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Study of phonon spectra of (Cd,Hg)Te-based semiconductor solid solutions using synchrotron radiation

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Let me present an overview of recent achievements made by the Polish-Italian team in our more than 15-year collaborative research on (Cd,Hg)Te-based semiconductor solid solutions. The specialized source of synchrotron radiation available in DAφNE-light laboratory at Frascati (Italy) [1] was used for far-infrared reflection measurements FTIR. Optical TO-phonon spectra were interpreted within the framework of the Verleur and Barker model upgraded by authors [2]. In addition, the authors' original methodology was applied. The final version of this upgraded interpretation model for optical TO-phonon spectra includes the following Lorentzian parameters: S_i, ω_{TOi} and γ_i representing a generator capacity, phonon line frequency, and a damping factor, respectively.

This model has been used to interpret a large number of phonon spectra for many semiconductor compounds such as $Hg_{1-x}Zn_xTe$, $Hg_{1-x}Cd_xTe$, $Zn_xCd_{1-x}Te$, $Hg_{1-x-y}Zn_xCd_yTe$, $Hg_{1-x-y}Mn_xCd_yTe$ with different compositions to determine parameters S_i, ω_{TOi} and γ_i of each existing mode. Phonon spectra with mercury vacancies obtained for some $Hg_{1-x}Cd_xTe$ and $Hg_{1-x}Zn_xTe$ compounds were examined and interpreted using the pseudo-quad model [3].

The most remarkable success is experimental observation of the returnable electron-phonon interaction by measuring the phonon spectra obtained with the synchrotron. Measurements of the temperature dependence of phonon modes made with exceptional thoroughness and accuracy (typical spectral frequency was 1 cm^{-1}, and 2 cm^{-1} in some cases) revealed the discontinuity effect in the $Cd_{0,115}Hg_{0,885}Te$ sample (see Fig. 1). It refers to how the frequency of HgTe-like and CdTe-like TO-phonon modes depends on temperature at the point of forbidden zero crossing (defined as $E_g \equiv \Gamma_6 - \Gamma_8 = 0$, the so-called Dirac point [4]). These discontinuities are resonant. Similarly, this phenomenon was observed in the $Zn_{0,1}Hg_{0,9}Te$ sample, in which we also deal with the Dirac point. In this sample, the discontinuity of the dependence of phonon mode frequency vs. temperature was observed for ZnTe-like and HgTe-like TO-phonon modes [5]. Since these dependencies are resonant, the phenomenon explanation is based on the modified Kawamura model [6].

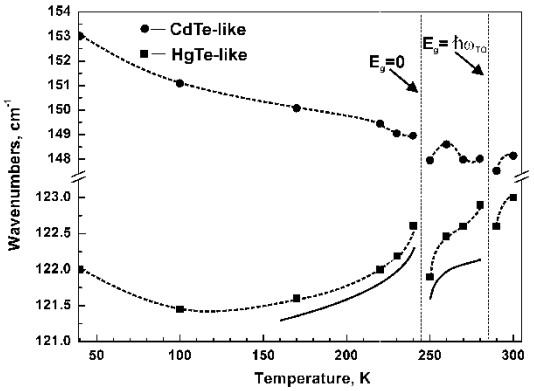

Figure 1. Plot of the frequency positions in the wave number *vs* temperature range of the HgTe-like and CdTe-like [4].

The most recent research made by the Polish-Italian team is concentrated on a general analysis of phonon spectra of mercury-containing compounds, for example $Hg_{1-x}Zn_xTe$ and $Hg_{1-x}Cd_xTe$, taking into account their composition and temperature[7]. A generalization of the theoretical temperature shift of the phonon mode frequency as an analytic equation is derived. It includes both the anharmonic contribution and the electron-phonon e-p interaction which is returnable in this case - the electron subsystem effect on the phonon one. Data show that our equation satisfactorily describes the temperature shift of both $Hg_{0.885}Cd_{0.115}Te$ and $Hg_{0.90}Zn_{0.10}Te$ containing Dirac point, although one of the two constants describing the anharmonic shift of the HgTe-like mode should be positive that is abnormal too. In the case of the $Hg_{0.80}Cd_{0.20}Te$ and $Hg_{0.763}Zn_{0.237}Te$ solid solutions, the role of the returnable e-p contribution is negligible, but a positive temperature shift for the HgTe-like modes occurs. This result does not explain the positive temperature shift of these modes merely by the contribution of the (e-p) interaction. Indeed, the relativistic contribution to the chemical bonds induces an abnormal temperature shift of the electron states in Hg-based semiconductors. The effect is expected since the Hg d spin-orbit split contribution to chemical bonds may lead to an abnormal temperature shift of the HgTe-like modes.

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