RF Sputtering of ZnO (002) Thin Films on top of 3C-SiC-on-Si (100) Substrates for Low Cost Piezoelectric Devices

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RF sputtering is employed in the deposition of ZnO thin film because of high deposition rate, good control of the film texture and stoichiometry, thickness uniformity and surface smoothness. In this work, we deposited c-axis ZnO thin films on top of epitaxial 3C-SiC/Si (100) substrates by RF magnetron sputtering.

We characterized the samples via XRD to assess crystal quality, AFM to assess the surface roughness, and by capacitance method to measure the piezoelectric coefficient of deposited film. Fig 1 (a) shows the XRD spectra of samples deposited at different O_2/Ar ratio. The data reveals that deposition at 40 % ratio assists in the formation of highly c-axis oriented ZnO film. The effect of annealing temperature on crystal orientation is shown in Fig 1 (b). The data reveal that annealing the samples at 600 ˚C in horizontal tube furnace in 100% nitrogen environment for 1 hour improves the crystal quality. The FWHM of diffraction peak of (002) orientation decreases from 0.45˚ (un-annealed) to 0.29˚ (annealed). The AFM scan in Fig 2 using Cypher AFM (with etalon cantilever) indicates that the surface roughness (in rms) of the deposited film increases from 10 nm (un-annealed) to 20 nm (annealed). This is due to recrystallization at high temperature, in which small crystallites coalesce together to make larger crystallites [1]. The piezoelectric coefficient (d_{33}) of ZnO film was measured using parallel plate capacitance measurement [2], as shown in Fig 3 (a). The thickness of ZnO layer contracts and expands with varying bias voltages from -2.5V to +2.5V, respectively. Figure 3 (b) shows the change in capacitance values across a range of frequencies. We picked the data at a frequency of 12000 Hz to calculate the longitudinal charge constant d_{33} based on Eq 2 and Eq 10 of reference [2]. Our calculated value of 4.56 pm/V is comparable to the 5.9 pm/V, which is the reported d_{33} value of the thin film ZnO in [3]. The results from this work can be applied in the development of low cost high piezoelectric devices.

References

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[2] M. Al Ahmad and R. Plana, "Piezoelectric coefficients of thin film aluminum nitride characterizations using capacitance measurements," *Microwave and Wireless Components Letters, IEEE,* vol. 19, pp. 140-142, 2009.

[3] S. Trolier-McKinstry and P. Muralt, "Thin film piezoelectrics for MEMS," *Journal of Electroceramics,* vol. 12, pp. 7-17, 2004.

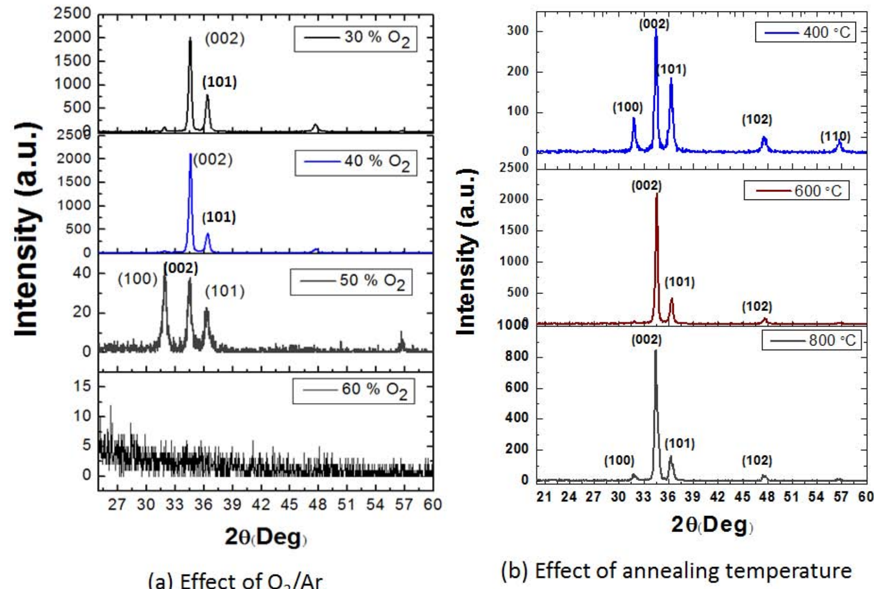


Figure 1: Grazing angle XRD of ZnO thin films being deposited at: (a) different O_2/Ar ratio and is un-annealed, (b) different annealing temperatures at the O_2/Ar ratio of 40%

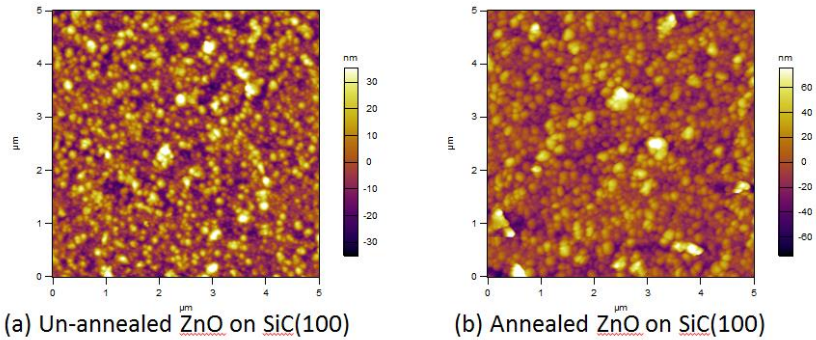
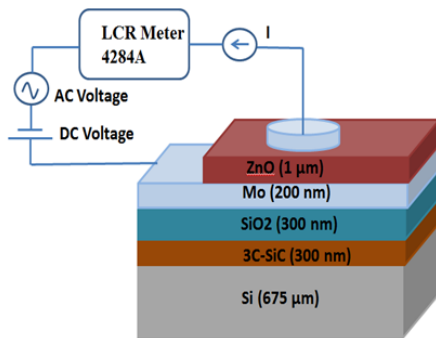
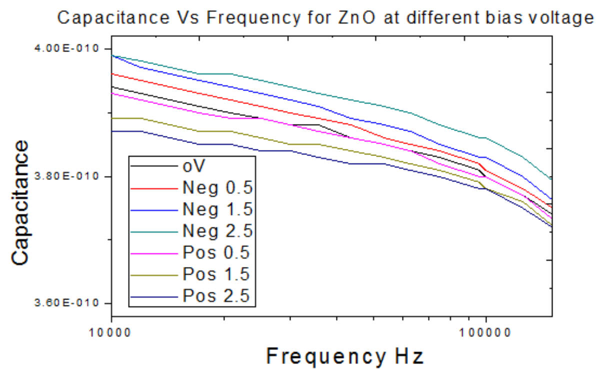


Figure 2: AFM image of ZnO thin film being deposited at 40 % O_2 /Ar ratio. Figure (a) shows the un-annealed sample, and Figure (b) shows the annealed sample at 600 Celcius.



(a) Schematic for d_{33} capacitance measurement



(b) The plot of Capacitance vs Frequency

Figure 3: (a) The schematic of the piezoelectric coefficient measurement, (b) Plot of capacitance vs frequency at six different DC bias voltages