

PLASMON-PHONON INTERACTION IN CdO

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The reflectivity spectra of sintered CdO-samples was analysed in the spectral range between 60 and 1600 cm^{-1} . The optical constants were calculated by using a fitting procedure of the reflectivity spectra on the basis of a model which describes plasmon-phonon interaction. An oscillator with $\omega_{TO} = 260 \text{ cm}^{-1}$ was clearly observed.

1. Introduction

Cadmium oxide is a semiconducting material of *n*-type, with high free carriers concentration because of more cadmium according to the stoichiometry. Electrical properties of CdO in thin films form or as polycrystalline samples obtained by sintering have been mainly investigated. Because of the high free carriers concentration optical properties of CdO have not been enough known. The energy gap of CdO is $E_g = 2.35 \text{ eV}^{(1)}$. The optical and transport parameters ϵ_∞ , n , τ , m^*/m_0 are determined by analysis of plasma edge reflectivity spectra in the range from 1.2 to 15 μm^2 .

In this paper the optical properties of the CdO samples sintered in different ways have been investigated by analysis of the reflectivity spectra in infrared and far-infrared spectral region. In order to determine optical and transport properties of CdO, the fitting procedure has been applied. The change of optical properties of CdO has been analysed depending on sintering conditions.

2. Experimental results and analyses

Procedure for obtaining of the samples, some transport and optical properties of CdO which has been used in this paper, had already been published^{3,4}. Reflectivity spectra of CdO which is given at Fig. 1³⁾, has been obtained using Perkin-Elmer model of 437 spectrophotometer in the range from 1600 to 250 cm^{-1} and Beckman FS 720 far-infrared spectrometers in the range from 250 to 60 cm^{-1} .

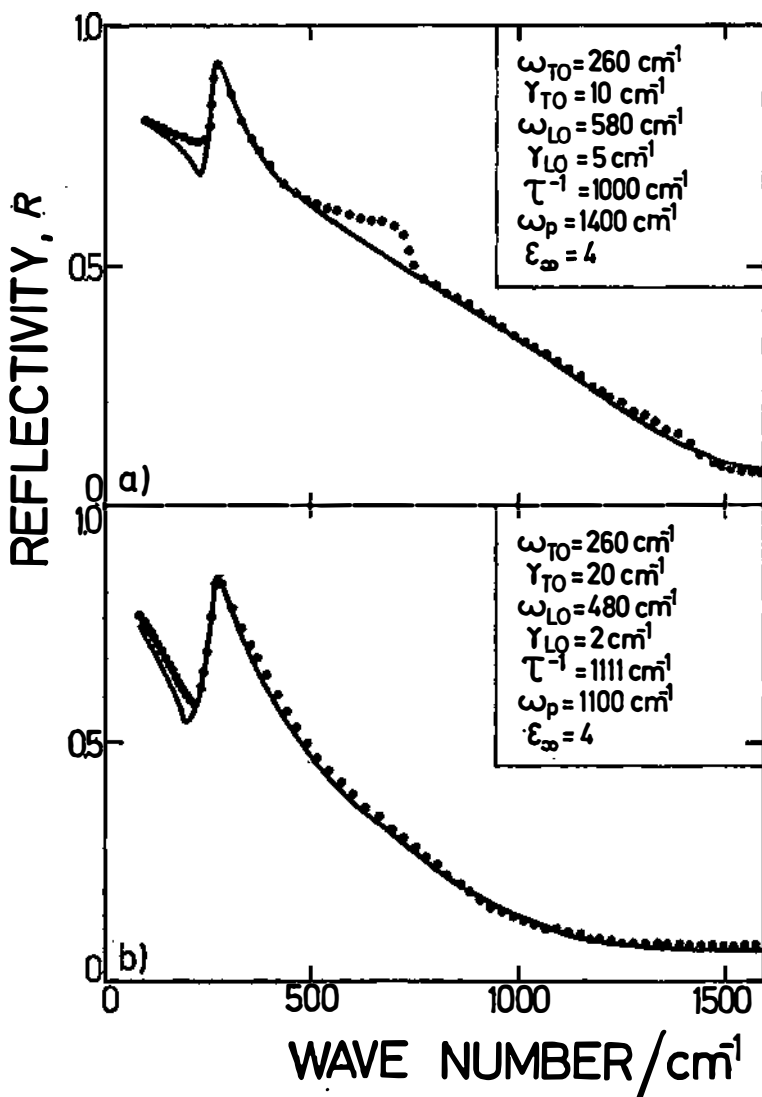


Fig. 1. Infrared reflectivity spectra of CdO in the range 60—1600 cm^{-1} . Full lines denote calculated spectra and dots are experimental data. The samples were obtained by following conditions: pressure of compression $3.92 \cdot 10^8$ Pa during the period of 60 minutes at 473 K (a) and 773 K (b) annealing temperatures.

