PLASMON - PHONON INTERACTION AND SURFACE OPTICAL MODE IN $Cd_{1-x}Fe_xTe_{1-y}Se_y$ SINGLE CRYSTALS

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ABSTRACT

The interaction between electrons and phonons represents a notable phenomenon in the realm of condensed matter physics, exerting a substantial influece on diverse electronic and optical characteristics of materials. Within this context, an exhaustive investigation of the Raman and Far-Infrared reflectivity spectra of Cd1-xFexTe1-ySey single crystals can yield valuable insights into the various impacts of plasmon - phonon interactions on the fundamental physics of II - IV semiconductors. Spectral analysis was executed employing a suitable fitting procedure. In the analysis of Far-Infrared spectra, a dielectric function incorporating the presence of plasmon - LO phonon interaction was employed. All phonon features were elucidated within the framework of the modified random - element - isodisplacement (MREI) mode. Additionally, in all samples, a surface layer characterized by a low concentration of free carriers (depleted region) was formed. Consequently, a surface opticam mode (SOP) was registered in samples with a predominant CdTe component (y less than 15%) and in samples with a majority CdSe component (z greated than 95%).

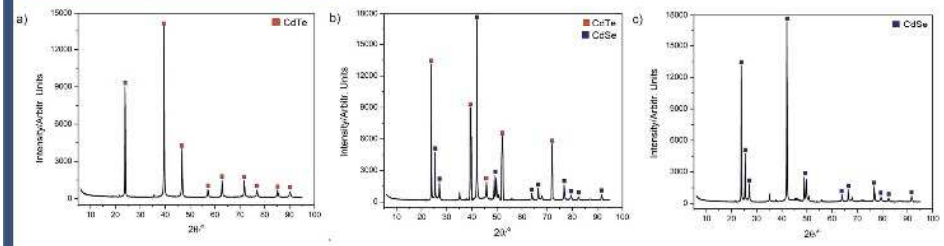
PREPARATION OF SAMPLES

Single crystals of Cd1-xFexTe1-ySey were grown using the **Bridgman technique** employing chemically pure constituents. The Fe concentration (x) was determined with a precision of ±0.005 through magnetic susceptibility measurements at room temperature. Additionally, a more precise determination of Fe content was carried out using an X-ray microprobe. Both methodologies yielded identical results within the margins of measurement error. The selenium content in the samples was deduced from these data. Samples with varying compositions were investigated (see Table 1).The selenium quantity in this solid solution varies widely, while the added Fe concentration remains below 4%. Therefore, it is justified to consider this material, in one part of the discussion, as a doped ternary solid solution, i.e. CdTe1-ySey + Fe.

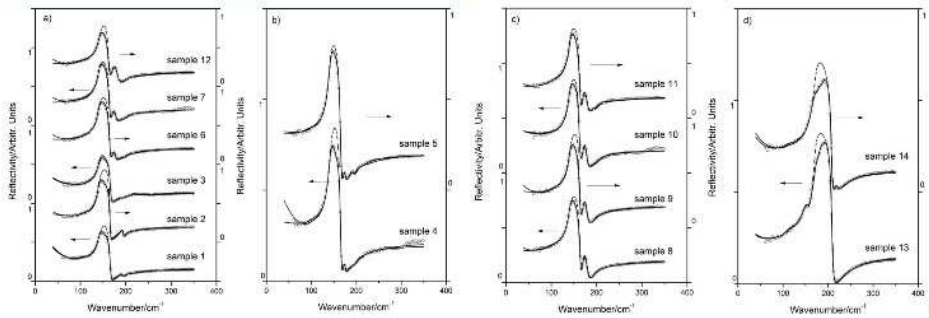
Table 1. List of $Cd_{1-x}Fe_xTe_{1-y}Se_y$ samples

No.	Name	x/%	y/%
1	CFT1	3	0
2	CFTS8	4	0.5
3	CFTS3	1	1
4	CFTS9	1	3
5	CFTS7	2	3
6	CFTS6	2	6
7	CFTS12	1	7
8	CFTS13	$8\,10^{-18}$	10
9	CFTS2	$3.5\,10^{-19}$	10
10	CFTS1	1	10
11	CFTS4	2	10
12	CFTS11	2	15
13	CFTS10	$6\,10^{-18}$	95
14	CFTS5	2	99.8

