FABRICATION AND AC PERFORMANCE OF FLEXIBLE INDIUM-GALLIUM-ZINC-OXIDE THIN-FILM TRANSISTORS

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Flexible and conformable devices operated in contact with the human body, or fabricated using cost effective roll-to-roll techniques are one of the next major steps in the development of consumer electronics. Specifically, flexible transistors promise to enable new applications including rollable display backplanes or active RFID tags. Additionally, analog circuits such as amplifiers, buffers, or transceivers made from flexible transistors can be used to realize front-end conditioning and readout circuits for wearable sensors. Thin-film transistors (TFTs), fabricated on polymer substrates using oxide semiconductors, especially amorphous Indium-Gallium-Zinc-Oxide (IGZO), are particularly suitable to fabricate active electronics when bendability and electrical performance is required simultaneously. The IGZO TFTs presented here are manufactured on free standing polyimide foils using a maximum process temperature of 150°C. These TFTs are based on high-k Al_2O_3 insulating layers (deposited by Atomic Layer Deposition), metallic contacts, and RF sputtered IGZO. They exhibit state of the art performance including a field effect mobility of ≈15 cm^2/Vs, a threshold voltage of ≈0.3 V, an on-off current ratio $>10^8$, and a subthreshold swing of ≈125 mV/dec. They also stay fully functional while bent to tensile or compressive radii as small as 3.5 mm. However, while the DC performance of such IGZO TFTs is well understood, their AC performance has to be further investigated. Here, different approaches to improve their high frequency performance are presented and discussed. All devices are designed with ground-signal-ground contact pads to enable a reliable AC characterization using a two port network analyser. The measurements show that conventional bottom-gate TFTs, with a channel length of 3 µm, and gate overlaps of 15 µm allow a transit frequency up to 10.5 MHz. This value, which is in good agreement with the corresponding transconductance and gate capacitance measurements, is limited by parasitic resistances and capacities as well as by the lateral TFT dimensions. These limitations is caused by the difficulty in reliably realizing small features on free standing polymer substrates, due to thermal expansion. To improve the maximum operation frequency, different methods to reduce the TFT channel length have been developed. As shown in Figure 1, these include flexible TFTs defined by self-alignment, focused ion beam (FIB), and direct laser writing (DLW), as well as vertical TFT structures. All devices are functional and exhibit channel length down to 160 nm. It was found that although traditionally smaller feature structures are beneficial, a careful optimisation of the gate capacitance, overlap capacitance, and contact resistance is required for flexible IGZO TFTs. Consequently, the shortest transistors do not exhibit the highest frequencies, but a record high transit frequency of 135 MHz, and exceptional maximum oscillation frequencies of 398 MHz are demonstrated for 500 nm long self-aligned flexible transistors. This is also validated by, a mathematical model to predict the AC performance of heavily scaled IGZO TFTs realized using different fabrication techniques. Finally, optimized TFTs can be used to realize entirely flexible analog circuits leading towards imperceptible electronic systems.

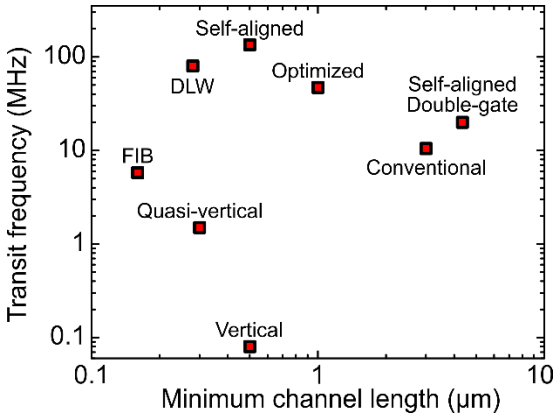

Figure 1 – Impact of different fabrication approaches on the geometry and measured AC performance of flexible short channel IGZO TFTs.