DEFINITION OF ELECTROMECHANICAL COUPLING COEFFICIENT FOR BULK ACOUSTIC WAVES FROM ENERGY CONSIDERATION

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Till recently it was considered that velocity of piezoactive acoustic waves propagating in piezoelectric materials decreases at total or partial switching off of piezoeffect. However, recently there appear publications showing that there are such materials and crystallographic orientations for which the velocity of bulk as well as surface acoustic waves in presence of piezoeffect \( v_{pz} \) may be less than the velocity of the same waves at total or partial switching off piezoeffect \( v \). It is also well known that measure of piezoactivity of acoustic waves is the square of electromechanical coupling coefficient that is most frequently defined as

\[
K^2 = \frac{(v_{pz}^2 - v^2)}{v_{pz}^2} \quad \text{or as} \quad K^2 \approx \frac{2(v_{pz} - v)}{v_{pz}} \quad \text{if} \quad v_{pz} - v \ll v_{pz}. 
\]

But for that situations when \( v_{pz} < v \) the aforementioned expression loses sense because it shows the possibility of the negative value of \( K^2 \). Such cases lead to necessity of more precise definition of this coefficient and the most correct way is energy consideration. But there are no unambiguous approaches to definition of electromechanical coupling coefficient from this consideration. At present there exist at least two generally used definitions:

\[
K^2_1 = \frac{W_{el}}{W_{el} + W_{mech}} \quad \text{and} \quad K^2_2 = \frac{W_{elmech}}{W_{el} \times W_{mech}}, \quad \text{where} \quad W_{elmech}, W_{el}, \text{and} \ W_{mech} \text{are densities of electromechanical, electrical, and mechanical energies of acoustic waves.} 
\]

In this paper the coefficients \( K_1, K_2, \) and \( K \) have been calculated for all types of bulk acoustic waves propagating in crystals of quartz, lithium tantalate, lithium niobate, and potassium niobate for various propagation directions in the main crystallographic cuts. It has been shown that for weak piezoelectric materials all three definitions give practically the same values for all propagation directions. As for strong piezoelectric materials, in general case the values of these coefficients are different. At that the values of coefficients \( K_1 \) and \( K \) are most close each other and they coincide for a number of crystallographic orientations. It has been also shown that for every type of bulk acoustic wave for arbitrary crystallographic orientation the density of electromechanical energy is identical with density of electric energy.

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CALCULATION OF TEMPERATURE DEPENDENCY OF ACOUSTIC PROPERTIES OF DIATOMIC GASES USING SPECTROSCOPIC DATA

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A problem that arises in most fields of experimental acoustics is the temperature dependency of physical properties of solids, liquids, and gases. The obvious way to avoid this problem is to keep the temperature constant during an experiment. On the other hand, if the thermal properties of the specimen examined are known, this is no longer a problem if the temperature is monitored. This study focused on the temperature dependency of the specific heat. For commonly used gases such as Oxygen, Nitrogen and Air tabulated data are available. However, for other gases tabulated data might be hard to find. It is therefore of interest to either measure or calculate thermal properties. The former is a time consuming process so the later is a more attractive solution. In this paper, spectroscopic data have been used to calculate the thermal dependency of the specific heat for diatomic molecules. Spectroscopic data reveals information about the rotational and vibrational energy levels of a molecule. It is also possible to extract information about the number of molecules populating each level. We have assumed that the rotational levels within the molecule are fully developed and that only the vibrational states of the molecule contributes to the specific heat. This assumption is correct for most diatomic molecules for high temperatures (above \(\sim 200\text{K}\)). The internal energy of the gases have been calculated by assuming that the population of the vibrational energy levels follow a Boltzmann distribution. The specific heat is the rate of change of energy with temperature and is straightforward to calculate once the internal energy is known. Diatomic molecules were used, due to their simplicity. Oxygen and Nitrogen was chosen as reference gases and the presented method gives excellent agreement with tabulated values. It is possible to extend the method to more complicated molecules. With this method the contribution to the specific heat from each energy level of the molecule is revealed. This information is particularly useful in theoretical calculations of acoustic relaxation.

