Abstract

The development of new generations of laser source for fiber optic’s applications require more fast new photosensors with spectral characteristics in visible range. The idea of this work is development of technology and device – fast photosensor with spectral range adapted to modern lasers for the quickly increasing needs of optoelectronics and fiber optics communications. By pulsed laser deposition (PLD) usage UV N2 Laser for ablation $\lambda = 337.1 \text{ nm}$, energy per pulse 8 mJ and CW 60 W CO2 Laser for heating are produced thin CdS$_x$Se$_{1-x}$ films on quartz substrate. Polycrystalline thin films with thickness from 0.5 to 2.0 $\mu$m and dominant orientation – (002) are formed by energy density 4.5 J/cm$^2$ and repetition rate 20 Hz. The thin films are investigated by EDAX and SEM. The films are additional thermo treatment for increasing ratio photocurrent – dark current. This ratio reaches 10$^7$. By means of TEA UV N2 Laser with energy per pulse-0.3 mJ, pulse duration 2 ns are formed planar Ohm contacts from CdO directly onto thin film. The contacts are investigated by XRD. By means of coordinate table the contacts are formed on the backside of the structure. The dimension of photosensitive structure is 250x250 $\mu$m. The distance between contacts areas is 10 $\mu$m. The spectral response of devices is measured. The maximum spectral sensitive is at $\lambda = 575 \text{ nm}$. Lux ampere characteristics are measured. The increasable fronts and decreaseable fronts at the structure are measured. They are 2 ns, at ratio 1000.

Keywords: Fast photosensor, visible range, PLD, planar Ohm contacts, EDAX, SEM, XRD.

1. INTRODUCTION

The photosensitive devices on base of CdS$_x$Se$_{1-x}$ are well known and there are standard technologies developed for their producing, like: thermal evaporation, magnetron sputtering, spray pyrolysis etc. Disadvantages of these technologies are impossibility to observe the stoichiometry during producing of layers from multi component compounds and complicated technological equipment.

Interest is the development of photosensors with PLD technology because of technological priority like: strong control of stoichiometry in process ablation – deposition, high deposition speed, easy control of growing of films with different thickness – from supper lattice to thick films, producing of films from amorphous to epitaxial structures and last but not the least simplicity of apparatus. In a number of papers successful using of PLD for deposition of different kind of A$_2$B$_6$ layers for different application [1,2,3,4]. Photosensitive organic polymers and devices on theirs base were intensively developed, but devices on base of A$_2$B$_6$ remain actuality [5,6]. At is known, the fast development of optoelectronics and fiber optics communications require new active and passive elements. It involves building up fast switching elements. Up to now photosensors are used on base of PIN diodes. Disadvantages of these devices are that the maximum of their spectral sensitivity is in the near infrared spectral range. The usage of lasers in visible spectral range for fiber optics communications is a question of present and future interest. The idea of this work is development of technology and device – fast photosensor with spectral range adapted to modern lasers and for the quickly increasing needs of optoelectronics and fiber optics communications. The choice of CdS$_x$Se$_{1-x}$ as compound is in connection with easy achieves and control of photosensitive pick with sample alternation of parameter – x.
produced at density of energy of N2 laser 4 J/sm², best characteristics regarding stoichiometry were achieved when the target had the same stoichiometry. The films with thickness from 0.5 to 2 μm were deposited using a high-speed rotating target to deflect and decrease the flight direction of the droplets to avoid the deposition droplets on films surface. The distance between substrate and target can vary from 1 to 5 cm. The quartz substrate is with dimensions – 2x2 cm² and thickness d = 0.3 mm. The substrate was heated directly by CO₂ laser up to 1000°C. The temperature of the substrate was selected by adjusting the radiation power of the CO₂ laser, measured by laser power meter. The temperature of the substrate was controlled by a Pt - PtRo thermocouple, brought into direct contact with the substrate. The typical N₂ laser energy density is 4.5 J/cm². This apparatus for PLD was successful used also for producing HTSC YBCO thin films [7]. The deposited thin films from CdSₓSe₁₋ₓ are with thickness from 0.5 to 2 μm. The thickness of films were measured by means of interferometer method. For light source was used HeNe laser at λ = 632.1 nm. The thickness was defined at the first interference maximum according to formula: d = λ / 4Nn, where λ is the wavelength of probe radiation, N – the number of laser pulses for reaching first interference maximum, n – coefficient of refraction. The rate of films growth is 1 – 2 A/s. The stoichiometry of the films and the target was studied by EDAX. The comparative analysis showed that the films and the target had the same stoichiometry. The films with best characteristics regarding stoichiometry were produced at density of energy of N₂ laser 4 J/sm², repetition rate 15 Hz, distance target – substrate of 4 cm and heating temperature 380°C.

