Low voltage p-channel organic TFT on low-cost substrates

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Printed and flexible circuitry has vast potential for novel applications in fields such as sensing and body measurements, due to the simple processes and the possibility of integration of sensor and circuitry using the same production processes. However, there are numerous issues inhibiting the use of such circuitry, including the issue of relatively high voltage operation and the need for low voltage, low power complementary circuitry. Solution-processed n-type metal oxide TFTs operating at low voltage have been reported [1], although work to reduce the processing temperature is still on-going. While high mobility p-type organic materials have been available for some time, the operating voltages are still relatively high. The availability of reliable and low operating p-channel organic FETs will foster the development of fully solution-processed integrated circuits.

In this work, low-voltage organic TFT with dimension characteristics of (W=1000µm and L=60µm), were produced on Cellophane-tape, PET and glass, which are cheap and widely available. A bottom gate top source-drain (S/D) structure was used. The gate was made of 100nm of evaporated aluminium. A 10 nm thick high-k dielectric layer (Al₂O₃) was obtained by electro-chemical anodization of aluminium in a 0.01 M solution of Citric Acid at room temperature, under a current density of 75 µA/cm². The S/D electrodes were made of a 100nm layer of evaporated Silver, modified by treatment with a self-absorbed monolayer (SAM) to improve charge injection- We used a commercial (SP400, Merck), organic semiconducting material as active layer. It was deposited by spin coating at 500rpm for 15 seconds and 1200rpm for 120 seconds. Unlike the previously reported operation voltage of 30V using the same material, we demonstrated devices working below the low drain bias voltage of -3 V. On Cellophane tape we achieved an ON/OFF current ratio of 10⁴; a turn-on and threshold voltage (V₉) of -1.4V. In PET numerous issues are inhibiting a threshold (V₉= -1V), but a slightly lower ON/OFF 10³. The devices produced on glass for comparison also operated at (V₉= -1V) with the ON/OFF ratio of 10⁴. The hole mobility (3.63 cm²/V. s) was similar across the three substrates and comparable to the values reported earlier using solution-processed low-k dielectrics, in contrast to common expectations that the field-effect mobility in organics is degraded by contact with a high-k dielectric. The results were independent of substrate, indicating a potential for integration into future smart systems on a variety of different substrate.

References
[1] Sagar R. Bhalerao, Donald Lupo, Amirali Zangiabadi et al “0.6V Threshold Voltage Thin-Film Transistors with Solution Processable Indium Oxide (In₂O₃) Channel and anodized High-k Al₂O₃ Dielectric, IEEE electron device letters, Vol.40, No 7, July 2019