Finite Element Analysis of Temperature and Viscosity Effects on Resonances in Thin-film Bulk Acoustic Wave Resonators

G. Rughoobur[1], M. DeMiguel-Ramos[2], L. García-Gancedo[1], T. Mirea[2], J. Olivares[2], M. Clement[2], E. Iborra[2], W. I. Milne[1], and A. J. Flewitt[1*]

1. University of Cambridge, Electrical Engineering Division, 9 JJ Thomson Avenue, Cambridge, CB3 0FA, UK;
2. Universidad Politécnica de Madrid, GMME-CEMDATIC-ETSIT, Spain.

Introduction: The shear mode of film bulk acoustic resonators (FBARs) is preferred to the longitudinal mode owing to its lower acoustic losses in a liquid [1]. However in addition to mass loading, the resonance is also affected by temperature and liquid viscosity [2]. These two parameters can either be sensed or compensated using a layer of silicon dioxide, which has a unique temperature coefficient of elasticity [3]. In this work, we aim to characterise the effect of temperature and viscosity on all the individual resonances in a four-resonance-mode zinc oxide FBARs for biosensors.

Computational Methods: A quasi-shear wave was obtained by rotating c-axis of the piezoelectric layer 30° to the surface normal electric field. The thermal coefficients of the stiffness matrix c^E, for ZnO were added. Using the MEMs module, a parametric sweep from 0 to 100 ^oC was set up to determine the resonant frequency of each mode at each temperature.

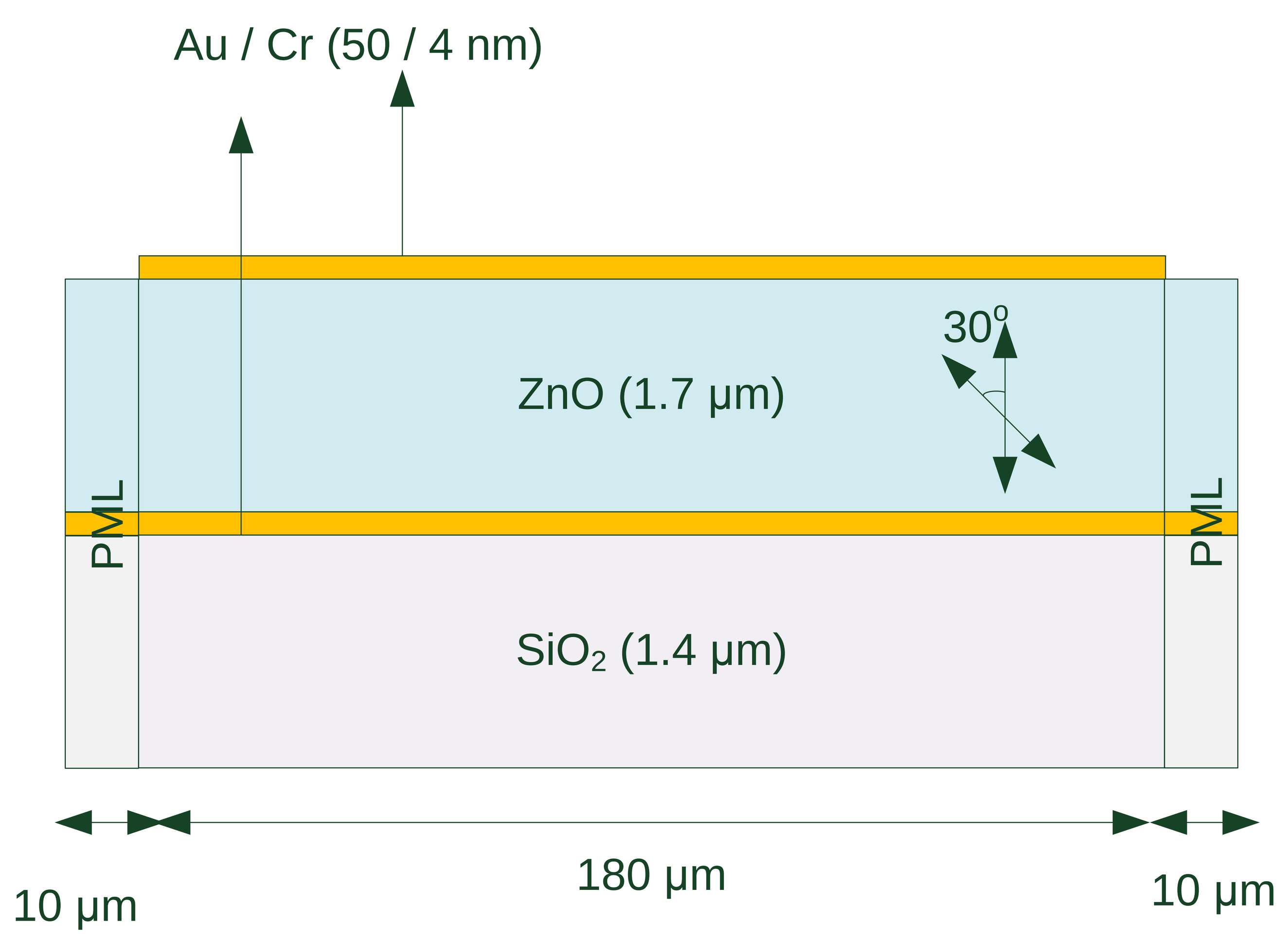

Figure 1. Four resonance mode FBAR structure

Results: The return loss parameter in Figure 2 shows four resonances as expected with frequencies 517 MHz, 887 MHz, 951MHz and 1.61 GHz.

