Dispersive Rayleigh Type Waves in Layered Systems Consisting of Piezoelectric Crystals Bismuth Silicate and Bismuth Germanate

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Summary
The lowest-order modes of the dispersive six-partial waves of Rayleigh type (RTW6) have been numerically obtained for two layered systems consisting of a layer on a substrate in [100] propagation direction of (001)-cut for both cubic crystals of class 23. Dispersion relations are shown for both a layer of $\mathrm{Bi_{12}SiO_{20}}$ on a substrate of $\mathrm{Bi_{12}GeO_{20}}$ and vice versa. Dispersion relations show one mode in each case with clear maximum and minimum, at which it is analytically shown that the group velocity is equal to the phase velocity. It was concluded that in corresponding highly-symmetric cases, the obtained "non- dispersive" six-partial surface waves in the treated layered systems are a new non-dispersive type, termed Rayleigh-Zakharenko type (RZTW6) "non-dispersive" six-partial surface waves. These can exist in layered systems consisting of a layer on a substrate. The possibility of the existence in layered systems of "non-dispersive" waves of both the nine-partial Zakharenko type (ZTW9) for centrosymmetrical crystals, and the thirteen-partial Zakharenko type waves (ZTW13) for non-centrosymmetrical crystals is suggested. In addition, it is shown that dependence of the phase velocity $V_{ph} = V_{ph}(kh_1, kh_2, \ldots, kh_m)$ in a multi-layered system can be reduced to dependence $V_{ph} = V_{ph}(kh)$ for a layered system consisting of a layer on a substrate. Thus, both systems can be studied in the same way.

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1. Introduction

Surface acoustic waves (SAW) have very important applications for Acoustoelectronics devices due to their unique properties. Up to the present time, surface Rayleigh waves are widely used in filters, delay lines, etc. Initially, Lord W. Rayleigh [1] analytically discovered that SAW with polarization in the sagittal plane can propagate in an isotropic bulk medium along the surface of the medium, damping with depth of the medium. Later, SAW with the same polarization were numerically studied in isotropic media and in anisotropic, piezoelectric monocrystals in [2]. This reference also shows both the piezoelectric four-partial waves of Rayleigh type (RTW4) and the non-piezoelectric two-partial waves of Rayleigh type (RTW2). These waves are "non-dispersive" waves. The term "non-dispersive" is introduced in order to distinguish these waves, for which the phase velocity V_{ph} is equal to the group velocity V_g ($V_{ph} = V_g \neq 0$), from dispersive waves ($V_g > V_{ph}$ or $V_g < V_{ph}$). For an isotropic medium there is no dependence of V_{ph} on propagation direction.

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With waveguides consisting of a thin film on a substrate, the waves of Rayleigh type are dispersive waves with the phase velocity dependent on the non-dimensional value of kh, where k is the wavenumber in the direction of wave propagation, and h is the layer thickness. Figure 1 shows the layered system. It is more complicated to analytically study layered systems, where, in the simplest case, six-partial RTW6-waves propagate [3]. Also, there are the so-called highly-symmetric propagation directions, where the dispersive RTW-waves consist of piezoelectric ten-partial RTW10-waves. Details about the directions of both the dispersive RTW6-waves and the dispersive RTW10-waves in layered systems are given in [4] for thirty classes of crystal symmetry.

Nowadays there is much theoretical and experimental published work concerning the study of dispersive RTW-waves in layered systems consisting of isotropic, anisotropic, piezoelectric materials. See, for example, references [5, 6, 7, 8, 9, 10, 11]. P. Schnitzler [5] has theoretically studied wave propagation in a CdS-layer of class 6mm on a germanium substrate, neglecting the piezoelectric effect. The same case of transversal isotropy, but with the CdS-layer on a sapphire substrate, has been calculated by D. F. Loftus [6]. R. V. Schmidt and F. W. Voltmer [7] have calculated the dispersion relations for a layered sys-