Electron contribution to the attenuation of surface phonons in metallic superlattices

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With the use of the picosecond ultrasonics Chen *et al* [1] observed in Al/Ag superlattices the lattice vibrations that remain near to the free surface for longer than 200 psec. The frequencies of these surface vibrations (surface phonons) are in good agreement with the values predicted by the theory of elasticity taking account of the internal structure of a unit period. Their measured damping rates are found to vary linearly with frequency (in the range 100 to 300 GHz for various bilayer thicknesses) and they are nearly independent of temperature from 70 to 300 K. These results are consistent with the Pippard theory for the attenuation of high-frequency phonons in bulk metals. However, the magnitude of the damping is about 3 times and approximately 24 times larger than the value expected for aluminum and silver, respectively. Thus, one might suppose that the attenuation is increased because of the effects of the band structures of both the phonons and electrons in superlattices as was proposed first by Chen *et al.*

Our aim is to study theoretically the damping of surface phonons in Al/Ag superlattices through an extension of the Pippard free-electrons model to multilayered structures, considering the electron and phonon subbands. More specifically in our model of the superlattices, we use :

(1) a Kronig-Penney model for electrons,

(2) the continuum elasticity theory for acoustic phonons, and

(3) the deformation-potential coupling for the electron-phonon interaction.

We compare our results with the Pippard formula for the attenuation of high-frequency phonons in bulk metals and also with the experimental damping rates of surface vibrations in Al/Ag superlattices.

[1] W. Chen, Y. Lu, H. J. Maris, and G. Xiao, Phys. Rev. **B** 50, 14506 (1994).