Scattering Effects in Free Electron Gas in GaN

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The reflectivity measurements of highly doped GaN samples revealed unusual shape of the reflection curve in the energy range close to the frequency of LO phonon. This feature can not be explained using classical Drude model of free carrier dielectric function. In the present work we apply an extended Dynamical Dielectric Function (DDF) formalism [1] describing dynamical screening effects of the electron – impurity interaction leading to excitations of longitudinal plasmon-phonon modes by the electromagnetic wave [2].

In our studies based on the linear response theory the electron impurity scattering is included to the lowest order of the perturbation theory in accordance to the conservation laws. Using such approach we are able to described the effects of translational symmetry breaking by ionized centers.

Our calculations allows us to explain that unusual reflectivity shape and also explain why such phenomenon can be observed only in wide gap materials. In such a case we deal with high energy of optical phonon modes. In order to achieve the condition of plasma frequency exceeding the LO phonon frequency a very high concentration of free carriers is necessary. This is possible only for high concentration of ionized centers which leads to the pronounced scattering effects resulting in Fano like resonances in the DDF (see figure).

The reflectivity curve calculated using the extended DDF qualitatively agrees with the experimental data in the vicinity of the LO phonon frequency. In particular we reproduced the visible enhancement of the reflectivity in this spectral region.

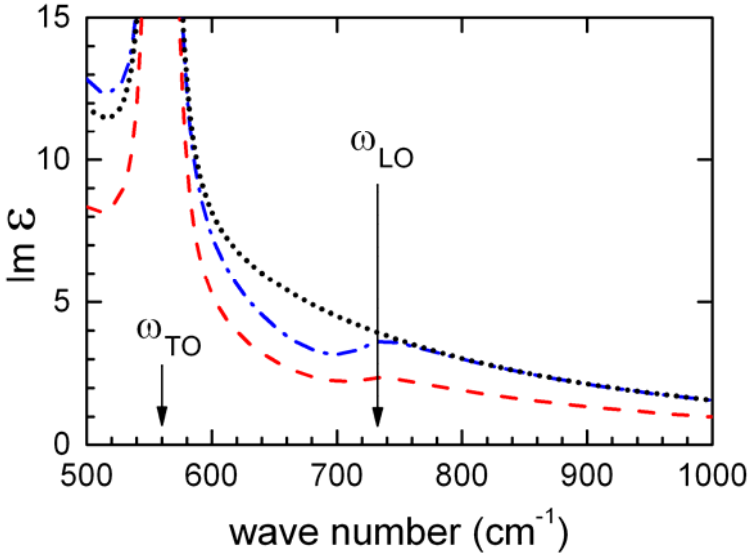

Figure:
The imaginary part of the DDF for GaN in the optical phonon energy region for fixed plasmon frequency and various concentrations of ionized centers (dashed line $1\ 10^{19}$ cm^{-3}, dash-dot line $2\ 10^{19} cm^{-3}$). The curve for Drude model depicted by the doted line was calculated with the plasma damping parameter $\gamma = 200 cm^{-1}$.

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[2] S. Goettig, J. Phys. C: Solid State Phys., **17**, 4443 (1984).