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PHONON PULSE REFLECTION FROM FRESHLY CLEAVED INTERFACES BETWEEN SOLIDS AND LIQUID HELIUM

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Résumé.— Les impulsions de phonons à 290 GHz ont été réfléchies des surfaces solides dans l'hélium liquide. Pour la première fois les surfaces ont été clivées (fraîches) à 1K. Il est surprenant d'observer des coefficients de réflexion non loin de 100 % pour ces surfaces presque idéales.

Abstract.— Phonon pulses of 290 GHz were reflected from solid surfaces in contact with liquid helium. The surfaces were freshly cleaved at 1K, for the first time. Surprisingly, the reflection coefficient was nearly 100 % on these almost ideal surfaces.

In recent years, experiments with phonon pulses have yielded direct information on the energy transfer between solids and liquid helium (Kapitza conductance) /1,2/. At high temperatures (>1K) or high phonon frequencies, (>50 GHz) respectively, this energy transfer is roughly 100 times more effective than the Khalatnikov process /3/ of single phonon transmission with conservation of energy and momentum (acoustic mismatch model). The underlying microscopic process of this highly effective energy transfer is still not understood.

One basic question to be answered experimentally was that of the process being an intrinsic effect of ideal surfaces or whether it was caused by irregularities /4/. We report here on experiments with nearly ideal surfaces which were prepared by cleaving in situ at 1K /5/.

The reflection of phonon pulses of 290 GHz was measured using superconducting tunneling junctions /6/. The junctions were evaporated on one side of an LiF crystal, whose far side extended into a vacuum chamber (see inset of Fig. 1). The crystal could be cleaved by a razor blade which was moved by a screw. Through the thread of this screw, the chamber was connected to a filling line which was normally also kept at an ultra high vacuum.

The echo pulses before cleaving are shown by the dash-dotted line of figure 1. The first pulse is a pure transverse mode, with the direction of polarization parallel to the surface. The second pulse is an oblique mode with an angle of 20° between the phase velocity and the normal or the surface. After cleaving, the time of flight was shorter,

naturally. The solid trace was still taken under UHV conditions (a vacuum of better 10^{-12} torr was estimated). The dotted trace was taken after helium was introduced into the chamber.

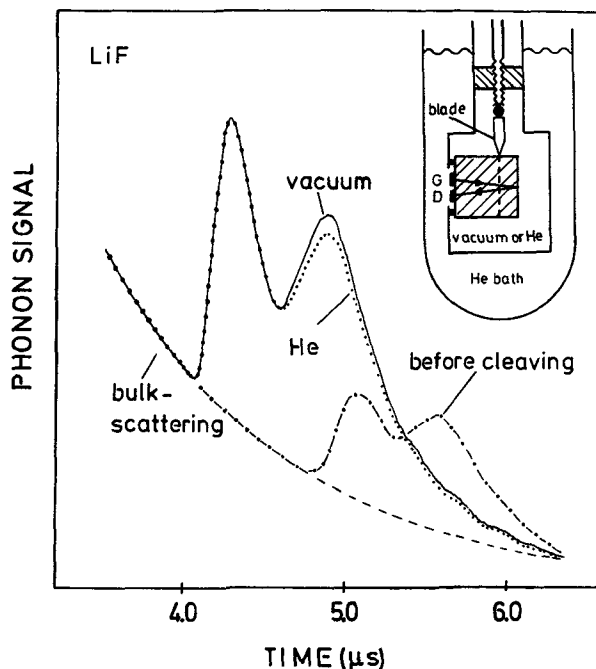


Fig. 1 : Phonon echo pulses vs. time ; dash-dotted trace : before cleaving in vacuum ; solid trace : freshly cleaved surface in vacuum ; dotted trace : same surface with bulk helium.

The first pulse, i.e. the purely transverse mode, was not changed at all. This is in contrast to all previous experiments /1/ where changes of the order of 50 % were always observed, particularly for the transverse waves. On the other hand, the Khalatnikov

model predicts exactly no energy transfer for purely transverse modes, indeed. This makes clear that the highly effective energy transfer ("anomalous" Kapitza conductance) is not intrinsic to ideal surfaces.

On the second pulse, i.e. the oblique mode, a change of 6 % with helium is observed (see Fig.1) This change is smaller than on less ideal surfaces. For comparison, we have warmed the same crystal to room temperature and then exposed to air for one day. Thereafter, the solid trace of figure 2 was obtained in vacuum, and the dotted trace in helium. The helium effect was now 12 % for the pure transverse mode, and 22 % for the oblique mode. A still greater effect was obtained by wiping the surface with acetone or by mechanically polishing.

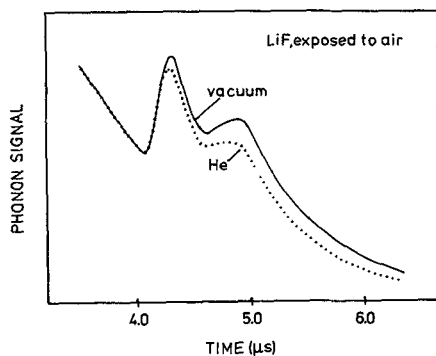


Fig. 2 : Cleaved surface of figure 1 after exposure to air at room temperature. Solid trace : vacuum ; dotted trace : helium.

Therefore, it is natural to assume that the residual helium effect on the oblique mode of figure 1 was also caused by residual irregularities. Even on these atomically clean surface, which look smooth and shiny to the eye, there are steps and irregularities on an almost atomic scale which could be resolved by using an electron microscope. This view is supported by other experiments with less perfectly cleaved surfaces, when helium effects up to 10 % were observed.

We conclude that the anomalously large energy transfer observed in phonon pulse and also in heat conductivity experiments is caused by surface irregularities rather than being an intrinsic effect of the ideal surface.

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