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OPTICAL CHARACTERISTICS $Hg_{1-x}Mn_xSe$ (x = 0.11)

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In this paper the optical characteristics of the semimagnetic semiconductor $Hg_{1-x}Mn_xSe$ in the range from the ultraviolet to far infrared part of the spectrum of the elektromagnetic radiation, at several temperatures in the interval from 10K to 300 K were studied. In the wave range from 300 - 900 nm two maxima were observed in the reflection spectra at 430 nm and 820.6 nm, stemming from the interband electron transitions in HgSe. The phonon modes at about 101 cm^{-1} and 137 cm^{-1} stem from the HgSe lattice vibration, and at 215cm^{-1} from the MnSe lattice.
By the analysis of the reflection spectrum the dependence of the imaginary part of the dielectric permeability on the wave number, $\varepsilon_2(\omega)$, as well as the value of dielectric permeability at very high frequencies were determined. The temperature dependence of the reflection spectrum in the range from 50 - 600 cm^{-1} show the presence of a very strong plazmon-phonon interaction.

INTRODUCTION

The semimagnetic semiconductor $Hg_{0.89}Mn_{0.11}Se$ occurs by alloying HgSe (having a property of a semimetal, E_g = -0.10eV) with MnSe (magnetic semiconductor, E_g = 2.5 eV) /1/.

Mercury selenide has sphalerite crystal structure (a=6.084 Å) with tetrahedral coordination /2/. The stable modification of manganese selenide α - MnSe has a crystal structure of type NaCl (a = 5.642 Å) with octahedral coordination and two metastable modifications β - MnSe and γ - MnSe are of sphalerite type (a = 5.620 Å), i.e. wurtzite type of crystal structure (a = 4.12 Å and c = 6.72 Å) /2/.

System HgSe - MnSe is a solid solution for x < 0.385 and it has a sphalerite structure with the lattice constant linearly decreasing with the increase of the content of Mn^{2+} ions /2/.

The optical features of HgSe are stadied in the region of plazmon-phonon and phonon-photon interactions /3/, /4/, as well as α - MnSe spectra in the region plazmon-photon interaction /5/. The optical spectra β-MnSe were not stadied. We do not know whether optical studies of the semiconducting compound $Hg_{1-x}Mn_xSe$ were

performed ih the range plazmon-photon and phonon-photon interaction.

The paper provides the first preliminary measurements of the reflection spectrum of the semimagnetic semiconductor $Hg_{0.89}Mn_{011}Se$. The paper particularly analyzes the plazmon-photon, phonon-photon and plazmon-phonon interactions in a wide temperature interval from 300 K to 10 K.

EXPERIMENTAL

The infrared reflection spectra of the semiconducting compound $Hg_{0.89}Mn_{0.11}Se$ were recorded on Bruker 113 V FTIR spectrophotometer in the 5000 cm^{-1} (2μm) - 50 cm^{-1} (200μm) region.

In order to establish the molar percent of MnSe and HgSe in the samples used, which were prepared at the Institute of Physics of the Polish Academy of Sciences, the X-ray structural analysis of the powder was made.

The samples obtained by cutting the ingot normally at its axis, were prepared in the shape of thin, well polished slabs.

The reflection spectra were registered at the temperatures: 10 K, 60 K, 150 K, 200 K and 300 K.

RESULTS AND DISCUSSION

The powder diagram of the sample $Hg_{1-x}Mn_xSe$ (x = 0.11) is shown in Fig. 1. From the position of the denoted difraction peaks we found that the lattice constant of these crystals is 6.046 Å, which according to /2/ corresponds to the solid solution $Hg_{1-x}Mn_xSe$ with x = 0.11.

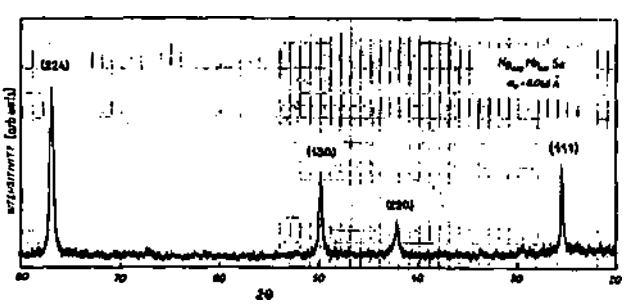

Fig. 1.
The powder diagram $Hg_{0.89}Mn_{0.11}Se$

Fig. 2 shows the reflection spectrum of $Hg_{0.89}Mn_{0.11}Se$ in the region from 250 - 2500 nm. Two maxima at 430 nm and 820.5 nm are clearly visible. Their position does not change with the change of MnSe concentration in HgSe. Apart from that similar changes were found even in pure HgSe /3/, so that with certainty it can be concluded that the maxima observed stem from electron interband transitions in HgSe.

Fig. 3 displays the reflection spectrum in the range of wave numbers from 500 -5000 cm^{-1} There is almost no change of the

reflection coefficient in this range (R ≃ 30 - 32 %), except a slight increase of about 2000 cm^{-1} This could be perhops linked to the energy gap of this compound having in view the results of the paper /6/, wherein on the basis magnetooptical measurements the band structure of semicdonducting compound $Hg_{1-x}Mn_xSe$ is determined.

