

Session: FC2-A

**THIN FILM RESONATORS (FBAR)**

Chair: A. Kong

Northrop Grumman Corporation

FC2-A-1 511DE 1:30 p.m.

**MATERIALS PROPERTY DEPENDENCE OF THE  
EFFECTIVE ELECTROMECHANICAL COUPLING  
COEFFICIENT OF THIN FILM BULK ACOUSTIC WAVE  
RESONATORS**

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The input electric impedance for a three-layer (electrode/piezoelectric film/electrode) thin film bulk acoustic wave resonator is derived by one-dimensional transfer matrix method to describe the thin film resonator behavior, especially the effect of electrode layer on resonator properties. Based on the impedance spectra, the effective coupling coefficient of thin film resonator can be evaluated with respect to the resonator structure and thin film properties. The results for both AlN and PZT thin film resonators reveal that the mechanical Q factor of the thin film piezoelectric material has a significant effect on the effective coupling coefficient of the device. The effective coupling coefficient decreases with the increase of the mechanical quality factor Q. It is also dependent on the thickness and material properties of the electrode layers. For a specific electrode material, a maximum value can be obtained at an appropriate thickness ratio of electrode/piezoelectric layers.

*This research is supported by Pittsburgh Digital Greenhouse, a State funded consortium for system-on-a-chip (SOC) technology development.*

FC2-A-2 511DE 1:45 p.m.

**FABRICATION AND TESTING OF ALN FBARS WITH A  
SILICON ELECTRODE**

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**Introduction** Thin film bulk acoustic resonators (FBAR) have been examined for use in new generations of RF devices. A key novelty of the research presented here is that the aluminum nitride is deposited directly on the silicon substrate, which expands silicon integration possibilities. This abstract is a brief overview of the fabrication and testing of thickness-activated piezoelectric AlN membranes.

**Fabrication** The resonator is a circular shaped membrane with a diameter of 300  $\mu\text{m}$ . It consists of the AlN piezoelectric layer sandwiched between a top metal electrode and a layer of silicon that acts as both an elastic support layer and an electrode. Below the silicon is the air cavity. The AlN films were sputtered directly on <100> silicon wafers. The AlN films were patterned with a chlorine-based plasma etch, using sputtered  $\text{TiO}_2$  as the masking material. The air cavity is created by flipping the sample over and etching the silicon by switching between a  $\text{SF}_6$  etch plasma and  $\text{CF}_4$  protective polymere. The air cavities created had smooth sidewalls and floors, which are desirable to achieve a higher quality factor in an acoustic device.

**Results** The tested resonators were designed and fabricated to operate at acoustic wavelengths on the order of 1 micron. Resonance occurs when the wavelength,  $l$ , is an integer quotient of half of the device acoustic length,  $d$ . For a three-layered FBAR device with a single frequency source, the resonant frequencies become:  $f_o = n/2(d_1/v_1 + d_2/v_2 + d_3/v_3)^{-1}$  where  $v$  is the acoustic velocity and the indexes 1,2,3 represent the top electrode, piezoelectric film and silicon membrane respectively. For material properties and dimensions of experimental devices (AlN 1.7  $\mu\text{m}$ , Si 11  $\mu\text{m}$ , Au 100 nm) the fundamental frequency ( $n=1$ ) was calculated to be 325.6 MHz. Reflection coefficients for the resonators were measured using a HP VNA 8722D at atmospheric pressure. The over-moded resonances occurring at the 5th 9th harmonics can be observed from the scattering parameter data. The experimental primary mode frequency is 340.5 MHz. Discrepancies between theoretical and experimental resonators can be explained by fabrication variations in resonator thickness.

**Conclusion** Thickness actuated acoustic devices were fabricated using standard MEMS fabrication techniques. Silicon serves as both an acoustic transmission line and bottom electrode. These devices behave according to predictive acoustic model, which gives a platform to further analytically engineer device performance. Work is currently being done to reduce the noise and increase the quality of the devices along with incorporating substrate-decoupling structures. Our thanks to Hongtao Xu for help with the network analyzer and RF probe station.

**FC2-A-3 511DE 2:00 p.m.**

### **ELECTRICALLY TUNABLE AND SWITCHABLE FILM BULK ACOUSTIC RESONATOR**

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Phase noise of a voltage-controlled oscillator (VCO) based film bulk acoustic resonator (FBAR) and varactors is dominated by the relatively high  $1/f$  noise of the varactors. A VCO can be formed without varactors, using the fact that FBAR frequency can be tuned by varying DC bias between the top electrode and the bottom electrode through piezoelectric stiffening effect in the piezoelectric film of an FBAR. But this approach offers typically only about tens of ppm/V.