Seed Layer Controlled Deposition of ZnO Films with a Tilted *c*-axis for Shear Mode Resonators

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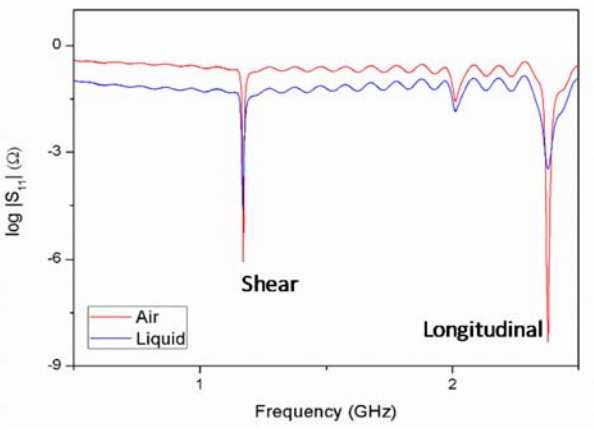
Bulk acoustic wave (BAW) resonators operating in longitudinal mode have been lately proposed for sensing applications. Thanks to its large piezoelectric coupling coefficient, simple deposition process, and low acoustic loss below 2 GHz, ZnO has been one of the preferred choices as the piezoelectric material in these devices. However, longitudinal modes are not suitable for biosensing applications in liquid media, since their Q factors decrease dramatically when operating in a viscous environment. This effect is significantly reduced if the resonators operate in the shear mode. Shear modes can be excited in ZnO-based resonators providing that the films exhibit grains with a *c*-axis tilted with respect to the surface normal. This is commonly achieved by off-axis sputter deposition on rough substrates since ZnO micro-crystals tend to grow normal to the surface whatever its topography, however to date homogeneity and reproducibility have not been achieved, limiting the usefulness of this technique. In this work, we have studied different structures and seed layers based on ZnO and AlN, to enhance the growth of tilted ZnO grains. A reproducible method to obtain good quality ZnO shear mode resonators is demonstrated for the first time.

ZnO films are off-axis deposited at room temperature in a HiTUS sputtering system on silicon substrates covered with Bragg mirrors composed alternating λ/4 layers of Mo and porous-SiO_2. Different structures are investigated, which include Mo/ZnO/Mo piezoelectric stacks directly deposited on the rough uppermost SiO_2 layer of the reflector, and ZnO films grown on 1000 Å-thick seed layers (ZnO or AlN) grown either on top of or below the Mo bottom electrode on polished Bragg mirrors. We have studied the sputtering conditions of the seed layers to optimize the formation of inclined facets that promote the growth of tilted ZnO grains.



Response of one of the test devices operating in air and in liquid

Regardless of the structure analyzed, all the resonators exhibited both shear and longitudinal resonances, with a frequency ratio between them (f_L/f_S) of around 2.02. The resonators were tested in air and liquid (see Fig.), showing a reduction of the Q factor of the shear mode of around 55% whereas the Q factor corresponding to the longitudinal dropped by more than 90%. When placing an AlN seed layer below the bottom electrode, therefore getting rid of a non-active layer in the resonant area, the resonators showed reproducible values of Q_{shear} over 200 and k^2_{shear} over 3%.