Surface waves in strongly anisotropic HTSC structures

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We analyze shear surface waves localized near a monoatomic layer adsorbed on the free surface of a strongly anisotropic layered lattice crystal. Both the long-wavelength approximation and a discrete lattice model are studied. The considered structure is characteristic of many HTSC-crystals, YbaCuO in particular. It is shown that in some cases a noncentral interatomic interaction results in the appearance of surface shear waves of a special type with one or two termination points and a damping parameter that is a nonmonotonic function of the two-dimensional wave vector. We also study a resonant wave transmission effect the appearance of which is due to the weak coupling of the defect to the host lattice.

A characteristic feature of HTSC crystal structures is the presence of a weak interlayer bond which strongly influences various types of excitations. It is unquestionably of interest to study the surface acoustic waves in such compounds. It is known that Rayleigh surface waves are modified in strongly anisotropies systems: these waves become retarded and deeply penetrating [1]. These properties have technological applications. Together with Rayleigh-type surface waves, horizontally polarized purely shear surface waves (SH-waves) are also modified. In the long-wavelength limit the penetration depth of SH-waves (in contrast to Rayleigh waves) is much greater than the wavelength [2], [3]. The fact that single-component SH-waves are structurally simpler than two-component Rayleigh waves can be used in experimental research.

In this report we present the results of theoretical research of basic characteristics of SH-waves in the presence of strong anisotropy. We also consider the effect of resonant wave transmission through an interface between two contacting layered crystals.

To find out general properties of surface waves it is convenient to study the long-wavelength limit first. The considered strongly anisotropic structure possesses two distinct parameters: the constant of intralayer interaction (the biggest parameter) and the constant of weak interlayer interaction (the smallest one). The typical order of value of relation of these two parameters is 0.1. Thus, to allow for the influence of weak interlayer interaction on the wave propagation along the atomic planes, the fourth power of wave vector must also be taken into account in the terms of lattice dynamics equations containing as a factor the constant of the strongest interaction in the lattice. Such an approximation makes it possible to describe correctly the long-wavelength dynamics of the crystal and to obtain peculiar solutions having eigenfrequencies outside (surface states) and inside (quasi-surface states) the continuous spectrum of the ideal lattice. The dispersion curves corresponding to these solutions can have the so-called termination points. For a more general case, when the lattice dynamics equations are solved without approximation, it is shown that specific deeply penetrating waves, having two termination points, can appear due to the influence of noncentral interatomic interaction.

If a planar defect lies in the interior of a crystal, i.e. is an interface between two contacting media, it can substantially influence its dynamic, thermodynamic, and kinetic characteristics. To study such an influence it is necessary to elucidate the features of the interaction of phonons with a planar defect. The study of resonance effects in the scattering of acoustic vibrations on a defect and problems of formation of bound states related to them are of considerable interest, as are questions of the formation of coupled vibrational states, since such effects can give rise to features in the kinetic characteristics of intercrystalline interfaces, as have been observed in experiments [4]. The description of resonance phenomena in highly anisotropic crystals in the framework of the macroscopic theory encounters significant difficulties, since the domain of applicability of such a theory for highly anisotropic systems is substantially limited [1]. This raises the question of studying such effects in highly anisotropic compounds with the use of lattice models.

We use the methods of lattice dynamics to consider the scattering of acoustic waves on an impurity monolayer lying in the interior of a crystal. It is shown that the presence of such a layer can lead to the appearance of a resonant transmission effect. This effect is due to the presence of weak coupling of the defect to the main lattice and cannot be described in the framework of the standard theory of elasticity, since the displacements of the defect layer are substantially different from that of the adjacent layers. For nongrazing angles of incidence this effect can be illustrated qualitatively for the example of an infinite linear chain containing a point impurity.

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