As Fig. 1 shows, the reflectivity spectra of CdO is characterised by plasmon-phonon interaction. Namely, the plasma edge and oscillator at about 250 cm^{-1} are noticable.

The sample 1a is related to the following conditions of the sintering: pressure of compression $3.92 \cdot 10^8 \text{ Pa}$, temperature of annealing 473 K during the period of 60 minutes and the sample 1b is related to the pressure of compression $3.92 \cdot 10^8 \text{ Pa}$, annealing temperature 773 K during the period of 60 min. The reflectivity spectra shown in Fig. 1 are analysed by using of a fitting procedure in the model which describes plasmon-phonon interaction. In the case of coupling of plasmons with longitudinal optical phonon, dielectric constant contains contributions of free carriers and lattice vibrations:

$$\epsilon(\omega) = \epsilon_\infty + \epsilon^{lat}(\omega) + \epsilon^{f.c.}(\omega), \tag{1}$$

where ϵ_∞ is the dielectric constant at very high frequencies.

The dielectric constant $\epsilon^{lat}(\omega)$ in factorized form in anisotropic medium with n oscillators can be written as:

$$\epsilon_\infty + \epsilon^{lat}(\omega) = \epsilon_\infty \prod_{j=1}^n \frac{\omega_{LOj}^2 - \omega^2 - i\omega\gamma_{LOj}}{\omega_{TOj}^2 - \omega^2 - i\omega\gamma_{TOj}} \tag{2}$$

where ω_{TOj} and γ_{TOj} are transverse frequency and damping coefficient of the j -th oscillator, and ω_{LOj} and γ_{LOj} are longitudinal frequency and damping coefficient of j -th oscillator.

Free carrier contribution to dielectric constant could be presented as:

$$\epsilon^{f.c.}(\omega) = \frac{\omega_p^2}{\omega(\omega + i\tau^{-1})}, \tag{3}$$

where ω_p is plasma frequency ($\omega_p^2 = e^2 N / m^* \epsilon_0 \epsilon_\infty$, N is concentration, and m^* is effective mass of the free carriers)

Fig. 2 shows the reflectivity spectra in the case when only one plasmon and one phonon exist. Two characteristic cases are of interest: a) when $\tau^{-1} < \omega_{LO}$ and b) when $\tau^{-1} > \omega_{LO}$. The first case is related to the semiconducting materials, where mobility is of order $10^3 \text{ cm}^2/\text{Vs}$, i. e. of covalent crystal, as, for example, Si, GaAs, etc. The other case represents layer crystals or semimetals, in which mobility is of order $50 \text{ cm}^2/\text{Vs}$.

As the spectra from Fig. 1 is in accordance with the ones from Fig. 2.b, the first preliminary data in fitting procedure for CdO was $\tau^{-1} > \omega_{LO}$. In fitting procedure at first we calculated ϵ_1 and ϵ_2 from Eq. (1), and then n and k , using the following relations:

$$\begin{aligned} n &= \sqrt{0.5(\epsilon_1 + \sqrt{\epsilon_1^2 + \epsilon_2^2})}, \\ k &= \sqrt{0.5(-\epsilon_1 + \sqrt{\epsilon_1^2 + \epsilon_2^2})}. \end{aligned} \tag{4}$$

