HIGH SENSITIVE ULTRA-VIOLET PHOTO DETECTOR AND INTERMEDIATE TYPE EXCITONS IN SEMITRANSPARENT METAL-A^3B^6 SEMICONDUCTOR BARRIER STRUCTURES

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Photoelectric spectrums of Shottky barriers on InSe, GaSe and GaS layered crystals are investigated from band edge of corresponding crystals up to ultra-violet (6.5eV) quantum energies. Spectral dependence of photo-resistors and barrier structures are essentially different, especially in the region of intermediate type excitons. It is shown that InSe-Au Shottky barrier structure is high sensitive photo detector ($10^6 - 10^7 V/Wt$) in ultra-violet region.

1.INTRODUCTION

Semiconductor materials are used widely in problems of detection of electromagnetic radiation with different quantum energies- from far infrared (FIR) up to γ-radiation regions.

The most of semiconductor photo detector devices operate on the base of the conductivity change $\delta\sigma$ of the material under the radiation. For different regions of quantum energies $\hbar\omega$ the mechanisms of interaction of radiation with carriers in semiconductor, and as a consequence the change of conductivity, is due to different mechanisms.

For FIR these mechanisms are the shallow impurity photo ionization, free carriers heating and, for small and zero gap semiconductors, increase of free carrier concentration due to interband absorption.

For near IR and visible regions the interband absorption is the main mechanism ($Hg_xCd_{1-x}Te$- and PbSnSe type semiconductors in IR and InSb, InSe, GaAs, GaSe ZnSe CdSe CdS and so on in visible regions).

With increasing of the quantum energy from the visible to ultra violet (UV) region the interband absorption still remains the main mechanism of photo conductivity (PC). But with increasing of the energy gap- E_g of semiconductor the efficiency of PC is decreased because the increase of carriers effective mass takes place. As a result the mobility $\mu_i = e\,\tau_p / m_i^*$ (τ_p- carriers elastic scattering time) and lifetime τ_i of photo-excited carriers decrease take place ($\delta\sigma \approx \sum_i e_i \mu_i \delta n_i, \delta n_i = G\tau_i$ where $G-$ the rate of carriers generation).

There is another more valuable reason for decreasing of PC efficiency with increasing of quantum energy. This is the decrease of the radiation penetration length $J(x) = J_0 \exp(-\alpha x)$, ($x_p \approx \alpha^{-1}$) inside of semiconductor as a result of absorption coefficient (α) increase with quantum energy. For example at UV energies $\varepsilon > 4E_g$ for the most of above indicated semiconductors $\alpha \geq 10^7 cm^{-1}$ and penetration α^{-1} is about of a few tens $\overset{o}{A}$. This means that all radiation would be absorbed at the surface of semiconductor. But from scattering of carriers point of view the situation is different inside and on the surface of semiconductor. The existing of 3 types of surface states causes the decrease of PC at small penetration length. For this reason in classic semiconductors the PC efficiency falls to zero at UV region.

As against this the absence of surface states is characteristic for layered semiconductors (LS), because all bindings between atoms are directed inside of layered packets, and forces between layers are very weak- Van-der-Wals ones.

