UDC 541-67:661.863/888

THE ELECTROPHYSICAL AND OPTICAL PROPERTIES OF GADOLINIUM MONOANTIMONIDE THIN FILMS

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Received 28.09.2012

Within a wide temperature interval 90 – 700 K the main the dependence of electro-physical parameters of GdSb films (specific resistance, Hall constant and thermo-electromotive force) on temperature have been measured. It has been shown that the films are semimetals. The reflection and adsorption spectra of prepared films have been studied for the first time within the intervals of 0.05 – 5.5 eV. On the basis of received data the diagram of the dependence of penetration real part and loss functions on the photon energy have been plotted. It has been shown that the spectra of optical parameters have quite a complex nature.
Keywords: film, rare earth, evaporation, specific resistivity, Hall constant, thermo-electromotive force, absorption spectra, reflection spectrum.

Разработана технология приготовления тонких кристаллических плёнок GdSb методом вакуумно-термического испарения из двух независимых источников Gd и Sb, в широком интервале температур 90 – 700 K. Исследованы температурные зависимости удельного электросопротивления, постоянной Холла и термо-ЭДС. Показано, что пленки являются полуметаллами. В области энергии фотонов 0.05 – 5.5 эВ измерены спектры отражения и поглощения. В результате полученных данных вычислены энергетические зависимости деиствительной и мнимой части диэлектрической проницаемости, а также функции потерь. Исследования выявили сложный характер оптических параметров изготовленных плёнок.
Ключевые слова: плёнка, редкоземельный элемент, удельное электросопротивление, постоянная Холла, термо-ЭДС, спектр отражения, спектр поглощения.

Розроблена технологія приготування тонких кристалічних плівок GdSb методом вакуумно-термічного випаровування із двох незалежних джерел Gd і Sb, у широкому інтервалі температур 90 – 700 K. Досліджені температурні залежності питомого електроопору, постійної Хола і термо-ЕРС. Показано, що плівки є напівметалами. В області енергії фотонів 0.05 – 5.5 еВ виміряні спектри відбиття і поглинання. У результаті отриманих даних обчислені енергетичні залежності дійсної та уявної частини діелектричної проникності, а також функції втрат. Дослідження виявили складний характер оптичних параметрів виготовлених плівок.
Ключові слова: плівка, рідкоземельний елемент, питомий електроопір, постійна Хола, термо-ЕРС, спектр відбиття, спектр поглинання.

INTRODUCTION

The antimonides of rear-earth elements (REE) attract a great attention of the investigators. Which is the result of their interesting, frequently often mutually exclusive electric, thermal, optical and other properties [1, 2]. The REE monoantimonides are semi-metals with high temperature of melting and are the materials for manufacturing the resistors. But all these compounds have not been studied properly. To this lesser studied material having the interesting property belongs the gadolinium monoantimonide [3 – 6]. In particular, by its adiabatic demagnetization it is possible to be received a very low temperature. In the represented work the data have been brought dealing with study of GdSb electrophysical and optical properties.

EXPERIMENTAL TEQNIQUE

In the represented work the GdSb thin films have been received from two independent sources by the vacuum-thermal evaporation method [7]. Measurement of specific resistance, Hall constant and thermal-electromotive force of received films has been performed on the apparatus which gave a possibility to carry out the measurements within one cycle. Measurement of Hall constant has been performed through using the constant magnetic and direct current.

In the given work the spectra of reflection and transparency of received films in the section of the energies of 0.05 – 5.5 eV have been measured at room temperature. For the experimental base a universal spectral-computing complex КСВУ-2 and infra-red spectral-computing complex КСВУ-2 and infrared spectral-computing complex КСВИ have been used. Processing of the received results has been effected on the basis of Cramer-Cronig disperse correlation [8].

