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Organic Thin-Film Transistors with High Thermal Stability

Authors : Sibani Bisoyi, Ute Zschieschang, Alexander Hoyer, Hagen Klauk

Abstract : Abstract— Organic thin-film transistors (TFTs) have great potential to be used for various applications such as flexible displays or sensors. For some of these applications, the TFTs must be able to withstand temperatures in excess of 100 °C, for example to permit the integration with devices or components that require high process temperatures, or to make it possible that the devices can be subjected to the standard sterilization protocols required for biomedical applications. In this work, we have investigated how the thermal stability of low-voltage small-molecule semiconductor dinaphtho[2,3-b:2’,3’-f]thieno[3,2-b]thiophene (DNTT) TFTs is affected by the encapsulation of the TFTs and by the ambient in which the thermal stress is performed. We also studied to which extent the thermal stability of the TFTs depends on the channel length. Some of the TFTs were encapsulated with a layer of vacuum-deposited Teflon, while others were left without encapsulation, and the thermal stress was performed either in nitrogen or in air. We found that the encapsulation with Teflon has virtually no effect on the thermal stability of our TFTs. In contrast, the ambient in which the thermal stress is conducted was found to have a measurable effect, but in a surprising way: When the thermal stress is carried out in nitrogen, the mobility drops to 70% of its initial value at a temperature of 160 °C and to close to zero at 170 °C, whereas when the stress is performed in air, the mobility remains at 75% of its initial value up to a temperature of 160 °C and at 60% up to 180 °C. To understand this behavior, we studied the effect of the thermal stress on the semiconductor thin-film morphology by scanning electron microscopy. While the DNTT films remain continuous and conducting when the heating is carried out in air, the semiconductor morphology undergoes a dramatic change, including the formation of large, thick crystals of DNTT and a complete loss of percolation, when the heating is conducted in nitrogen. We also found that when the TFTs are heated to a temperature of 200 °C in air, all TFTs with a channel length greater than 50 µm are destroyed, while TFTs with a channel length of less than 50 µm survive, whereas when the TFTs are heated to the same temperature (200 °C) in nitrogen, only the TFTs with a channel smaller than 8 µm survive. This result is also linked to the thermally induced changes in the semiconductor morphology.

Keywords : organic thin-film transistors, encapsulation, thermal stability, thin-film morphology
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