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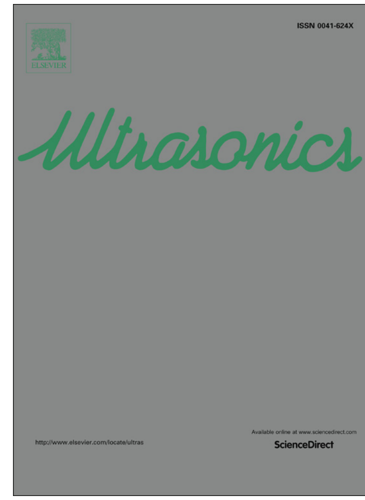

Influence of Electrodes on the Effective Electromechanical Coupling Coefficient Distributions of High-Overtone Bulk Acoustic Resonator

Mengwei Liu, Jian Li, Chenghao Wang, Junhong Li, Jun Ma

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

Mengwei Liu, Jian Li, Chenghao Wang, Junhong Li, Jun Ma

Institute of Acoustics, Chinese Academy of Sciences, Beijing, 100190

Abstract

In this paper, the influence of the electrodes on effective electromechanical coupling coefficient k^2_{eff} distribution of high-overtone bulk acoustic resonators (HBAR) is investigated using the four-layer thickness extension mode composite resonator model. The k^2_{eff} distributions and the spacing of the parallel resonance frequency (SPRF) distributions are calculated for HBARs with different electrode and substrate materials. The frequency of first peak f_M in k^2_{eff} distribution curve is close to the frequency of first valley in SPRF distribution curve, which has the maximum deviation of about 20%. The f_M ratio of $Al_{0.1um}$-$ZnO_{0.6um}$-$Au_{0.1um}$-$Sapphire_{400um}$ to $Au_{0.1um}$-$ZnO_{0.6um}$-$Al_{0.1um}$-$Sapphire_{400um}$ is 1.91 which indicated that the k^2_{eff} distribution of HBAR is affected significantly by different electrode materials. We discuss for the first time the influence of the acoustic impedance ratio of the electrodes to substrate to the k^2_{eff} distribution, which is independent on the thickness ratio of the electrodes to piezoelectric film. It is found that for the pure-hard and pure-soft substrate HBARs, the resonator frequency of piezoelectric sandwich structure can be used to estimate the resonator frequency f_M of the first peak of k^2_{eff} curve, which has the maximum deviation of 7%. The fabricated HBAR(I) Al-ZnO-Al-Sapphire and HBAR(II) Al-ZnO-Au-Sapphire shows identical outlines of k^2_{eff} and SPRF curves with the simulations, which have f_Ms of about 2GHz and 3GHz. The k^2_t of ZnO films are extracted from the first peak of the k^2_{eff} curve. The ZnO film deposited on Al and Au electrodes have k^2_t of 0.0597 and 0.0615, respectively.

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

I. Introduction

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