SIMULATION OF THE TRANSLATIONAL MOTION OF SINGLE AND MANY BUBBLES IN AN ULTRASONIC FIELD

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Bubbles in ultrasonic fields experience forces that lead to translational motion. Primary and secondary Bjerknes forces are often dominant in typical applications of cavitation, like ultrasonic cleaning baths. Because of nonlinear radial oscillations, accompanied by rectified diffusion, surface oscillations, and merging and splitting events, bubble translation in real systems can turn out to be quite complex. In the case of many bubbles, one might encounter an inherently sensitive (chaotic) system. To simulate experimentally observed bubble motion, a model is employed that treats every bubble as a particle under inclusion of the above effects with one-to-one real world parameters. Different experimental set-ups are considered. Among them are single translating bubbles in a standing pressure wave (bubbles seeded by electrolysis or a femtosecond laser pulse), many bubbles in a filamentary streamer structure, many bubbles in a double layer structure, and many bubbles below a sonotrode tip. The pressure field distributions are determined by hydrophone measurements or by FEM calculations. The results show that trajectories of single bubbles and interaction of two bubbles are simulated quite accurately. In the case of many bubbles, experimental methods give positions and velocities, but still not sufficient bubble size data for a one-to-one simulation. However, on the basis of accessible data, a reasonable quantitative agreement of simulations and experiment is achieved for a filamentary structure. For the more complex bubble patterns where no experimental bubble trajectories are available yet, a qualitative reproduction is accomplished.

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MODAL EXPANSION ANALYSES OF SECOND-HARMONIC GENERATION OF LAMB MODES IN LAYERED PLANAR STRUCTURES

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This work develops an effective approach for studying generation of the second harmonics of Lamb modes (LMs) in layered planar structures. Under second-order perturbation, there are second-order bulk and surface/interface driving sources in layered planar structures as a primary LM propagates. The driving sources can be thought of as forcing functions of a series of double frequency Lamb modes (DFLMs). The total second-harmonic fields consist of a summation of DFLMs in the stress-free layered structures. If the phase velocity of a DFLM component equals that of the primary LM, the amplitude of field of the corresponding DFLM component grows linearly with propagation distance. For the cases where the phase velocities of DFLM components are not equal to that of the primary LM, the amplitudes of fields of the corresponding DFLMs oscillate with sine function of propagation distance. For the practical measurement of second-harmonic signals, the DFLM component with the
same phase velocity as that of the primary LM plays a dominant role. The other DFLM components are less important for second-harmonic measurement because, in general, the effective area of detection transducers is finite, and the spatial average of sine function of propagation distance is trivial. For the expansion coefficient of a DFLM component, besides the DFLM phase velocity, it is affected by both bulk driving forces of double the fundamental frequency in each solid layer and interface/surface traction stress tensors of double the fundamental frequency, which are arising form the nonlinearities of materials composing layered structures. Numerical simulations show that the forcing function associated with the soft adhesive layer of a layered planar structure plays a dominant role in the process of second-harmonic generation. Thus the characteristic of soft adhesive layer may be effectively figured by the second harmonics.

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IN-SITU STUDY OF ACOUSTOMIGRATION BY SCANNING ACOUSTIC FORCE MICROSCOPY

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Stress induced material transport in surface acoustic wave devices, so-called acoustomigration, is a prominent failure mechanism, especially in high-power applications. We used Scanning Acoustic Force Microscopy (SAFM) to study acoustomigration of metal structures in-situ, i.e. during the high-power loading of the device. SAFM allows for the simultaneous measurement of the acoustic wave field and the topography with submicron lateral resolution. We will present acoustic wave field and topographic image sequences giving a clear insight into the nature of the film damage on a submicron scale. The 900 MHz test structures were fabricated on 39°YX-LiTaO₃ incorporating 420 nm thick Al electrodes. By correlating the acoustic wave field mapping and the local changes in the topography point-by-point, already the initial stages of what leads to acoustomigration can be visualized.