# Fabrication of nanoscale ZnO FETs using the functional material Zinc Neodecanoate directly as a negative e-beam lithography resist

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**Abstract**

ZnO-based electronics and optical devices have recently been extensively investigated [1-2] as it is a very promising semiconductor material with a direct wide-bandgap (3.37eV) at room temperature, a large exciton binding energy (60meV), and may also offer valuable features such as high mobility, excellent environment stability, and high optical transparency. We demonstrate here ZnO based thin film transistors (TFTs) fabricated by a metal-organic sol-gel solution process with a zinc neodecanoate precursor. The ZnO films were produced by spin-coating the precursor solution onto the substrates and subsequently annealing in air for 1 hour at 500℃. AFM and SEM characterizations show the films consisted of particles which have an average size of 45nm and are closely packed. X-ray diffraction measurement (Fig. 1) reveals that the particles have a hexagonal structure and are randomly orientated. TFT devices are fabricated by patterning Al source and drain electrodes of 100nm thickness on top of the ZnO film by standard lithographic processes. To evaluate the performance of the TFT devices, different channel widths (W) and channel lengths (L) were used, thus varying the W/L ratio from 1:3 to 5:1. A schematic illustration of the TFT structure is shown in Fig. 2(a). Plan-view images of devices with different W/L ratios are shown in Fig. 2(b) and (c). Electrical measurements (Fig. 3) show that the devices exhibit n-channel enhancement mode behaviour, with a saturation mobility of $1.16 cm^2 V^{-1} s^{-1}$, a drain current on-to-off ratio of $8.1\times10^7$ and a threshold voltage of 16.1V in ambient environment.

Zinc neodecanoate can also be used as a negative resist, and direct e-beam patterning can be introduced after spin coating to 'write' cross-linked nanowires on the substrate. Development dissolves the unpatterned areas which are then heat treated at 500℃ to form ZnO nanowires on the substrate. This process is capable of fabrication ZnO nanowire from 10 nm up to 500 nm wide, with a length of a few hundred microns. Fig. 4 shows an AFM image of such a prepared ZnO nanowire of 50 nm width. Cross section analysis shows that the wire has well defined edges. FETs based on the ZnO nanowires show similar behaviour as the thin film devices, operating as n-channel devices in enhancement mode. The results imply that high-performance ZnO TFTs produced by a simple and low cost technique could be applicable to electronic systems.

**References:**

[1] Hoffman R. L., Norris B. J. and Wager J. F., 2003. *Appl. Phys. Lett.* **82** 733.

[2] Ko S. H., Park I., Pan H., Misra N., Roger M. S., Grigoropoulos C. P. and Pisano A. P. 2008. *Appl. Phys. Lett.* **92** 154102.

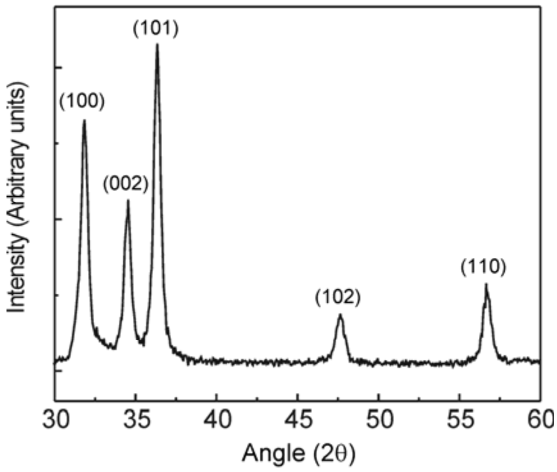


**Figure 1.** XRD pattern of the ZnO film.

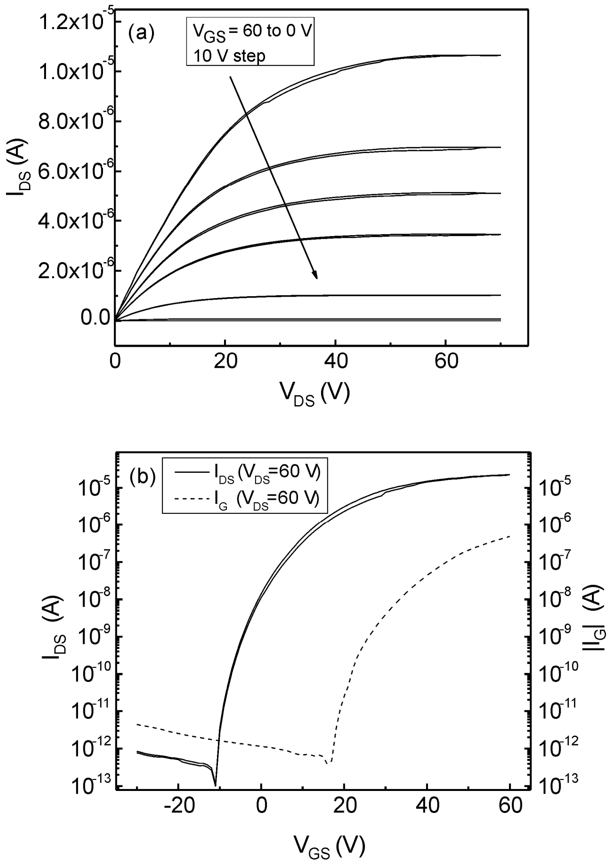


**Figure 3**. (a) Drain current – drain voltage ($I_{DS}$-$V_{DS}$) characteristics of a ZnO TFT device with a width-to-length ratio of 1:2. (b) Transfer characteristics and gate leakage current of the same device.

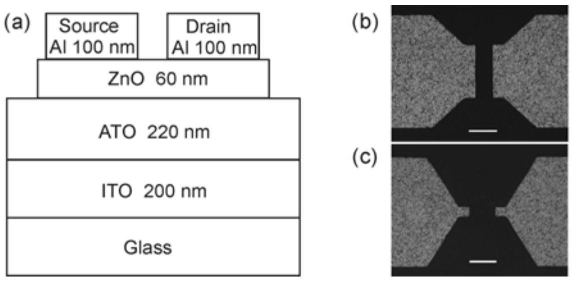


**Figure 2**. (a) Schematic illustration of a typical ZnO-TFT structure. (b) and (c) top view of two TFT devices with W/L ratios of 3:1 and 1:3, respectively. Scale bars are 50µm.

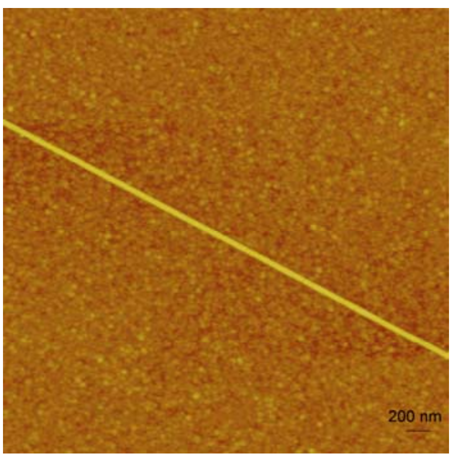


**Figure 4**. AFM image of a 50nm wide ZnO nanowire fabricated by direct e-beam patterning.