On Fig. 2 is shown EDAX analysis for thin film with thickness 800 nm after laser thermo treatment by CW CO₂ laser.

Fig.2 EDAX analysis of PLD CdSSe film

Homogeneous films are deposited on area of 2 cm². The film morphology was studied by SEM. Polycrystalline films with distinct orientation along axis (002) at this technological parameters have been prepared.

On Fig.3 is shown the photo of CdSₓSe₁₋ₓ film with thickness 1.5 μm.

Fig.3 SEM photo of CdSSe film deposited by PLD

2.2. Laser formation of Ohm contacts

The technology for formation of Ohm contacts for compounds like CdSₓSe₁₋ₓ are characterized with selection of material for contacts, the process of deposition and the surface properties of semi conducting material. The traditional technologies are thermal vacuum evaporation, cathode and magnetron sputtering, pulverization of metals like In, Ga, alloy of In-Ga or Al and subsequent diffusion in to semi conductive material [8,9]. The dissociate work of electrons for In, Ga are 2.5 eV and 3.8 eV respectively and is smaller then the energy for electron coincidation for films CdSₓSe₁₋ₓ (4.6 eV). Depending on that they are donors admixtures.

The diffusion of these metals determines the areas with high conductivity (so called chemical antystoped layers). The problem of producing this type of contacts is the requirement for strong observation of technological regimes – temperature for diffusion, depending on that process and presence of O₂. Distribution of these technological parameters defines formation of Ohm contacts with unlinear characteristics and instability at higher temperature. Another disadvantages of these materials are their bad transparency in visible spectral range, which limits the increasing of bearer’s injection. For transparent contacts usually are used oxides of metals like ZnO, SnO, In₂O, InSnO, and CdO. The oxides with definite stoichiometric composition are characterized with relative high specific resistance. The increasing of resistance of these materials is possible with purposeful alteration of their stoichiometric composition and formed of systems of type XOₓ (XO₂+XO+X), where X is the selected metal. This type of oxides is characteristic with n-type of conductivity. The donors are vacations of O₂ knots on crystalline lattice or metal’s ions in the space between knots. Films from this type are produced throw cathode sputtering or chemical methods [9,10]. In papers [11,12] was demonstrated successful producing of high power Ohm contacts from Cd-CdO, by means of treatment of films with UV N₂ laser. The method is based on the use of focused laser beam of UV pulse laser for inducing a selective chemical reaction on preliminary given area of the films under treatment and in a preliminary given depth in the films. The TEA N₂ laser radiation (λ = 337.1 nm, energy per pulse ~ 0.3 mJ, repetition rate up to 20 Hz, pulse duration ~ 2 ns, aperture 2x2 mm²) is focused by a quartz objective on to the sample. With the help of a holder the sample is put on the X-Y CNC coordinate table, controlled by PC [12]. The experiments require air atmosphere and room temperature. The irradiated surface of the film under treatment depends both on the dimensions of the focused laser beam and the...
predefined CAD programmed. The density of laser beam energy, the repetition rate of the laser pulses and the speed of moving of sample has been experimentally selected for the chosen technological regime. The experimentally chosen parameters have been selected so that there is no ablation of film. The density of single laser pulse energy is under the threshold of evaporation of film, but high enough for selective evaporation of the lighter chemical bond volatile elements, such S, Se. The experimentally chosen energy density of the laser beam is from 1 to 2 J/cm² and the repetition rate 10-12 Hz. After treatment the resistance was measured with the help of a four-probe method. The resistance is 10⁹ Ω m. The optical transmission of CdO is for λ < 440 nm ~0.2 and for λ > 440 nm is higher than 70%. Vertically the structure of contacts built is as follows CdS-Cd-CdO. On Fig.4 XRD indicates, that the surface consists of CdO.