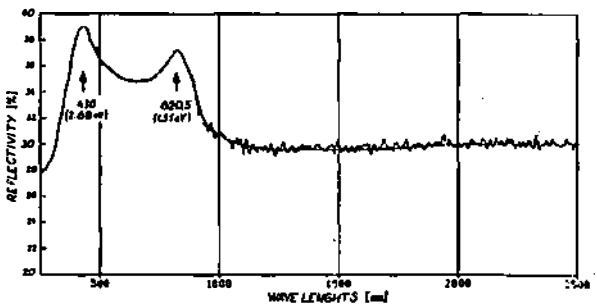

Fig. 2.
The reflection spectrum $Hg_{0.89}Mn_{0.11}Se$ at room temperature in the region from 250nm to 2500nm

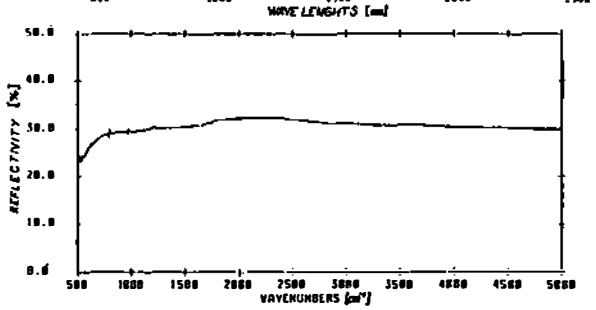

Fig. 3.
The reflection spectrum $Hg_{0.89}Mn_{0.11}Se$ in the region from 20μm to 2μm

The reflection spectra in the region from 50 cm^{-1} to 600cm^{-1}, at temperatures of 10 K, 60 K, 150 K, 200 K and 300 K are shown in Fig. 4. Three oscillators with TO frequencies at about 101cm^{-1}, 137cm^{-1} and 215 cm^{-1} are clearly noticeable. The first two modes are at frequencies which are very approximate to those in HgSe /4/, while the third mode, which is according to paper /7/ sensible to the composition of Mn^{2+} ions ih crystals $Hg_{1-x}Mn_xSe$ probably corresponds to the MnSe vibrations. Since the vibrational spectra β-MnSe are not known, and as α-MnSe has the structure of the type NaCl with ω_{TO} = 141 cm^{-1} /5/, we can assume that the 215cm^{-1} mode represents TO mode β-MnSe.

Besides the three modes mentioned above we notice a mode about 400 cm^{-1} which is particularly clearly pronounced at low temperatures. It stems probably from interband electron transitions in $Hg_{1-x}Mn_xSe$. Its more detailed determination is not possible because the band structure of this material is not sufficiently known.

Fig. 5 presents the dependence of the imaginary part of the dielectic permeability ε_2 on the wave number, at 300 K. The maxima of this function represent ω_{TO} frequencies of the oscillators observed. Apart from that, by the K-K analysis the value of the dielectric permeability was determined, too, at very high frequencies ε_∞ = 11.7 (at ω = 5000 cm^{-1}).

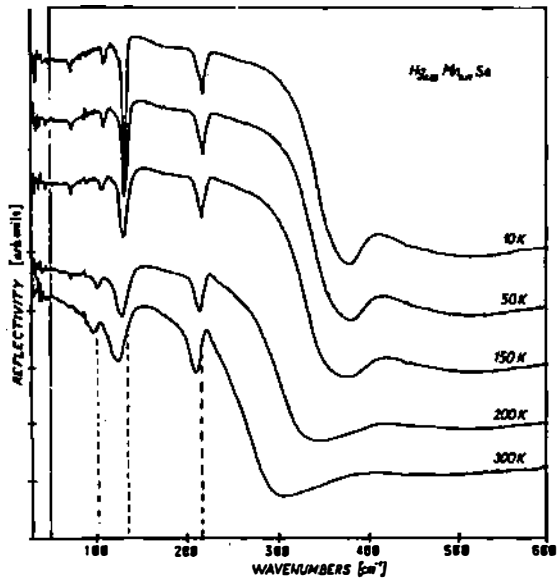

Fig. 4.
The reflection spectra $Hg_{0.89}Mn_{0.15}Se$ at various temperatures. For clarity sake, the spectra are interspaced by about 0.15

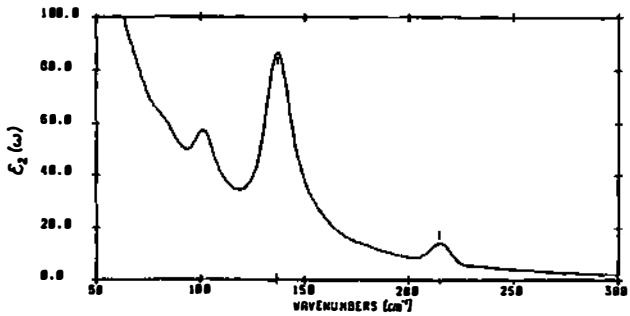

Fig. 5.
The dependance of $\varepsilon_2(\omega)$ optained by Kramers-Kronig's analysis of the reflection spectra $Hg_{0.89}Mn_{0.11}Se$

More detailed analysis of these spectra will be possible only upon the numerical harmonisation of parameters according to the mode for phonon-plazmon interaction, as well as the measuring results of transport parameters of this material depending on temperature, However, on the basis of the shift of plasma minimum towards higher wave numbers, at the temperature decrease ($\omega_{min} \simeq 300cm^{-1}$ to 300 K, $\omega_{min} \simeq 390\ cm^{-1}$ to 10 K), it can be expected that the concentration of free carriers at the temperature decrease enhances or/and the effective mass decasy /8/.

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