Piezoelectric ZnO Films Deposited by RF Magnetron Sputtering for Microfluidic Applications

K. Wätje [a], H.J. Krenner [a], A. Wixforth [a], and W. Assmann
[a] Lehrstuhl für Experimentalphysik I, Universität Augsburg

Surface acoustic waves (SAW) on piezoelectric substrates find widespread application for high frequency signal processing applications. Recently, SAW induced streaming for actuation and agitation of smallest amounts of fluids has attracted considerable attention in the field of microfluidics. This streaming causes stirring in the fluid and induces mixing, even for very low Reynolds numbers [1,2]. Apart from single crystal substrates like $LiNbO_3$, low cost, high quality alternatives are required for on-chip bio-sensor applications. As an alternative, zinc oxide layers deposited by rf magnetron sputtering hold the promise of cheaper production and easier integration into the assembly.

For a SAW driven setup it is particularly important to optimize the polycrystalline piezoelectric film with respect to its composition, orientation and morphological uniformity. Stoichiometric ZnO is a perfect semiconductor, oxygen deficient ZnO is a transparent conductor. Even smallest amounts of impurities (e.g. Al) could lead to a conductivity and a short circuit of the interdigital transducers (IDT) which generate the SAW. Therefore, it is necessary to monitor the film composition to find suitable deposition parameters. Here, ZnO layers were deposited by rf magnetron sputtering from a ceramic ZnO target. Fig. 1 shows the composition of ZnO films grown at different temperatures, a sputtering power of 250 Watt and a pressure of 1.2 Pa. The inset shows the composition of ZnO layers on silicon deposited at room temperature in 1.2 Pa argon atmosphere with different sputtering power examined by ERD analysis.

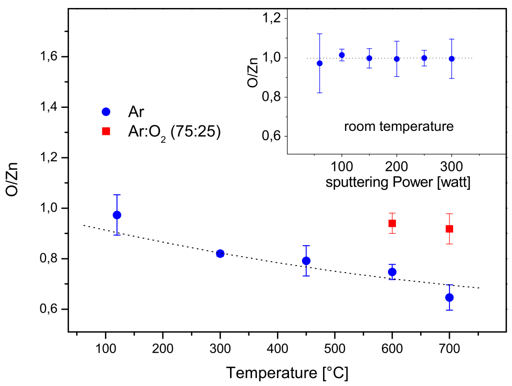

Fig. 1: Composition of ZnO layers, measured with ERDA for films deposited at different temperatures (P=const.=250 Watt) and different sputtering powers (T=const.=RT).

At room temperature the composition seems to be relatively unaffected by the rf power. Additional oxygen (up to 30%) in the sputtering chamber shows no impact on the film composition. Additional XPS measurements of the Auger peak, LMM2 and valence band edge of Zn found no indication of metallically bonded Zn atoms within the XPS detection limit. Therefore, the films are chemically identical to pure ZnO. As outlined in Fig. 1, sputtering at higher substrate temperatures leads to a decrease of the oxygen-zinc ratio. This might be due to the higher desorption probability of the oxygen in the layer surface. Adding oxygen to the sputtering gas prevents a decrease of the oxygen-zinc ratio at higher temperatures to maintain the correct stoichiometry. To excite SAW metallic IDT are defined on the top of the ZnO layer by a lift off process. Together with the sound velocity v_{SAW} of the layer and the IDT layout, the resonance frequency f is given by $f = v_{SAW} \cdot \lambda^{-1}$. The wavelength λ equates two times the finger spacing of the IDT. For the mixing experiment in Fig. 2, stoichiometric ZnO layers on glass substrates were deposited at 250 Watt in pure Argon at RT. Films were structured with tapered IDT and a finger pair distance from 23.0-26.0 μm. Water droplets with a volume of 1 μl were pipetted onto the IDT. To visualise the induced streaming, a small amount of polystyrol beads was added to the droplet. As the diameter of the beads is 4.6 μm, the diffusion constant is very low $(1 \cdot 10^{-13} m/s)$, and can be neglected and no stirring in the droplet would take place without SAW induced streaming . Fig. 2a and b show two images taken at different agitation frequencies. This mixing experiment was performed directly on the IDT with an amplitude power of 16 dBm. As the SAW- velocity is constant, a higher frequency requires lower finger- pair distances. Therefore the SAW-path migrates from the right side (Fig. 2a) to the left side of the IDT, where the distance of the finger-pairs is narrower (Fig. 2b) and the stream lines follow accordingly as indicated by the arrows.

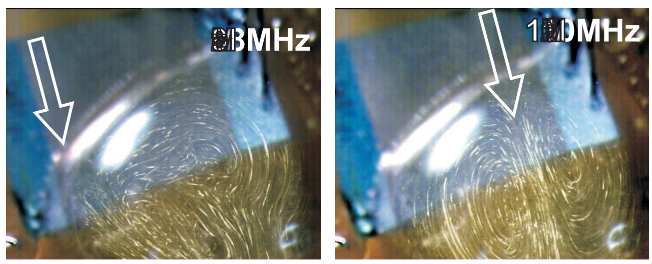

Fig. 2: Mixing experiment on a ZnO film with a tapered IDT at different frequencies.

This experiments clearly demonstrates that the fabricated ZnO films are a suitable substrate for SAW driven microfluidic devices.

References

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[2] T. Frommelt *et al.*, Phys. Rev. Lett. **100** (2007) 34502