2.3. Making the structure

The quartz substrate with the formatted active layer from CdSxSe1-x is put on XY CNC coordinate table, controlled by PC and with help of TEA N₂ Laser described in point 1.2. Contact of CdO at each 10⁻³ m, 120⁻³ m wide strips are formed in the active film. After the formatting of this the quartz substrate is scribed with standard technology and the results is photosensitive structure that is shown on Fig. 6.

2.4. Measurement devices' parameters

2.4.1. Spectral response

On Fig.7 is shown Spectral Response of photo sensor. It is measured with Spectrophotometer CF-46

![Fig.7 Spectral response of photo sensor](image)

2.4.2 Lux Ampere Characteristic

On Fig.8 is shown the Lux Ampere Characteristic of photo sensor. It is measured by standard device in interval of 0 - 2000 Lx.

![Fig.8 Lux Ampere Characteristic of photo sensor](image)
2.4.3 Dynamic properties

The dynamic properties of the photosensor are defined from increasing and decreasing time of the photoconductivity. There is not possibility to get background light from outside sources in fiber optic systems. It is also important that the light stream from Laser must be received without bending. The time dependence of photoconductivity relaxation for A2B6 compounds from the stimulation level is given with relation \( \tau = \tau_0 \left( \frac{I_0}{I} \right)^\alpha \) where \( \alpha = 0.4 - 0.8 \) [9]. The fronts of increasing and decreasing of relaxation time \( \tau_r \) and \( \tau_f \) of the described sensor are 2 ns and they are measured by oscilloscope Tektronix -1GHz. As a source for short light impulses is used Day Laser with \( \lambda = 570 \text{ nm} \), pumped with N2 Laser with pulse duration 5 ns. On Fig.9 is shown dependence of the ratio voltage fall \( \frac{U_r}{U} \) on the charge resistor \( R=10 \text{ kΩ} \) connected sequence to sensor at power voltage \( U=5\text{V} \) and repetition rate of LED. As a source for short light impulses is used. Super luminescent LED with \( \lambda_{\text{max}}=570 \text{ nm} \) at two ratio \( \gamma=10^3 \) and \( \gamma=10^5 \).

3.Conclusion

The new sensor be known by other photosensors with the next parameters:

* Regarding classical photoresistors it is considerable faster \( \tau_r \) and \( \tau_f \) are 2 ns, that do it competitive like PIN photodiodes, but at higher ratio of signal - \( \gamma=10^3 \).
* The photosensor is based on CdSxSe1-x that allows easy regulation of maximum spectral photosensitivity in visual spectral region.
* The usage technologies for prepared - PLD and direct formation of transparent high power Ohm contacts for visual spectral region by means of coordinate table and PC create possibility for easy and cheap manufacturing of the device.
* Photosensor find application as two directions in dependence from the type of the package:
  - Fiber-Optics Applications –according described design;
  - Standard application - at packaging in package, where the light illuminate both two sides simultaneous. As the contacts are transparent, then there is super injection into active layer and this make the device faster;
* The basic conclusion from recent paper is that the PLD Technology and Direct Laser formation of Ohm transparent contacts in the structure create possibility for producing of new class fast photosensors with two sides super injection on bearer into the active layer. The investigation reveals the big possibility for application of device.

References