Electrostatic discharge robustness on organic ring oscillator.

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Abstract
We have improved robustness of organic thin-film transistors (TFTs) for electrostatic discharge (ESD) with polymer encapsulation layer. Finally, we obtained 5-V operation organic ring-oscillators (RO) withstanding over 300-V ESD stress. Encapsulated organic transistors in this ring-oscillator can also stand over100 V which is 5 times as large as transistors without encapsulation. In addition, it can release ESD stress as failure current up to 70 mA improved from 35 mA of bare transistors. In previous our work, it has been reported that source/drain electrode was damaged strongly and came off apart from bottom organic semiconductor layer after applying 14-V ESD stress into the organic circuits[a]. Therefore we make encapsulation layer on top of the pentacene transistors with poly chloro para xylylene(Parylene) by chemical vapor deposition (CVD) to suppress that ESD detach those electrodes away.

1. Introduction
Organic electronics is expected to realize novel devices such as flexible display [2], electrical skin [3] and large area sensor [4]. Several researchers, on the other hand, start to investigate application to biomedical devices [5,6], intensively. Organic thin-film transistors (OTFTs) are fundamental elements in these circuits. High electrical characteristics of OTFTs such as high mobility (~1 cm/Vs) or long atmospheric stability are required to be utilized into the devices. Robustness of electrostatic discharge of OTFTs is also important for bio electronics. It is because organic device on flexible substrate is easy to get charge, and to be broken by ESD when it is put on conductive human body.

In this study, we fabricate ESD robust OTFTs with polymer encapsulation structure that also brings good electric characteristics such as high thermal stability [7] and atmospheric stability [8].

2. Experiment
Organic transistors with SAM gate dielectrics were manufactured by vacuum evaporation and solution processes. First, we deposited 25-nm-thick aluminum as a gate electrode on polyimide film substrate by thermal evaporation and solution processing. Then, we deposited 50-nm-thick Au by thermal evaporation onto the pentacene surface to make source/drain electrodes. After deposition 50-nm-thick Au by thermal evaporation onto the pentacene surface to make source/drain electrodes. After deposition 50-nm-thick Au by thermal evaporation onto the pentacene surface to make source/drain electrodes. After deposition 50-nm-thick Au by thermal evaporation onto the pentacene surface to make source/drain electrodes.

Fig.1. Device structure: (a) Cross section structure of OTFTs. (b), (c) Chemical structure of DNTT (b) and n-octadecyl phosphonic acid (c). (d) Optical image of OTFT without encapsulation from top view.
that, we deposited 1-μm-thick parylene by CVD. To contact underneath electrode, we made via hole using green laser.

We have used the transmission line pulsing method with human body model equivalent pulses. These pulses have a 100-nsec. pulsewidth and a 10-nsec. rise time. We elevated an amplitude of those pulse from 0 V, gradually.

3. Results

As shown in Fig. 2, encapsulated p-OTFT stands ESD stress up to 109 V. On the other hands, bare transistor was broken by ESD stress of 17 V. Then failure current through encapsulated organic TFT becomes up to 73 mA, and that of bare organic TFTs becomes 59 mA. Effect of channel width is consistent. When we change channel width from 500 to $3.8 \times 10^4$ μm, failure current of ESD increases up to 468 mA, linearly, while, channel length doesn’t affect ESD characteristics in change from 55 to 124 μm. It implies that channel resistance/conductivity of organic semiconductor is inconsequential for ESD robustness, but contact resistance or parasitic capacitance between electrodes can affect ESD characteristics.

ESD characteristics of encapsulated organic RO are shown in Fig. 3. We apply ESD stress in two ways: one is a path from electrode for higher voltage in circuit named V_{DD} to grand (GND), and the other is a path from GND to V_{DD}. In both way, organic RO shows 5 times higher ESD robustness on failure current than invertor circuit which is used in RO. This is quite consistent because our RO can be considered as 5 parallel invertors. Finally, encapsulated organic RO stands ESD stress up to over 300 V. Then failure current is 486 mA. This is equivalent to ESD stress of 730 V in human body model (HBM). Device is more stable against ESD from GND to V_{DD} in both circuit, RO and invertor.

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References