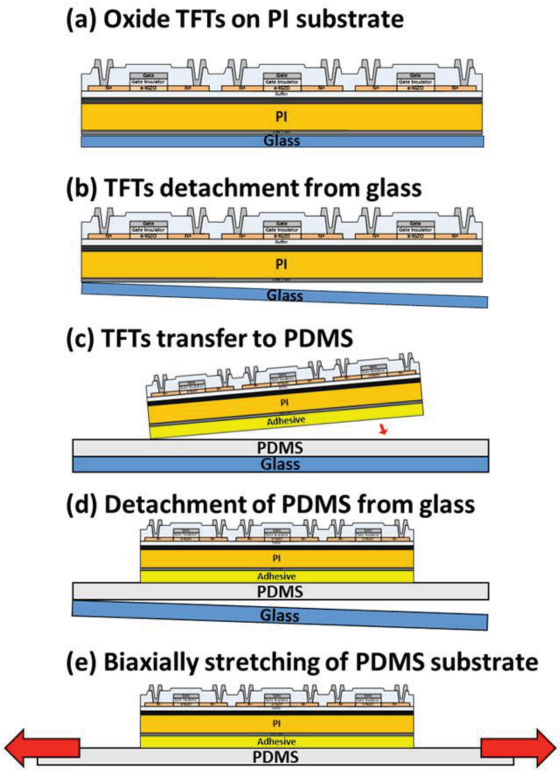

Fig. 1 Schematic illustration of a-IGZO TFTs on PI/PDMS substrate. (a) Fabricated a-IGZO TFTs on PI. (b) Detachment of fabricated TFTs from glass substrate. (c) Transfer of the TFTs to PDMS. (d) Detachment of PDMS from carrier glass. (e) Biaxially stretching of PDMS substrate up to 20 %

achieve a thickness of 10 um. The CNT/GO layer was used to reduce the adhesion between the PI film and the carrier glass [14]. After coating, the carrier glass/CNT/GO/PI substrate was annealed at 450 °C in N_2 ambient. After the formation of the flexible PI layer, multilayers consisting of SiN_X and SiO_2 were deposited by plasma-enhanced chemical vapor deposition (PECVD) to form a buffer layer that acts as a gas barrier. The coplanar-structured a-IGZO TFTs were fabricated on PI substrate. On top of the buffer layer, 25 nm-thick IGZO was deposited by sputtering, then 100 nm-thick SiO_2 as gate insulator and 150 nm-thick Mo for gate electrode were deposited and self-aligned. After the patterning process, 300 nm of SiO_2 was deposited as an

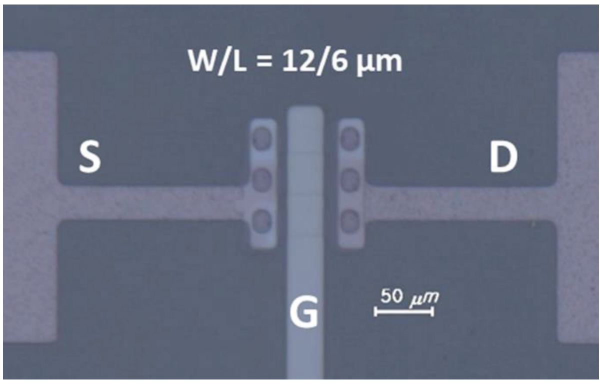

Fig. 2 Optical image of the a-IGZO TFT

interlayer, followed by a 250 nm-thick Mo for S/D electrode. Post-annealing was conducted at 250 °C. For preparing the stretchable PDMS substrate, PDMS solution (base:curing agent = 10:1 wt%) was spin-coated on the carrier glass and then cured on a hot plate.

The fabricated TFT (Fig. 1 (a)) was mechanically detached from the carrier glass as shown in Fig.1 (b), and transferred to the prepared PDMS substrate (Fig.1 (c)). We used an adhesive material to transfer and fix the TFT on the PDMS. After the TFT was transferred to the PDMS, the TFT/PI/adhesive/PDMS was detached from the glass as shown in Fig.1 (d), and strain was applied by stretching the PDMS up to 20 % (Fig.1 (e)).