RESULTS OF THE EXPERIMENT AND THEIR CONSIDERATION

In fig. 1 there is shown an X-ray diffraction pattern of gadolinium monoantimonide thin film deposited on cital substrate. The analysis has shown that the films have a NaCl type crystal lattice with crystal lattice equal to 6.25 D which is in good conformity to literary data of volume crystal of monoantimonide [9].

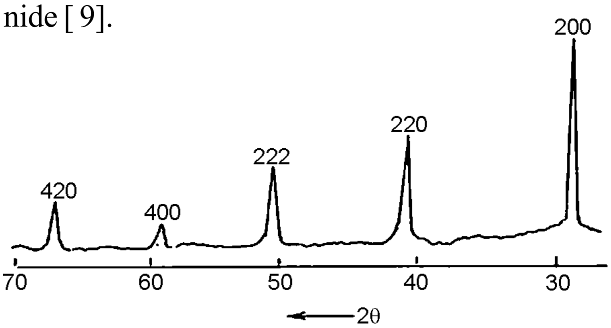

Fig. 1. X-ray diffraction pattern of gadolinium monoantimonide film (the substrate – polycrystalline pyroceramic, thickness of the film – 1.2 mkm).

In fig. 2 – 6 there is brought the dependence of electro-physical parameters on temperature in the whole section.

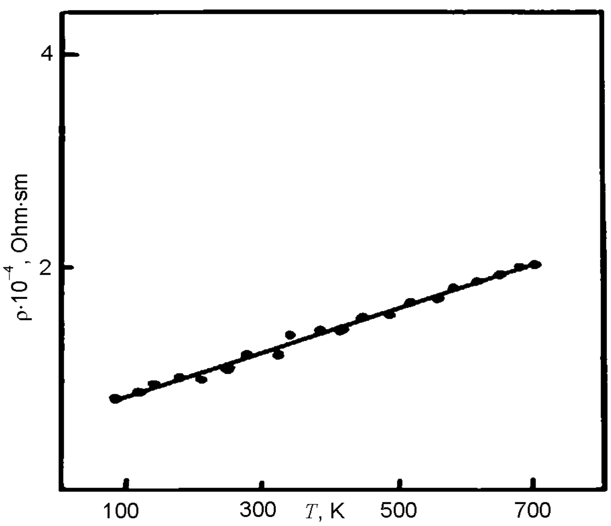

Fig. 2. A diagram of specific resistance dependence on temperature (the substrate – polycrystalline pyroceramic, thickness of the film – 1.1 mkm).

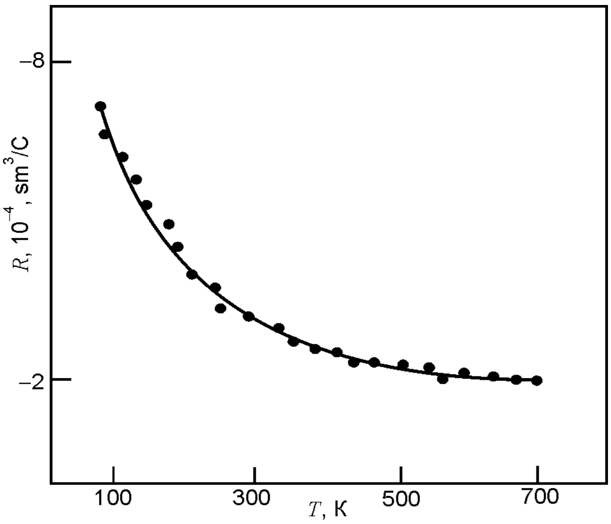

Fig. 3. Diagram of Hall constant dependence on temperature (the substrate – polycrystalline pyroceramic, thickness of the film – 1.1 mkm).