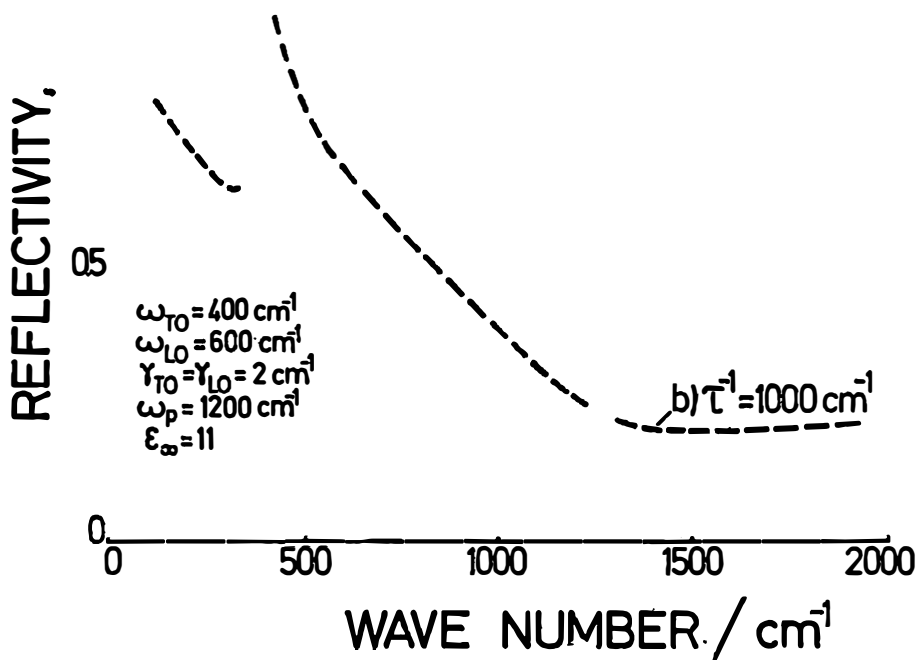


Fig. 2. Synthesized reflectivity spectra for a) $\tau^{-1} = 100 \text{ cm}^{-1} (< \omega_{LO})$ and b) $\tau^{-1} = 1000 \text{ cm}^{-1} (> \omega_{LO})$.

Finally, reflectivity spectra, was calculated using the relation

$$R = \frac{(n - 1)^2 + k^2}{(n + 1)^2 + k^2}, \tag{5}$$

which was applicable in the case of incidence beam normal to surface of sample, what was achieved in experimental measurements of spectra.

3. Discussion

In Fig. 1 the full line denotes the theoretical spectra obtained from the oscillator fits with parameters shown in insert of Fig. 1., while dots denote the experimental data. In the case 1.b an agreement between experimental and calculated spectra is very good, while in the case 1.a in the range between 500 and 800 cm^{-1} there is a plateau which can not be connected with plasmon-phonon interaction of a simple type as it was considering in this paper. In our opinion, this plateau becomes because of an imperfect sintering process.

In Fig. 1.b the reflectivity spectra is shown in the case for annealing temperature of 773 K. In this case the oscillator is more clearly observed and relaxation time and plasma frequency position (carriers concentration) are lower than in the case 1.a. This means that higher temperature brings increment of homogeneity of structure of investigated samples. Similar conclusion were obtained on the basis of electrical measurements, of CdO transport properties⁵⁾. Beside, an oscillator with $\omega_{TO} = 260 \text{ cm}^{-1}$ was clearly noticed in both cases. Because of plasmon-phonon interaction the shifting of ω_{LO} is occurring in both cases, so that in the case 1.a $\omega_{LO} = 580 \text{ cm}^{-1}$, while in the case 1.b $\omega_{LO} = 480 \text{ cm}^{-1}$. As far as we know the far-infrared reflectivity spectra of CdO have never been published and we have not been able to compare our results with any in literature. Only the transmission spectra of CdO in infrared spectral region has been known⁶⁾. The minimum of transmission spectra at 240 cm^{-1} corresponds to values of transversal mode at $\omega_{TO} = 260 \text{ cm}^{-1}$.

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PLAZMON — FONON INTERAKCIJA KOD CdO

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Originalan naučni rad

Spektri refleksije sinterovanih uzoraka CdO su analizirani u spektralnom opsegu između 60 i 1600 cm^{-1} . Optičke konstante su izračunate korišćenjem procedure podešavanja spektra refleksije na bazi modela koji opisuje plazmon-fonon interakciju. Oscilator sa $\omega_{TO} = 260 \text{ cm}^{-1}$ je jasno uočen.