3 Results and Discussion

During the fabrication of the TFT, CNT/GO solution was spray-coated layer before coating polyimide on the glass as shown in Fig. 1. The CNT/GO layer reduces the adhesion force between the glass and PI, enabling the transfer of the TFT to the PDMS substrate as shown in Fig. 1 (b) and (c). Fig. 2 shows the optical image of the a-IGZO TFT used in this work. We adopted a conventional coplanar structure for the TFT, and the width and length of the channel are 12 and 6 µm, respectively.

We measured transfer and output characteristics before and after the processes. In the transfer curve, the drain current (I_D) was measured by sweeping the gate voltage (V_{GS}) from - 20 V to + 20 V with drain voltage (V_{DS}) of + 0.1 V. In the output curve the I_D was measured with the V_{GS} = + 10 V. Threshold voltage (V_{TH}) was taken as the V_{GS}

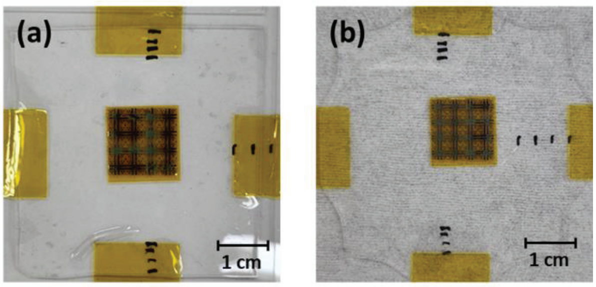

Fig. 3 Photographs of TFTs transferred to the PDMS substrate. (a) Initial and (b) 20% biaxially stretched state of the TFTs on PDMS

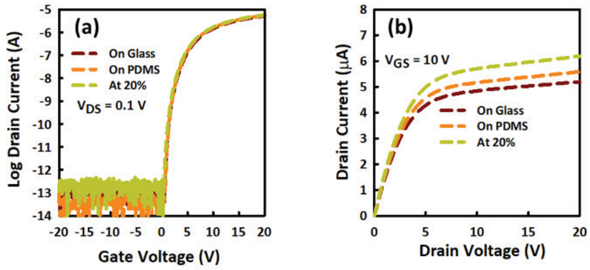

Fig. 4 (a) Transfer and (b) output characteristics of the a-IGZO TFT on glass, on PDMS (after detachment from glass), and at biaxially stretched PDMS up to 20%

at which the I_D = (W/L)*10 pA. The field-effect mobility (μ_{FE}) was extracted from the conventional metal-oxide-semiconductor field effect transistor (MOSFET) equation [15].

As shown in Fig. 1 and Fig. 3 (a) and (b), we transferred the a-IGZO TFT to the PDMS. The electrical characteristics of the TFT were measured on glass (before detachment), after transfer on PDMS, and also after applying strain on the PDMS substrate.

Fig. 4 (a) and (b) show the transfer and output characteristics of each process. The electrical parameters of initial state exhibited V_{TH} of 1.2 V, μ_{FE} of 5.0 cm^2/Vs, and SS of 0.60 V/dec. After transfer to the PDMS, the electrical performances such as V_{TH}, μ_{FE}, and SS were 1.1 V, 5.2 cm^2/Vs, and 0.54 V/dec, respectively. There was negligible change in the electrical characteristics of the device. After the transfer process, the PDMS substrate was stretched biaxially to 20 % compared to the initial state. Transfer and output characteristics were measured under 20 % biaxially stretched state. The device showed V_{TH} of 1.0 V, μ_{FE} of 5.5 cm^2/Vs, and SS of 0.59 V/dec. The parameters showed a slight change in the field-effect mobility and drain current under initial and stretched state. This work indicates PI/PDMS substrates can be an excellent candidate for stretchable devices.

4 Conclusions

In this experiment, we demonstrated stretchable a-IGZO TFTs on PDMS. Before coating polyimide, CNT/GO solution was used to make a detachment of polyimide from glass. The fabricated TFTs on PI were transferred on top of the PDMS. PDMS was stretched and the electrical characteristics were compared before and after stretching the PDMS. As a result, the change in V_{TH}, μ_{FE}, and SS are -0.1 V, +0.2 cm^2/Vs, and -0.06 V/dec, respectively.

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