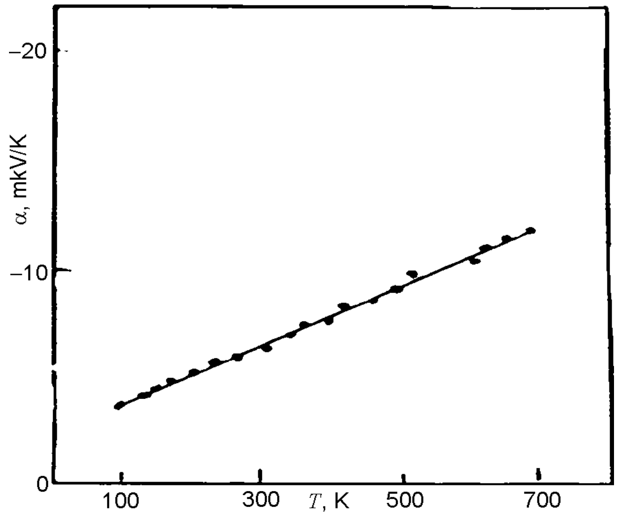

Fig. 4. Thermo emf dependence on temperature (the substrate – sapphire, thickness of the film – 1.2 mkm).

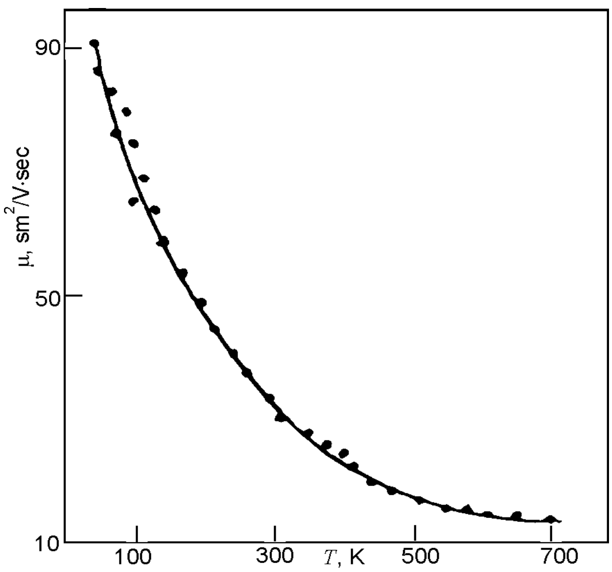

Fig. 5. Diagram of electrons mobility on the temperature (substrate – polycrystalline pyroceramic l, thickness of the film – 1.1 mkm).

As it is seen from the fig. 6 – the value of the specific resistance and the character of temperature dependence is analogous for tulium, iterbium, samarium and praseodium mono and diantimonides.

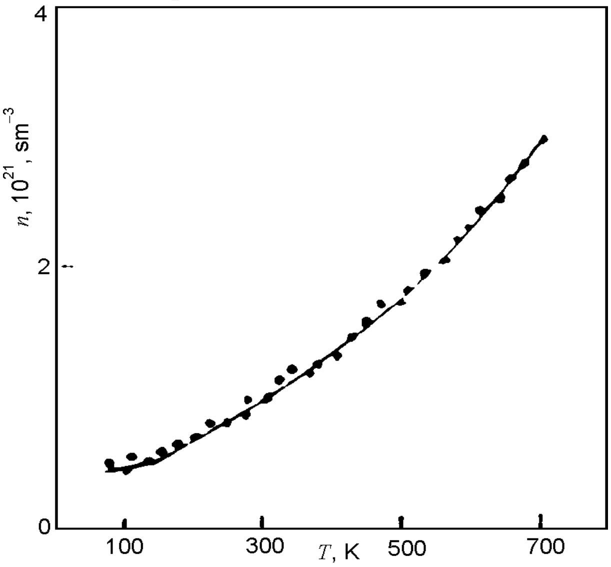

Fig. 6. Dependence of electron concentration on temperature. (substrate – polycrystalline pyroceramic, thickness of the film – 1.1 mkm).

