Phonons in condensed matter

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The book contains abstracts of 112 papers by 125 scientists from 14 countries presented at a regularly scheduled international conference on phonons in condensed matter. The previous conferences took place in 1972, 1975, 1979, and 1983. The papers are grouped according to their subject matter under the following topics:

1. Glasses and two-level systems.
2. Electron-phonon interaction and superconductivity.
3. Phonons in semiconductors.
4. Thin films, surface and thermalization.
5. Quantum liquids and Kapitza resistance.
6. Phonon scattering in dielectrics.
7. Phonon images.
8. Phonons with large wave vectors and optical methods.
9. New methods and phenomena.

We shall briefly present the main points which form the content of these sections.

1. It is well known that at low temperatures the thermal conductivity of disordered crystals (glasses) varies as T^2, attains a plateau for $1 \lesssim T \lesssim 10$ K and increases with a further increase of T. The special features of phonon scattering at low temperatures ($T \lesssim 1$ K) can be phenomenologically explained by the presence of "two-level states" (TLS) which supposedly arise as a result of quantum tunnelling of atoms or a group of atoms. So far a microscopic theory of TLS does not exist. An analysis of data on different disordered crystals (A. M. de Goër, France) leads to the conclusion that: a) the plateau (apparently) cannot be explained only by TLS and arises, more likely, due to the strong coupling between acoustical phonons and low-energy modes; b) TLS are present not only in amorphous, but also in weakly disordered regions; c) the most suitable candidate for a microscopic theory of TLS are Jahn-Teller defects strongly coupled with the lattice. The dependence of the transport mean free path on the phonon frequency turns out to be a universal function: $l^{-1} = A\nu + B\nu^4$ (J. M. Grace and A. C. Anderson, USA)—a fact which so far has not received a consistent interpretation. A number of possible mechanisms exists to explain the thermal conductivity for $T > 10$ K (B. Golding, J. E. Graebner, and L. C. Allen, USA), but it is not yet clear which one of them should be the preferred one. Tunnelling atoms, forming TLS in metals are also coupled to the conduction electrons. Therefore the difference in the behavior of TLS between amorphous metals in the normal and superconducting states merits attention (S. Hunklinger, P. Esquinazi, H. M. Ritter, H. Neckel, and G. Weiss, FRG). Detailed data have been obtained for quartz crystals in which TLS are created by irradiation with neutrons (R. Vacher, J. Pelous, N. Elkhayati Elidrissi, M. Boissier, France; N. Vanreyten and L. Michiels, Belgium), and with electron (A. Vanelstraete and C. Laermans, Belgium). Evidently, "glasses" will continue to be objects of intense investigation.

2. Superconducting tunnel junctions are an effective detector of the phonon spectrum of different nonequilibrium systems. By using such detectors it was shown that in contrast to the three-dimensional case the two-dimensional electron gas (in a MOS-structure) exhibits on heating a non-Planck radiation spectrum (M. Rothenfusser, L. Koesler, and W. Dietsche, FRG). It was also shown that the radiation spectrum of granular aluminum which arises under Joule heating is determined by the structure of the granulation and practically independent of the level of the dissipated power (P. Berberich and H. Kinder, FRG). Experiments on absorption of ultrasound in ultrapure (99.9999%) aluminum crystals made it possible to determine the effect of dislocations on the formation of a gap in the spectrum of electron excitations, with the gap first increasing, then sharply falling off and increasing again with increasing concentration (Y. Kogure, M. Sekiya, H. Ohtsuka, and Y. Hiki, Japan).

3. There has been an increased interest in the interaction of phonons with superlattices in semiconductors. It was shown by methods of phonon spectroscopy utilizing tunnelling superconducting junctions that in the passage of high frequency (up to 900 Hz) acoustic phonons through amorphous superlattices, in particular through 7 layers of SiO_2/Si (of thickness ~ 100 Å) large dips are formed in the transmission spectrum (O. Koblinger, J. Mebert, E. Dittrich, S. Döttinger, and W. Eisenmenger, FRG). This produces the possibility of utilizing such systems as a frequency filter for phonons.

The method of studying shallow and deep impurity levels based on "phonon ionization" of impurities utilizing the recording of changes in conductivity (W. Burger and K. Lassman, FRG) is widely represented.

4. Effects have been investigated associated with the "preparation" of surfaces or with the effect of layers of molecules adsorbed on the surface on the process of phonon reflection (T. Klitsner, R. O. Pohl, L. Koester, S. Wurdack, W. Dietsche, and H. Kinder, FRG). The conditions of the experiment made it possible for the phonons to experience $\sim 10^2$ reflections in the course of a diffusion or thermalization lifetime, and this made it possible to study these processes as a function of external factors (W. Knaak, T. Hauss, M. Kummrow, and M. Meissner, FRG).

