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Surface Acoustic Waves in Z-Sections of Piezoelectric Monocrystals of Hexagonal Syngony

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Abstract—A new statement of the problem on the calculation of kinematic and dynamic characteristics of surface acoustic waves in piezoelectric monocrystals is proposed. A procedure for solving the above problem is also proposed with due regard for the existence of electric field scattering on the crystal surface not covered with electrodes and the vortex component of electric field in the general case.
The procedure for mathematical description of surface acoustic waves at zero approximation is shown using an example of Z-section of monocrystals of hexagonal syngony. The system of eigenfunctions is built and eigenvalues are determined of the uniform boundary problem for the case of plain deformed state. The general solutions obtained for a particular case of isotropy of elastic properties of deformable solid body are reduced to the generally known definitions of the Rayleigh surface waves. The surface acoustic waves in Z-sections of ZnO and CdS monocrystals similar to the Rayleigh wave in isotropic elastic half-space are shown to exist in a narrow near-surface region, while taking into account the spread of electromagnetic field outside the limits of monocrystal on surfaces that are not covered with electrodes, and the vortex part of the electric field component made it possible to establish the fact that the vertical component of the shift vector of material particles had the maximum value at the depth of (0.15–0.2)λ rather than on the very surface of crystal. A similar peculiarity of Rayleigh waves is typical also for isotropic samples. The presence of local extremum (within 7%) is typical for the vertical component of shift vector in near-surface region having thickness 0.25λ. While penetrating inside the piezoelectric at the depth of more than 2.5 wavelength, the shift levels of material particles decrease by more than one order of magnitude.

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INTRODUCTION

Devices based on surface acoustic waves (SAW) find wide use in a series of technical applications including electronics and telecommunications.

SAWs are employed in constructing sensors of physical quantities [1, 2]. The use of SAW based resonators makes it possible to create SAW sensors of chemical substances [3], biochemical [4] and gas sensors [5]. For example, SAWs use used for constructing humidity sensors employing ZnO covered with a coat of graphene oxide having thickness 200 nm [6].

The mechanisms responsible for interaction of light and acoustic modes in optical waveguides [7] and the problems of phonon-electron interaction, including those at quantum level [8] are of much interest among researchers. In case of using SAWs in waveguide light modulators [7], the thickness of layer where SAWs are propagating often can amount to about hundreds of nanometers.

The description of results of investigations in the field of phonon interactions in quantum structures [8, 9], plasmon-phonon interaction [10] and other directions of modern SAW application can be also found in overview papers [7, 11].

On the other hand, a large number of electromechanical effects occurring during the operation of SAW-based devices and the comprehension of their impact on the general operability of the device are of crucial significance at the stage of experimental setup, designing and development of SAW devices. There are known the mathematical simulation methods based on using the finite elements, Green's function, and coupled modes that are widely utilized for the analysis and optimization of designs of SAW devices [12, 13].

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

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