Low Temperature Atomic Layer Deposition of ZnO for Optoelectronic Applications

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This work demonstrates the ultra-low-temperature atomic layer deposition (ALD) of ZnO thin films at 50 °C and 70 °C using a 1 M diethylzinc (DEZ) solution in hexane and water as precursors. This was achieved in a custom-built ALD chamber with precise control over the process parameters. Despite the ultra-low deposition temperatures, the resulting ZnO films demonstrated excellent uniformity. This approach not only solves the problem of substrate compatibility by enabling ultra-low-temperature growth but also demonstrates the use of solvent-diluted pure precursors.

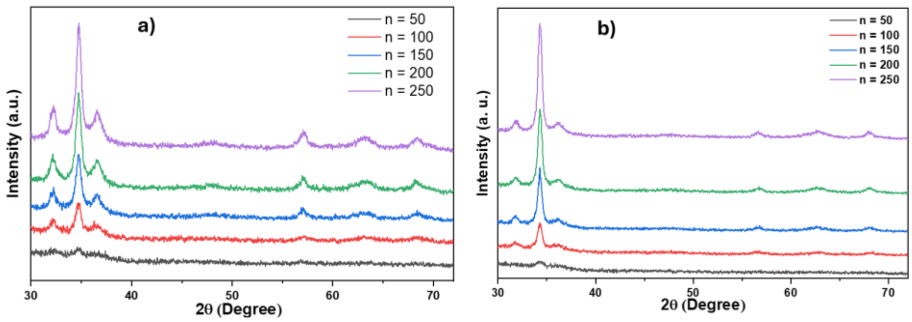

Figure 1: X-ray diffraction spectra of ZnO thin films as a function of the number of ALD cycles deposited at a) 50 °C and b) 70 °C.

Figure 1 represents the X-ray diffraction (XRD) patterns of the as-deposited ZnO thin films on quartz substrates. Figure 1a illustrates the structural evolution of the films deposited at 50 °C as the number of ALD cycles increased from 50 to 250. As the ALD deposition cycles increased to 100, distinct diffraction peaks corresponding to (100), (002), and (101) planes emerged. When the deposition temperature increased from 50 °C to 70 °C, the (002) peak became more intense and sharper, indicating improved crystallinity as shown in Figure 1b.

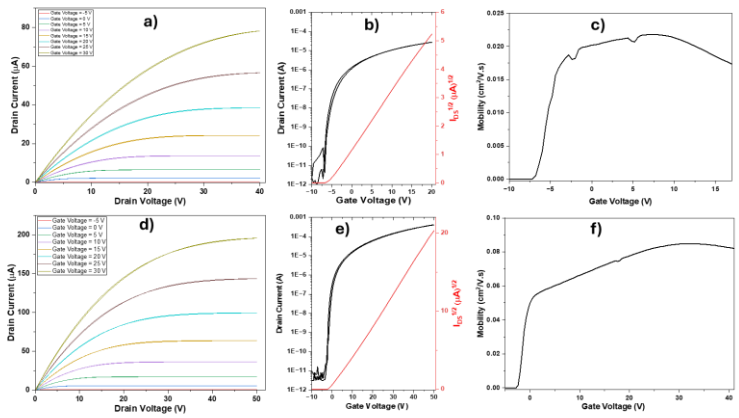

Figure 2: Electrical characteristics of fabricated FETs. (a-c) characteristics of ZnO-50 device, with a) output characteristics, b) transfer characteristics in saturation regime, and c) mobility as a function of gate voltage. (d-f) corresponding characteristics for the ZnO-70 device, illustrating d) output characteristics, e) transfer characteristics in the saturation regime, and e) saturation mobility as a function of gate voltage.

To evaluate the electronic properties of ZnO thin films deposited at ultra-low temperatures, we integrated them as the active layer in field-effect transistors (FETs), labelled as ZnO-50 (for deposition temperature 50 °C) and ZnO-70 (for deposition temperature 70 °C). The fabricated devices demonstrated exceptional electrical characteristics, shown in Figure 2, exhibiting an I_{on}/I_{off} ratio exceeding 10^8 with the saturation mobility of $0.085\ cm^2/V \cdot s$. These results clearly confirm the applicability of solution-based precursors for ultra-low-temperature ALD depositions in electronic device applications.