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Letter

Channel width effect for organic thin film transistors using TIPS-pentacene employed as a dopant of poly-triarylamine

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ABSTRACT

The effects of the physical channel width on the characteristics of organic thin film transistors (OTFTs), made with 6,13-bis(triisopropyl-silylethynyl)-pentacene (TIPS-pentacene) embedded into poly-triarylamine (PTAA, hole conductor within an active channel), have been examined in this paper. The devices are estimated by measuring the drain-source current (I_{DS}) for different contact metals such as Au and Ag, at fixed gate and drain voltages. The results show that the threshold voltage (V_T) and I_{DS} increase with increasing channel width. Furthermore, it has been observed that the field effect mobility is dependent on V_T, which is influenced by the channel width. The OTFTs, produced using Au and Ag contacts, exhibited the highest values of mobility in the saturation regime, namely 5.44×10^{-2} and 1.33×10^{-2} cm^2/Vs, respectively.

1. Introduction

Electronics based on organic thin film transistors (OTFTs) have attracted much attention in recent years. This interest can be attributed to the emerging demands in electronic devices, such as radio frequency tags (wireless transponders) and smart cards, display (active and passive) media, and large area sensor arrays [1–4] on inexpensive plastic substrates, so that flexible, unbreakable, and light-weight electronics are possible using OTFT. Moreover, these devices permit the capability of being processed from solutions, allowing large scale fabrication techniques, such as screen printing [5], ink jet printing [6], imprinting [7] and roll to roll processing [8].

The most basic parameters of an OTFT are the effective channel length (L) and the width (W) of a transistor, which optimize the device performances. These parameters play an important role in governing the characteristics of the device [9] and therefore it has become more and more essential to accurately determine the real sizes of the OTFT's geometry for the device analysis and process control. However, considerable progress has been made in recent years in improving the performance of OTFTs, yet many of the designs, materials, and process parameters influencing OTFT performances are still poorly understood and not adequately controlled. Moreover, only little work

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surrounding the channel width effect has been carried out in field effect transistors based on metal oxide silicon [10], poly-crystalline silicon [11], or hydrogenated amorphous silicon [12] and thus the channel width effects on the OTFT's performance are not well known at the present time.

This work focuses on the three issues as follows: (1) thin film study of 6,13-bis(triisopropyl-silylethynyl)-pentacene (TIPS-pentacene) with semiconducting polymer binder (poly-triarylamine, PTAA) in order to impose a function as forming a good interfacial contact between the organic semiconductor (OSC) and the source/drain electrodes; (2) employing two kinds of metals, one with a low work function (Ag) and the other with a high work function (Au), in order to compare the function of metallurgy for low cost devices; and (3) a structural study of the channel dimension in order to optimize the device parameters effectively and to obtain good performance of the device characteristics.

2. Experimental

Fig. 1c shows a schematic diagram of the OTFT structure where an insulator layer of silicon dioxide (SiO_2) is thermally grown on top of a heavy doped p-type Si wafer to act as the gate contact. A highly doped p-type Si wafer was used both as a substrate and as a gate electrode for the bottom-contact structure. Initially, the gate insulator, for most of the devices, was thermally grown to a thickness of 100 nm. Sequentially, a 200 nm-thick source-drain Au and Ag contacts were fabricated on top of the insulator by a thermal evaporation method (DOV Co., Ltd) to give the channel widths in the range of 500–2500 μm, and the channel length of 100 μm using a shadow mask. Particularly, the source-drain interdigitatd finger (SDIF) type electrode were employed in our device configuration since this SDIF pattern permits the use of printing and other techniques for fabricating display backplanes that are not capable of attaining the fine resolution limits of standard silicon processing using photolithography. Next, the TIPS-pentacene mixed with PTAA were deposited by a drop casting from a 2 wt% solution of TIPS-pentacene in monochlorobenzene. Fig. 1a and b exhibit the molecular structures of TIPS-pentacene and PTAA, respectively. In our sample, PTAA was employed as a dopant and TIPS-pentacene was used as a host material. Also, in order to improve device performance, polymer binder, PTAA was employed to fabricate OTFT device with organic soluble TIPS-pentacene for decreasing the injection barrier from the metal electrode to the OSC and used as a hole conductor between the OSC and source-drain contacts for reducing the surface dipoles [13]. Here, TIPS-pentacene was synthesized following the procedure reported by our previous study [14]. PTAA was synthesized by following the literature method and a modified method [15–18]. All reactions were performed under an argon atmosphere unless otherwise stated. Finally, after coating the OSC, the device was annealed using a hotplate at 110 °C for 1 min.

The optical absorption spectra of the host-guest (TIPS-pentacene-PTAA) system film was obtained uisng UV spectrometry (Ultraviolet–visible, UV–vis, HP 8453, PDA, type λ = 190–1100 nm). The surface morphology of the OSC lay-

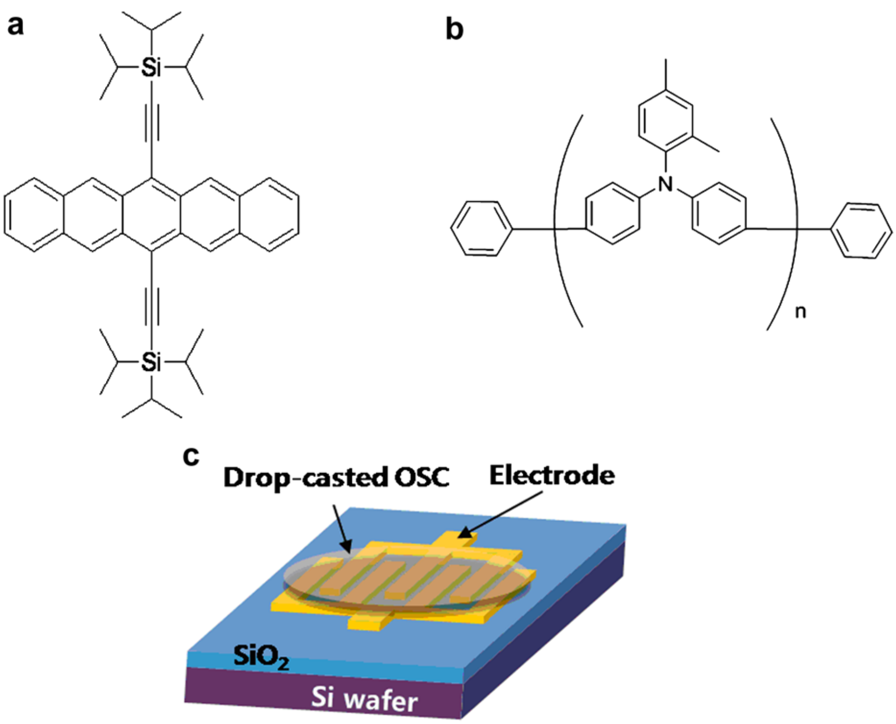

Fig. 1. The molecular structure of (a) TIPS-pentacene, (b) PTAA and (c) the schematic geometry of the OTFT on heavy doped silicon wafer with SDIF bottom contacts varying the *W*/*L* ratio from 25 down to 5 (channel length: 100 μm).