2.PHOTO ELECTRIC SPECTRUMS OF A^3B^6 LAYERED CRYSTALS AND THEIR SHOTTKY BARRIERS

We have investigated PC of some LS (InSe, GaSe and GaS) from band edge up to UV (6.5 eV). The results showed that at some quantum energies (2.4eV; 2.9 eV in InSe and 3.5; 3.9eV inGaSe) PC is decreased. The more detailed investigations have proved the existence of deep interband excitonic states in the region where PC decreases [1]. This excitons are characterized with small Bohr radius ($r_B \sim 10\dot{A}$) and higher binding energies ($\varepsilon_b \sim 100 meV$) than the band edge Wannier-Mott excitons (about $10-14 meV$ in these semiconductors). They are so called intermediate type excitons (ITE) which were widely investigated in alkaline-haloid crystals [2]. So the decrease of PC in the indicated region is due to the excitation of carriers from the higher effective masses bands, which are immediately captured to each other forming ITE. Being the highly binding carriers pair they can not broken up to free carries and do not give the contribution to the PC in indicated PC decreasing region. At higher energies (4-6.5eV) the PC efficiency of these layered semiconductors increases again, reaching the values much more than band edge PC. So these semiconductors are high sensitive photo detectors in UV region. But the full of PC in near UV as a result of binding of photo-excited carriers in ITE restricts the application of these photo detectors. To avoid this we have prepared the semitransparent metal (Au with 200-300A thickness) and LS Shottky barrier structures. The PC spectra of

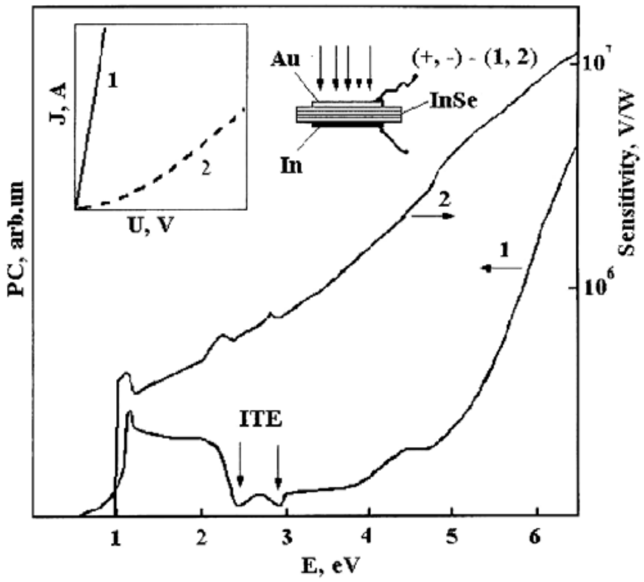

Fig.1. Photo conductivity and sensitivity spectral dependencies of Au-InSe-In barrier Shottky structure for two directions of applied electric field. The I-V – characteristics of the structure are shown in inset.

this device for two directions of applied electric field as well I-V characteristics are shown in figure1. As seen from curve 2 there is not PC decrease for barrier structure in the region where for semiconductor the PC full takes place. In opposite direction of the applied field the spectral characteristic of PC is similar to that of InSe photo resistor (curve1) [1]. The absence of the PC decreasing region is due to ionization of ITE in the electric field of the barrier, which according to our estimation is about $10^5 - 10^6 V/cm$. Decreasing of PC in opposite direction of applied electric field proves this fact (curve1). Note that the higher PC value in the UV than that in near band gap region can not be explained by perfect surface of LS only. So, in this case the UV PC would has the value as band gap one, at the best. Our comparative photo-Hall effect and photo excited carriers life-time experiments at near band gap and UV regions testifies that in the UV region photo signal is mainly due to the excitation of the holes with smaller effective masses from the deeper hole bands than band gap carriers. The same results as indicated in fig1 were obtained for GaSe and GaS Shottky barriers with ITE energy positions at 3.5-3.9eV and 4.1-4.5eV correspondingly. So we established that the main reasons of high effectiveness photo detectors of LS InSe and GaSe in UV region of radiation are: higher mobility ($\mu = e\,\tau_p / m^*$) of photo excited carriers, perfect condition of surface of LS and higher life time of photo-excited carriers τ_i. These devises are high sensitive ($10^6 - 10^7 V/Wt$ with noises smaller than 0.1 mkV) photo detectors.

[1] O.Z. Alekperov, M.O. Godjaev, M.Z.Zarbaliev and R.A. Suleimanov, Solid State Communications, 77, 65 (1991).
[2] *F.Bassani and G. Pastory* Parvachini, Electronic states and optical transitions in solids, Sidney, Pergamon Press, 1975, 391p.