ANNOTATION

of thesis presented for the degree of Doctor of Philosophy (PhD) in the specialty 6D060400 – Physics

NURKHAT K. ZHAKIEV

Study the electromagnetic and acoustic wave fields in anisotropic piezoelectric media using matricant method

Topicality of the Work.

Theoretical study the propagation processes of elastic waves in anisotropic media with different physical properties, such as the piezoelectric effect, and others, is one of the fundamental problems of the acoustics waves in solids, in particular acoustoelectronics. This topic included into priority researches of the Program Forced Industrial-Innovative Development of Kazakhstan for 2010-2014 years.

Various physical effects associated with the propagation and interaction of elastic waves in condensed media are found wide application in devices of acoustoelectronics, acousto-optic, wireless communication systems, ultrasonic defectoscopy, acoustic microscopy, and in development of sensors and transducers.

Existence the direct and inverse piezoelectric effects in dielectric media leads to the coupled and mutual generation of elastic and electromagnetic waves. Coupledness piezoelastic waves are complicated this problem, so approximate methods are used. In the quasistatic approximation impossible to describe the mutual transformation of elastic and electromagnetic wave energy. Therefore, study the coupled acustoelectromagnetic wave fields in anisotropic piezoelectric media using improved analytical aproaches to the full electromagnetic formulation should be considered as one of the complicated, but relevance problems of acoustoelectronics.

In present work - in linear elasticity theory framework and by representation the solutions as a plane waves the coupled acustoelectromagnetic waves in the cases infinite and half-space piezoelectric anisotropic media are investigated. Theoretical studies were carried out on the basis of a full system of Maxwell's equations with the equation of motion an elastic anisotropic media, as the most rigorous description.

Part of this dissertation was performed in grant funding for research on the 2012-2014 years: "Propagation of coupled elastic and electromagnetic waves in media of hexagonal, tetragonal, rhombic and monoclinic syngony" ID number: 0112RK02379 principal investigator by S.K. Tleukenov.

The **aim** of the work on theoretical research of the coupled acoustic and electromagnetic wave fields in the infinite and semi-infinite tetragonal and orthorhombic piezoelectric media using the full Maxwell's equations using matricant method.

The **object** of the study are the coupled elastic and electromagnetic waves in the cases infinite and semi-infinite tetragonal and orthorhombic piezoelectric media.

Research method – the analytical matricant method, had been developed by Professor S.K. Tleukenov. Method is based on the building the structure of the fundamental solution the initial of differential equations system. Internal symmetry in coefficients matrix allows to obtain the all elements of matricant for homogeneous media in explicit analytic form. One of the mathematical methods of studying the fundamental solution of ordinary differential equations system with variable coefficients.

Scientific novelty consists from following research results:

- The coefficients of matrices for wave propagation in tetragonal and orthorhombic piezoelectric media in the bulk and two-dimensional cases beyond the quasistatic approximation are obtained. The coefficients matrices was analysed. The analytical form of the wave vector in a homogeneous tetragonal and orthorhombic piezoelectric media are obtained; The slowness and phase velocities curves for coupled electroelastic waves are plotted.
- A theoretical and experimental study the drift (flow) angles between the phase and group velocity. For the first time, an explicit analytical expression of drift angle for the orthorhombic piezoelectrics are obtained. The group velocities, the phonon focusing factor of elastic energy are calculated.
- The problem of the reflection-refraction of electromagnetic waves at the liquid-piezoelectric boundaries are analytically solved and numerical analysed. It was shown that the electromagnetic wave excites elastic waves and calculated the energy transformation ratios depending on incidence angle.
- The acoustic wave fields for the reflection and refraction problem of the shear-horizontal wave at the boundary between insulator and piezoelectric media are studied. It was shown that in high anisotropic and strong piezoelectrics in the concave area of the slowness curve the birefringence of acoustoelectrical waves in piezocrystals with polarization unchanged is observed, it was predicted by M.K. Balakirev and I.A. Gilinsky.
- The existence conditions and the characteristics of the Bleustein-Gulyaev surface acoustic waves, such as the speed, the decay factor for the piezoelectric half-space of orthorhombic and tetragonal symmetry in metalized and free boundaries cases are analytically obtained.
- Firstly the decay factor for surface electromagnetic waves in the media and in the vacuum was obtained after use the full Maxwell's equations system and equations of motion.

The provisions for the defense.

- The obtained matrix of coefficients for piezoelectric media beyond the quasi-static approximation show the relationship and mutual transformation of energy between waves of different polarization and physical nature. Power flow angle is determined by only the piezoelectric parameters of the media. Matriciant method allows to calculate the group velocity, the phonon focusing factor of elastic energy;

- Using full acoustoelectromagnetic theory to the problem of the reflection-refraction of electromagnetic waves at the boundary between liquid and piezoelectric able to describe the excited elastic waves;

- In the concave area of the slowness curve of the superstrong piezoelectric (potassium niobate) the birefringence of acoustoelectric waves with unchanged polarization is possible.

- conditions for the existence of the Bleustein -Gulyaev surface acoustic waves for metallized and free boundaries allow to determine the wave characteristics (speed, rate of decrease, electromechanical factor) in analytical form. The decay factor of the electromagnetic waves in piezohalf-space and in the vacuum for Bleustein-Gulyaev waves impossible obtaine in the quasi-static approach framework.

The structure and scope of the dissertation. The total volume of the dissertation 102 pages in computer text, contains 39 figures, 6 tables. The dissertation consists of an introduction, four chapters, conclusion, list of cited sources 129 and one application.

Approbation of the work and publications. The main results of the thesis were published in 14 publication, there are: 4 articles in the journals, recommended by Committee of control of education of Ministry of Education and Science of Kazakhstan, 1 in the journals reviewed by the Scopus database, and one patent №1747, IS0013171 from 15.09.2014.

Theoretical and practical significance.

In this work the effectiveness of the matricant method for solving the problems of acoustoelectronics and acousto-optics by using full dynamical theory are shown. The results are importance for the development of the theoretical foundations the acoustic of piezoelectric crystals. The results can be used for calculations in the various devices designing in acoustoelectronic and acoustooptic.