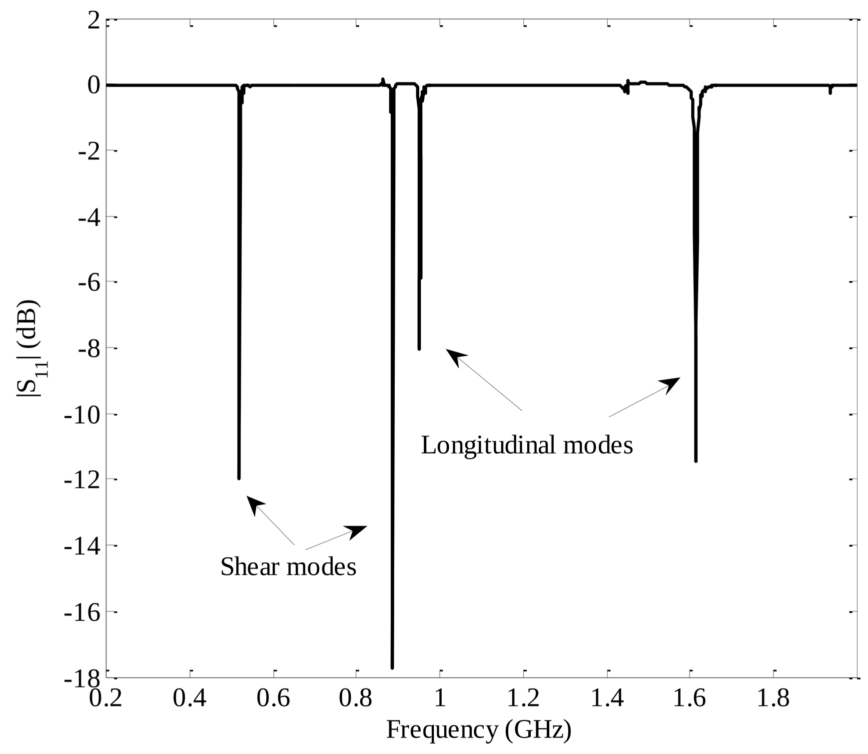

Figure 2. Frequency spectrum of the 4 resonances

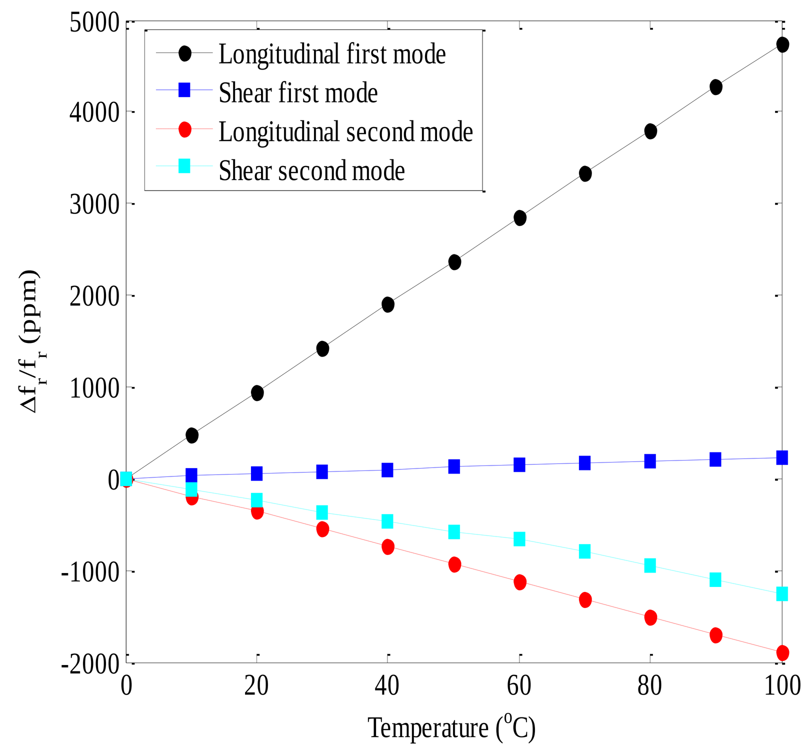

Figure 3. Resonant frequency shifts of each mode

	Longitudinal wave	Shear wave
1st mode TCF (ppm/^oC)	+47.9	+2.2
2nd mode TCF (ppm/^oC)	-19.0	-12.7

Table 1. Extracted TCFs of each resonant mode

Conclusions: We conclude that shear waves are less sensitive to temperature. Our future work will focus on the viscosity effects of liquids through the thin-film damping effect at the electrode-fluid interface

References:

1. Gunilla Wingqvist et al., AlN Thin Film Electroacoustic Resonator for Biosensor Applications, in IEEE Sensors, 2005., Institute of Electrical and Electronics Engineers, pp. 492–495 (2005).

2. Luis García-Gancedo et al., Dual-mode thin film bulk acoustic wave resonators for parallel sensing of temperature and mass loading, Biosensors and Bioelectronics, vol. 38, no. 1, pp. 369 –374 (2012).

3. K. M. Lakin, Thin film resonators and filters, in Ultrasonics Symposium, 1999. Proceedings. 1999 IEEE, vol. 2, pp. 895–906 (1999)

Excerpt from the Proceedings of the 2014 COMSOL Conference in Cambridge