X - RAY DIFFRACTION



FAR - INFRARED SPECTROSCOPY



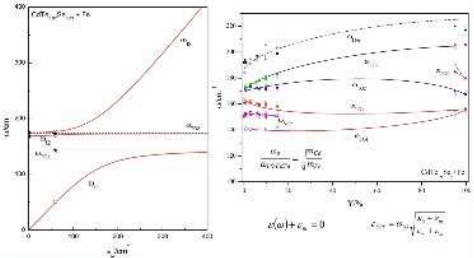
Dielectric Function Model of Plasmon - LO phonon modes

$$\varepsilon_j(\omega)=\varepsilon_\infty\frac{\prod_{i=1}^{n}\left(\omega^2+i\gamma_{i1}\omega-\omega_{i1}^2\right)}{\omega\left(\omega+i\gamma_p\right)\prod_{s=1}^{r}\left(\omega^2+i\gamma_{s0}\omega-\omega_{s0}^2\right)}\prod_{s=1}^{r}\frac{\omega^2-i\gamma_{s0}\omega-\omega_{s0}^2}{\omega^2+i\gamma_{s0}\omega-\omega_{s0}^2}\frac{\omega^2-i\gamma_{s}\omega-\omega_{s}^2}{\omega^2+i\gamma_{s}\omega-\omega_{s}^2} \quad (1)$$

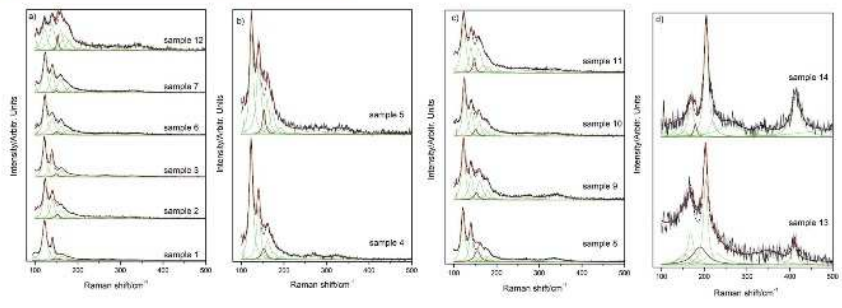
$$\omega_p=\frac{\omega_{t0}\omega_{l0}}{\omega_{t1}\omega_{t2}} \quad (2)$$

$$\omega_{LO1,2}=\frac{1}{2}\left(\omega_{t1}^2+\omega_{t2}^2+\omega_{l1}^2-\omega_{l2}^2\right)\pm$$
$$+\sqrt{\left[\frac{1}{4}\left(\omega_{t1}^2+\omega_{t2}^2-\omega_{l1}^2\right)^2-\omega_{t1}^2\omega_{t2}^2-\omega_{l2}^2\omega_{t1}^2-\omega_{l2}^2\omega_{t2}^2+\omega_{l2}^2\left(\omega_{t1}^2+\omega_{t2}^2\right)\right]} \quad (3)$$

$$\varepsilon_c(\omega)=\varepsilon_\infty+\sum_{i=1}^{n}\frac{\varepsilon_{si}\left(\omega_{iTO}^2-\omega_{iTO}^2\right)}{\omega_{iTO}^2-\omega^2-i\gamma_{iTO}\omega}-\frac{\varepsilon_{sp}\omega_p^2}{\omega\left(\omega+i\gamma_p\right)} \quad (1)$$



RAMAN SPECTROSCOPY



CONCLUSION

Our study of Cd $_xFe_xTe_{1-y}Se_y$ single crystals using Far-infrared and Raman spectroscopy has provided crucial insights into Plasmon-phonon interactions and surface optical modes. The modified factored dielectric function model successfully described the spectra, highlighting the significance of a low carrier concentration surface layer and accurately capturing coupled Plasmon-LO modes and TO frequencies.

Raman spectra analysis revealed TeO_2-related phonons and surface phonons, consistent with the two-mode behavior described by the Genzel model. The presence of a local Fe mode demonstrated notable electron-phonon interactions and isotope effects. Surface optical phonon frequencies for CdTe and CdSe offered unique contributions to the material's phonon properties. These results deepen our understanding of phonon characteristics in these semiconductors and suggest further research into the penetration depth of surface optical phonons in regions with low carrier concentrations.