Abstract Title

Anomalous Elastic Properties of Expandable Solids

Symposium Track

1. Fundamental Modeling in Nanomechanics

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Abstract body

1.Background

Cryatalline solids has roughly two length scales. The lattice constant of the unit cell of the order of nm is one of them measuring the atomic world, and another one of the order of μm roughly distinguish the micro-and-macroscopic world from the others. There should be mesoscopic world in between the two. The mechanical response of the cryatals in the three worlds is comprehensively described by the lattice dynamics of phonons, assuming linear small deviations of atoms from the equilibrium positions. Especially, the long-wave limit of the acoustic phonons describes the elastic properties of solids in the micro-and-macroscopic world.

In the long-wave limit, it is well known that the acoustic wave has $\omega = ck$ type frequency(ω)-wavenumber(k) dispersion relation where the constant c denotes the material-dependent velocity of sound. The acoustic properties are well described by the lattice dynamics of the long-wave limit, which are also described by the elastic theory of continuum.

2.Motivation

However, it is surprising that $\omega = ak^2$ type dispersion relation has partially been found in graphite cryatal. The lattice dynamics has been studied by using phenomenological parameters describing force constants [1]. We thus try in this paper to investigate the theoretical background of finding the peculiar frequency-wavenumber dispersion relations in crystals and to consider the physical significance, using the force-constants model .

3.Main results

We will first show in this paper that this type of dispersion is related with an instability of a homogeneous expansion of the crystal which is not in the degrees of freedom of the vibrational phonon modes. We will show some examples of such crystals in 1-, 2- and 3-dimensions and will show a general condition of finding the peculiar phonon systems. When we are able to kill these special degrees of freedom by controlling the volume of the crystals at an constant value, we have no other instability in the crystals and we can observe any physical response of them. It is the way we have been studied the physical response of the usual crystals by killing the degree of freedom of their parallel shift, which is achieved when we control the center of inertia of the crystal fixed, for example by using walls around it. We can achieve our case when the six surfaces of the peculiar cryatal are paseted on the six fixed walls.

We will next show the peculiar wave propagation of the acoustic waves.The important point is the anomalously low sound velocity in the long–wave region, which is similar to that in the flat-band phonon system [2]. In addition, it is remarkable that the “sound” velocity is not constant but has a dispersion just as the long-wave electronic states in a crystal do. In this case, we cannot expect the normal transport of sound without modification. The wave packet of the “sound” is extremely modified as the time elapses and moves very slowly in the crystal. Due to the dispersion of the “sound”, we can expect to construct a spectroscopy of the acoustic phonons.

4.Summary

To summarize, we develop a new aspect of anomalous elastic properties of a new class of crystalline solids. The solids are expandable but are supposed to be stable. The expected elastic properties are an extremely soft mechanical response as protein crystal or “toufu” may has, an extremely slow sound velocity, and a characteristic dispersion of the sound wave. The obtained results are quite new, and we have not found any related paper yet.

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Keywords

Anomalous dispersion relation of phonons, Anomalous wave propagation of phonons, Phonon spectroscopy, Graphite, Lattice dynamics, Flat dispersion relation of phonons, Flat band.

References

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