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RECOMBINATION IN $HgGaInS_4$ SINGLE CRYSTALS

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Abstract—Photoelectronic processes in $HgGaInS_4$ have been studied by photoconductivity, thermally stimulated conductivity and photoluminescence. An exponential distribution of traps with a slope of 23 meV/decade as well as a further electron trap system with an activation energy of 70 meV have been localized below the bottom of the conduction band. Radiative electron transitions are shown to occur mainly from exponentially distributed traps to an acceptor level characterized by an activation energy of 220 meV. © 1997 Elsevier Science Ltd. All rights reserved

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1. INTRODUCTION

$HgGaInS_4$ is a layered phase which forms as a result of interaction between the defective chalcopyrite $HgGa_2S_4$ and the spinel $HgIn_2S_4$. The structure of $HgGaInS_4$ lattice is based on a hexagonal close packing of anion atoms, where cations are distributed in layers and occupy both tetrahedral and octahedral voids [1]. The unit cell parameters of $HgGaInS_4$ hexagonal lattice are $a = 0.39$ nm and $c = 3.14$ nm [1].

Preliminary data concerning absorption, photoconductivity (PC) and luminescence (PL) have already been reported [2]. The band gap was determined to be 2.41 and 2.46 eV at 300 and 80 K, respectively [2]. The presence of quasi-continuously distributed states responsible for the exponential tail of the absorption edge was also stated.

In view of its potential applications in optoelectronic devices [2], it is important to explore the relationship between PC and PL emission properties, in order to explore correlation among the intraband energy levels involved in both processes. With this in mind, thermally stimulated conductivity (TSC), spectral distribution and temperature dependence of PC and PL, as well as PC dependence upon the excitation light intensity (lux-ampere characteristic), have been investigated.

2. EXPERIMENTAL

$HgGaInS_4$ single crystals, $10 \times 10 \times 0.1\,mm^3$ in volume, were grown at the Institute of Moldavian Academy of Sciences by chemical vapour deposition technique with iodine as transport agent. Chemical and structural analyses have shown that deviation from nominal composition was less than 3 at.% and no spurious phases were observed. Samples showed n-type conductivity and a resistivity of about $10^7\,\Omega\,cm$ ($T = 300$ K). Ohmic contacts were obtained by thermal vacuum evaporation of indium onto the (0001) crystallographic face of the samples. PC measurements were performed with a 9 V bias voltage.

A 150 W tungsten lamp coupled to a 0.3 m McPherson monochromator was used as a source of excitation of the photocurrent. The flux-current measurements were obtained by exciting the samples with the 514.5 nm Ar^+ laser line over eight orders of magnitude of the light intensity. To investigate TSC, the samples were illuminated at 85 K for 20 min with 500 nm radiation and then kept in darkness. After 10 min, a thermal scan at a constant rate of $0.1\,K\,s^{-1}$ started. D.C. detection technique was employed to measure the spectral distribution and temperature dependence of PC as well as the TSC and lux-ampere characteristics.

PL excitation was performed with a multiline Ar^+ laser ($\lambda_{exc} = 488 + 514.5$ nm). The PL signal, filtered by a monochromator type SPM-2 (Zeiss, Jena), was detected by a cooled photomultiplier. The energy

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