From fig. 6 and 7 it is clear that within the whole temperature interval, the Hall constant and thermal electromotive force have the negative sign. The absolute meaning of the Hall constant is significantly and nonlinearly reduced. The absolute value of thermoelectromotive force is linearly increased. The results of measurement of the Hall constant values have been used for calculation of mobility and concentration of charge carriers (electrons) by one-zone approximation. It should be indicated that such an approximation is not completely correct. As it is shown in fig. 6 and fig. 7 the electron concentration is weakly increased and the mobility is reduced. The character of dependence of electrophysical parameters on the temperature and the magnitudes of their absolute values give us a possibility to conclude that the gadolinium monoantimonide is a semimetal.

The reflection and absorption spectra of gadolinium monoantimonide films have been measured by us in a wide section (band) of spectrum at the room temperature 0.05 – 5.5 eV.

Fig. 7 – shows the reflection spectrum. As it is seen from the drawing during the energy of 0.287 eV. There is possible to notice a well-expressed longwave minimum; well expressed a reflection line (band) with the maximum at 0.41eV and minimum at 2.1 eV.

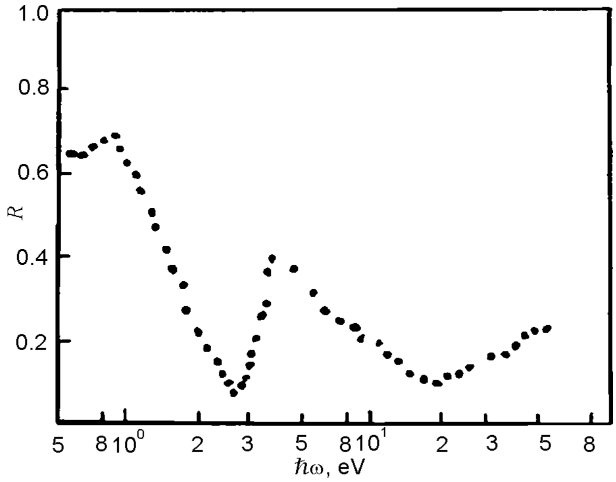

Fig. 7. The reflection spectrum of gadolinium diantimonide thin films (substrate – sapphire, film thickness – 1.2 mkm).

In fig. 8 it is shown the absorption spectrum on which it is possible to be distinguished three peculiarities: a relatively high transparency band (section) in the vicinity of 0.45 eV; a structure at 0.25 eV and a band (section) of absorption acute growth for the energies which exceed to 0.1 eV.

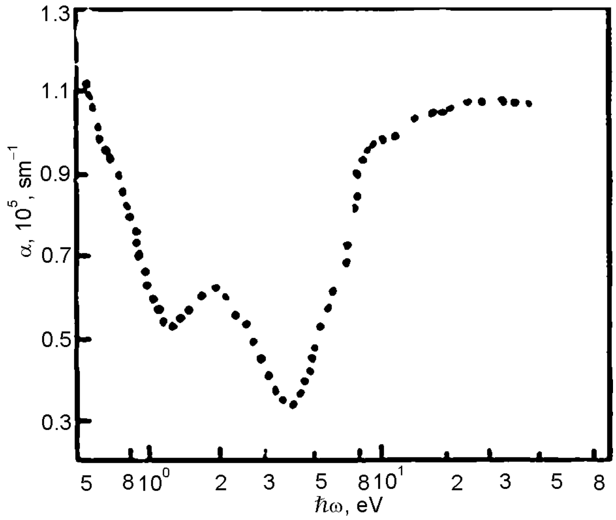

Fig. 8. The absorption spectrum of gadolinium diantimonide thin films (substrate – sapphire, film thickness – 1.2 mkm).

Unfortunately it is impossible to make an unambiguous explanation of reflection and adsorption spectra. The sole thing which might be told for sure is that a distinct minimum in the reflection spectrum and a relative longwave increase of absorption coefficient can be ascribed to plasma oscillations of charge carriers.

