

Accepted Manuscript

Influence of Electrodes on the Effective Electromechanical Coupling Coefficient Distributions of High-Overtone Bulk Acoustic Resonator

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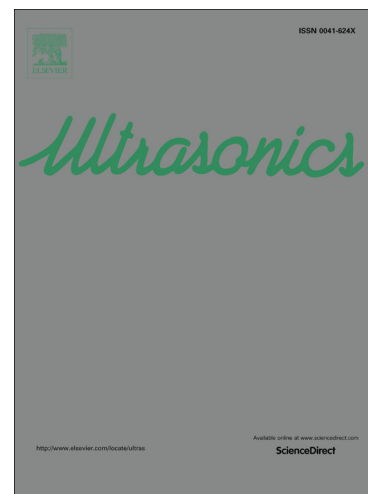
PII: S0041-624X(14)00299-6
DOI: <http://dx.doi.org/10.1016/j.ultras.2014.10.014>
Reference: ULTRAS 4944

To appear in: *Ultrasonics*

Received Date: 22 May 2014
Revised Date: 9 October 2014
Accepted Date: 13 October 2014

Please cite this article as: M. Liu, J. Li, C. Wang, J. Li, J. Ma, Influence of Electrodes on the Effective Electromechanical Coupling Coefficient Distributions of High-Overtone Bulk Acoustic Resonator, *Ultrasonics* (2014), doi: <http://dx.doi.org/10.1016/j.ultras.2014.10.014>

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1 Influence of Electrodes on the Effective Electromechanical Coupling
2 Coefficient Distributions of High-Overtone Bulk Acoustic Resonator

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5 Abstract

6 In this paper, the influence of the electrodes on effective electromechanical
7 coupling coefficient k_{eff}^2 distribution of high-overtone bulk acoustic resonators
8 (HBAR) is investigated using the four-layer thickness extension mode composite
9 resonator model. The k_{eff}^2 distributions and the spacing of the parallel resonance
10 frequency (SPRF) distributions are calculated for HBARs with different electrode and
11 substrate materials. The frequency of first peak f_M in k_{eff}^2 distribution curve is close to
12 the frequency of first valley in SPRF distribution curve, which has the maximum
13 deviation of about 20%. The f_M ratio of $\text{Al}_{0.1\mu\text{m}}\text{-ZnO}_{0.6\mu\text{m}}\text{-Au}_{0.1\mu\text{m}}\text{-Sapphire}_{400\mu\text{m}}$ to
14 $\text{Au}_{0.1\mu\text{m}}\text{-ZnO}_{0.6\mu\text{m}}\text{-Al}_{0.1\mu\text{m}}\text{-Sapphire}_{400\mu\text{m}}$ is 1.91 which indicated that the k_{eff}^2
15 distribution of HBAR is affected significantly by different electrode materials. We
16 discuss for the first time the influence of the acoustic impedance ratio of the
17 electrodes to substrate to the k_{eff}^2 distribution, which is independent on the thickness
18 ratio of the electrodes to piezoelectric film. It is found that for the pure-hard and
19 pure-soft substrate HBARs, the resonator frequency of piezoelectric sandwich
20 structure can be used to estimate the resonator frequency f_M of the first peak of k_{eff}^2
21 curve, which has the maximum deviation of 7%. The fabricated HBAR(I)
22 Al-ZnO-Al-Sapphire and HBAR(II) Al-ZnO-Au-Sapphire shows identical outlines of
23 k_{eff}^2 and SPRF curves with the simulations, which have f_M s of about 2GHz and 3GHz.
24 The k_t^2 of ZnO films are extracted from the first peak of the k_{eff}^2 curve. The ZnO film
25 deposited on Al and Au electrodes have k_t^2 of 0.0597 and 0.0615, respectively.

26 Keywords: HBAR; effective electromechanical coupling coefficient; electrodes; ZnO
27 film

28 I. Introduction

29 Bulk acoustic wave resonators with piezoelectric films including the film bulk
30 acoustic resonator (FBAR) and high-overtone bulk acoustic resonator (HBAR) have
31 been widely explored for various applications such as frequency control^[1-7] and
32 sensors^[8,9]. They have a much higher operating frequency (usually at GHz) than the
33 traditional quartz crystal resonator. HBAR structure consists of a piezoelectric
34 transducer and a crystal substrate with low acoustic attenuation. The substrate
35 thickness is about a few hundred times larger than the piezoelectric film, and the
36 resonator is designed to operate on very high overtone about a few tens or a few
37 hundreds. Comparing the coaxial ceramic resonators and FBARs having Q of about
38 150 and 1000 at GHz, HBARs demonstrate high Q greater than 10 000, which comes
39 from the fact that most energy is stored in the substrate with low acoustic loss.

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