5. The "ideal" acoustic model gives a good explanation of the Kapitza resistance (arising as a result of the passage of phonons across the boundary between the crystal and helium or another crystal) at low temperatures (or frequencies). At high frequencies anomalies are observed which can be explained by different models, and in this connection a detailed analysis of experimental data is given (W. Eisenmenger, FRG). The opinion is expressed that a decrease in

the Kapitza resistance at $T > 10$ K is associated with diffusion scattering (E. T. Swartz and R. O. Pohl, USA). A methodology has been developed which made it possible for the first time with sufficiently high accuracy ($\sim 5\%$) to confirm the irreversibility of the Kapitza resistance (Xu Yunhiu, Zheng Jia-qi, and Guan Wei-yan, PRC). Dispersion curves of $\omega(q)$ in superfluid ^{4}He and ^{3}He have been analyzed and compared (A. F. G. Wyatt, England). A (pseudo-one-dimensional" mode of second sound in superfluid ^{4}He has been observed (J. P. Eisenstein and V. Narayanamurti, USA). As predicted by theory, the speed of this mode turns out to be by a factor of $\sqrt{3}$ greater than the speed of ordinary second sound (i.e., of the order of the speed of first sound).

6. The use of pulsed methods of phonon scattering in dielectrics has made it possible to resolve the spectra of some impurity rare-earth ions, inaccessible to investigation by the method of IR-spectroscopy (J. Mebert, O. Koblinger, S. Döttinger, and W. Eisenmenger, FRG). Investigations were reported also of scattering of phonons by point defects (P. G. Klemens, USA), dislocations (Y. Hiki, T. Kosugi, and Y. Kogure, Japan), grain boundaries (C. Wood, D. Whittenberger, USA; R. A. Brown, Australia) and magnons (G. V. Lecomte, H. V. Löhneysen, J. Wosnitza, and W. Zinn, FRG).

7. The well-known phenomenon of phonon focussing due to crystal anisotropy undergoes a qualitative reconstruction when the phonon wave vector is close to the boundary of the Brillouin zone and phonon dispersion is significant. "Phonon images" recorded by frequency-selective detectors in the course of ballistic propagation of shortwave phonons contain information important for the analysis of the dynamics of lattice models (S. E. Hebboul, D. J. van Harlingen, and J. P. Wolfe, USA). The intensity distribution of focussed phonons is determined by caustics which depend on elastic constants and can change under piezoelectric "hardening", as a result of which considerable distortion of caustics occurs (A. K. McCurdy, USA). As calculations have shown "pseudosurface" waves can strongly alter the caustics, for example forming observable "halos" (A. G. Every, South Africa).

8. Problems were discussed associated with the generation of monochromatic stimulated radiation by optically excited levels of CR^{3+} in ruby, alexandrite and other crystals at low temperatures. Rapid radiationless decays of vibronic impurity levels lead to emission of phonons with wave vectors close to the boundary of the Brillouin zone, and this in turn leads to observable Raman transitions of electrons (J. I. Dijkhuis, Holland). Investigation of the dynamics of electrons, phonons and their interaction passes on to a qualitatively new level as a result of the appearance of pico- and femtosecond lasers. In particular it has been established that hot carriers in polar crystals decay in a cascade fashion, with the duration of the cascades being approximately 150 fs (W. E. Bron, USA). Of interest is the attempt to derive Lindemann numbers with the aid of quite simple theoretical assumptions associated with the indeterminacy principle and the rate of three-phonon decay at the boundary of a Brillouin zone (B. H. Armstrong, USA).

9. By using a moving source of hypersound, an interference method of acoustic topography of thin films has been developed (O. Weis, FRG). The use of double tunnel junctions has made it possible to regulate the gap in the excitation spectrum of a superconducting detector (one of the junctions) and this gave new possibilities for detecting phonons (I. Iguchi and Y. Kasai, Japan). The absorption of monochromatic phonons by a two-dimensional electron gas has been investigated in the regime of the integral quantum Hall effect at different magnetic fields; the superfluid ^{4}He itself serves as the frequency selector whose transmission band is varied by pressure; it is proposed to use similar methods for observing the gap in the regime of the fractional quantum Hall effect (J. P. Eisenstein, V. Narayanamurti, H. L. Stormer, A. Y. Cho, and J. C. M. Hwang, USA). It is proposed to utilize the focussing accompanying ballistic propagation of phonons to construct spatially-resolving detectors of solar neutrinos (H. J. Maris, USA).

On the whole the conference encompassed a very broad, although not entirely comprehensive (this in particular refers to section 2) group of problems associated with the physics of phonons in condensed matter. The reports included in the book under review are doubtless of great scientific value and will be very useful for specialists.