As it is seen from the fig. 9 a real part of dielectric penetration in spectrum of infrared band ε_1 strives to very high negative values indicating the fact that in optical processes the free charge carriers play a

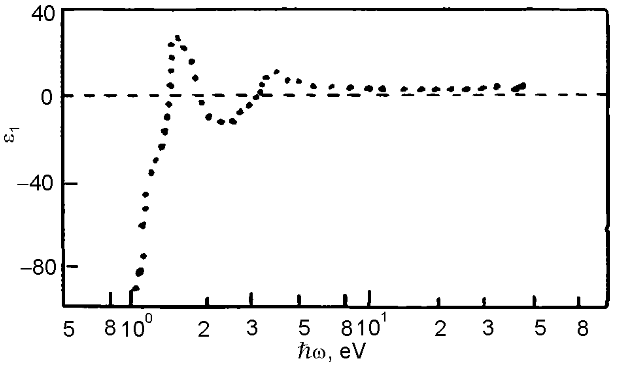

Fig. 9. The dielectric penetration spectrum of gadolinium monoantimonide (substrate – sapphire, film thickness – 1.2 mkm).

great part. The ε_1 changes its mark three times, besides twice by positive slope at 0.15 eV and 0.31 eV. Let's note that the energy at 0.31 eV corresponds to the relative energy at the maximum of loss function which indicates to the fact that this energy corresponds to the plasma resonance. Because of closeness of this energy to the energy of absorption band the absorption is very strong, and the excitations are damped and that is why that the "real" plasma adsorption frequency should exceed the theoretical value of this frequency.

CONCLUTIONS

Within a wide temperature interval 90 – 700 K the main the dependence of electro-physical parameters of GdSb films (specific resistance, Hall constant and thermo-electromotive force) on temperature have been measured. It has been shown that the films are semimetals.

The reflection and adsorption spectra of received films have been studied for the first time within the intervals of 0.05 – 55 eV. On the basis of received data the diagram of the dependence of penetration real part and loss functions on the photon energy have been plotted. It has been shown that the spectra of optical parameters have quite a complex character (nature).

REFERENCES

1. Gasgnier M. Rare earth compounds, oxides, sulfides, silicides, boron as thin films and thin crystals//Phys. Stat. Solidi A. – 1989. – Vol. 114, No. 11. – P. 11-71.
2. Delovaya pressa//2002. – No. 9, 132/06.03.
3. Daou R., Haase A., Doerr M., Rotter M., Weickert F., Nicklas M., Steglich F. Magnetoelastic quantum oscillation in GdSb to 55 T//J. Phys. Conf. Ser. 273 012111 doi: 10 1088/1742-6596/273/1/012111. – 2011.
4. Koiama K., Tomimatsu T., Yoshida M., Li D., Motokava M. Observation of cyclotron resonance on GdSb//Physica B: Condensed Matter. – 2002. – Vol. 312-313. – P. 880-881.
5. Nakane H., Yamazaki S., Fujishiro H., Yamaguchi T.,Yosizawa S., Numazava T., Okamura M. Low temperature properties of HoSb, DySb and GdSb//Cryocoolers. – 2002. – Part 10. – P. 443-448.
6. Nakane H., Yamazaki T., Yosizawa S., Numazava T. Specific heat and magnetic properties of GdSb//Cryocoolers.–2002.–Part 12.– P. 467-471.
7. Dzhabua Z.U., Gigineishvili A.V., Iluridze G.N., Minashvili T.A., Kupreishvili I.L. Prigotovlenie i mehanicheskie svojstva plenok GdSb//Materialy 5oj mezhdunarodnoj konferencii "Fiziko-himicheskie osnovy formirovaniya i modifikacii mikro- i nanostruktur". (Kharkov). – 2011. – T. 1. – S. 32-35.
8. Uhanov Yu.I. Opticheskie svojstva poluprovodnikov. – M.: Nauka, 1977. – 366 s.
9. Kost M.E., Shilov A.L. i dr. Soedineniya redkozemelnyh Elementov.– M.: Nauka, 1986.–271 s.