NUMERICAL MODEL OF ALN-BASED BULK ACOUSTIC HIGH-FREQUENCY RESONATORS

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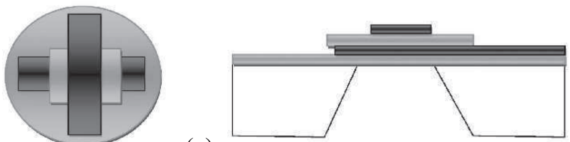
1. Introduction

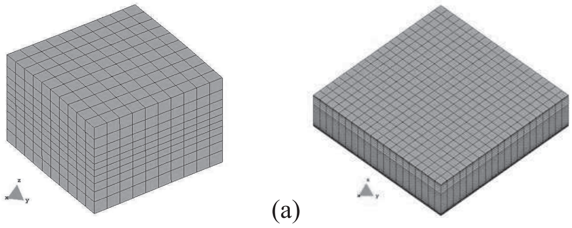
Thin film bulk acoustic resonators (TFBAR) have been adopted as alternatives to high-frequency SAW resonators, due to their inherent advantages, such as low insertion loss, low cost, high power handling capability and small size. TFBAR consists of a piezoelectric layer sandwiched between two metal electrodes. The electric field of the signal across the electrodes sets the piezoelectric film into vibration. For example, they are analysed in [1]. The crystallographic orientation of the piezoelectric film (c-$axis$ oriented normal to the film surface) is such that the device work in the fundamental thickness-extensional mode. Vibrations propagates in the thin Si_3N_4 membrane mechanically coupled to the bottom electrode. The resonance frequency is mainly determined by the thickness of the piezoelectric layer (several 100 nm) and they are suitable for mobile communication systems operating in the 1 to 10 GHz range.

2. Numerical model

The TFBARs are realized on a Si_3N_4 membrane, 200 nm thick, chemically etched on a Si substrate. The AlN film is grown on a metal (Al or Pt) bottom electrode previously sputtered on the Si_3N_4 diaphragm; then an Al or Pt metal top electrode is deposited on the AlN free surface, being the active area of the device in the range from 500x500 to 500x200 m^2.


(a) (b)
Fig. 1. The resonator, top view (a), cross-section (b)

The important modes for the resonator are the thickness modes. The thickness mode is evaluated on sample of AlN. The test example is prepared for 1000x1000x1000 nm cube (Fig. 2a) with the sliding boundary conditions along the 4 walls of the cube. The cube was discretized with 1000 8-nodes brick elements. We have obtained the thickness mode as mode 9 and the corresponding natural frequency 5.55GHz which matches the analytical solution for Masons resonator [2].


(a) (b)
Fig. 2. Test example (a), active part, thickness mode (b)

It is shown the analysis of the thickness mode of the following resonator Al(100nm)/ AlN(1000n Al(100nm)/ SiN(200nm) and the active area of 0.5x0.5 mm. The corresponding thickness mode is shown in Fig. 2b.

(a) (b)

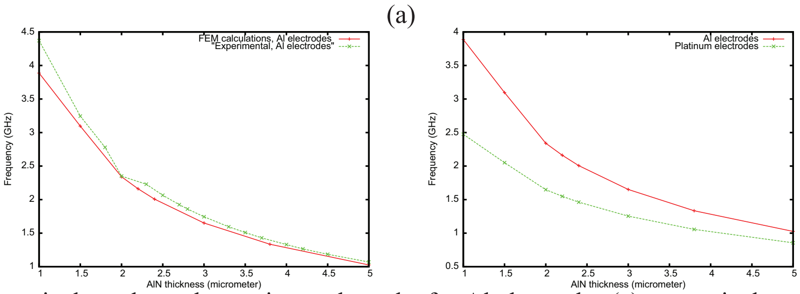
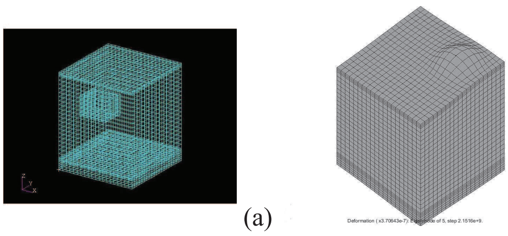


Fig. 3. Numerical results and experimental results for Al electrodes (a), numerical results for Al and Pt electrodes (b)

The thickness mode is identified as 4222 with the corresponding frequency of 3.889 GHz. Further, the analysis of different AlN resonators of the thicknesses between 1.0 and 5.0 μm is carried out and compared with the experiment. The results are shown in Fig. 3a It has been found that the difference between the experiment and the numerical results is in the range of 3% up 10%. The higher difference appears for thinner layers of AlN. The results of the analysis of the resonators with Pt electrodes is given in Fig. 3b.



(a) (b)

Fig. 4. Considered void (a), imperfect mode (b)

We consider an imperfect system with void, Fig. 4a. The system without void vibrates in thickness mode. This is in contrast to the imperfect one, Fig. 4b. First of all, the general mode is skewed and we can see a bulge on top. We may note, that the FEA is useful to capture the effect of tiny voids and impurities.

3. Acknowledgements

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4. References

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