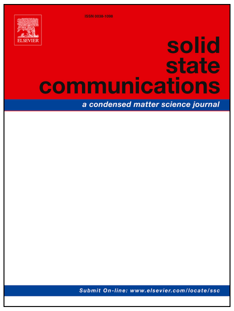

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# Dispersion, Mode-Mixing and the Electron-Phonon interaction in Nanostructures

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The electron-phonon interaction with polar optical modes in nanostructures is re-examined in the light of phonon dispersion relations and the role of the Fuchs-Kliewer (FK) mode. At an interface between adjacent polar materials the frequencies of the FK mode are drawn from the dielectric constants of the adjacent materials and are significantly smaller than the corresponding frequencies of the longitudinal optic (LO) modes at the zone centre. The requirement that all polar modes satisfy mechanical and electrical boundary conditions forces the modes to become hybrids. For a hybrid to have both FK and LO components the LO mode must have the FK frequency, which can only come about through the reduction associated with phonon dispersion relations. We illustrate the effect of phonon dispersion relations on the Fröhlich interaction by considering a simple linear-chain model of the zincblende lattice. Optical and acoustic modes become mixed towards short wavelengths in both optical and acoustic branches. A study of GaAs, InP and cubic GaN and AlN shows that the polarity of the optical branch and the acousticity of the acoustic branch are reduced by dispersion in equal measures, but the effect is relatively weak. Coupling coefficients quantifying the strengths of the interaction with electrons for optical and acoustic components of mixed modes in the optical branch show that, in most cases, the polar interaction dominates the acoustic interaction, and it is reduced from the long-wavelength result towards the zone boundary by only a few percent. The effect on the lower-frequency FK mode can be large.

## 1. Introduction

The interaction between electrons and the polar optical modes of crystalline nanostructure is central to the theory of electron transport in electronic devices working at and above room temperature. The standard approach assumes the Fröhlich interaction with long-wavelength modes. While this may be adequate for bulk material, it becomes questionable for nanostructures where the spectrum and structure of polar modes is affected by the presence of one or more interfaces between disparate crystalline layers. The necessity for allowable modes to satisfy mechanical and electrical boundary conditions forces, in general, the hybridization of longitudinally-polarized optical (LO), with transversely-polarized optical (TO) and electromagnetic interface (IF) modes, all at the LO frequency [1]. The difference between the LO ($\omega_L$) and TO ($\omega_T$) frequencies, forces the TO mode to be an interface mode. The electromagnetic dispersion governed by the large velocity of light entails that the electromagnetic component be also an interface mode. The further requirement that all components share the same frequency can be satisfied, in general, only by the property of phonon dispersion relations. It is this dependence on phonon dispersion relations that forces a re-examination of the polar interaction.