# ON THE POSSIBILITY OF THE QUANTUM YIELD INCREASING OF IR - RADIATION DETECTORS

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The construction and technological plan of manufacture of IR- radiation detectors that increases the quantum yield is proposed. The comparative analysis spectral and pulse characteristics of detectors manufactured on the basis $Cd_{0,2}Hg_{0,8}Te$ monocrystals by a traditional diffused planar process and presented plan is given. The obtained data confirm advantages of the presented construction and technological plan, that allow to increase a quantum yield up to 20 %.

At the present time the problem of increasing of IR-radiation photodetector sensitivity on a spectral region > 10 microns is actual one and investigators try to find the additional resources of its increases. The sensitivity of photodetectors of IR-radiation is described by the formula [1]:

$$R = \eta e\mu\tau/d\sigma \quad , \qquad (1)$$

where $d$ - width of a sample, $\sigma$ - conduction, $\tau$ - nonequilibrium carrier lifetime, $\mu$ - mobility, $\eta$ - quantum yield.

One of the method of the sensitivity increase is the use the factor of its proportional dependence on $\eta$, the value of that is equal 1 for ideal photodetectors, and for modern hipersensitivity photodetectors - 0,2-0,5 [2]. The semiconductor materials used for the detector manufacture are relatively transparent for wavelengths the fundamental absorption edge, when the absorption coefficient begins to decrease and the part of radiation transits through a material without any interactions with the crystal. If this part of radiation will be returned to a photodetector, then it will be possible noticeably to increase its photoelectric parameters. This purpose was realized in the article [1], by means of the mounting a mirror behind the photodetector, or the use of integrant cavity providing the returning scattered photons to a photodetector. In article [3], the prism form was given to germanium photoelectric inverse side, so that for the radiation entering through a leading face the process of total internal reflection took place. Thus, it is possible to increase value $\eta$ by the different constructor methods.

Constructions and production process of photoresistors, mentioned in [4], give us the possibility of applying both above mentioned methods of increasing of a quantum yield at of multiple photodetectors of IR-radiation manufacture.

The fact of carrying out the operations of a chemical etching of semiconductor crystal surfaces with the formed topology of the photosensitivity elements is used in this case. It is known, that in interelement backlashes of the order 0,1 mms the crystal etching velocity gradient that decreases in the depth of this crystal. This process leads to that the photosensitivity element has the prism form shape not of a parallelepiped with trapezoid form section. As, this surface is inverse one, then by drawing on it a reflecting coating, it is possible to achieve multiple internal reflection of radiation in volume of a photosensitivity element, that will lead to the increase of a quantum yield.

We manufactured two photoresistors with four elements with sizes 0,1x0,1 мм$^2$ and interelement backlashes 0,1 mms from two half-samples of the same monocrystal n-$Cd_{0.2}Hg_{0.8}Te$. One - on a traditional planar process, second – on the following technological plan:

- On one of plane surfaces of an initial semiconductor plate by the photoengraving method the topology of photosensitivity elements is constructed;
- The chemical etching of the semiconductor plate on depth ~ 20 microns is carried out;
- The protective coating of the photoresist is brought on all surface of crystal, except for fiducial points and the additional etching on the depths ~ 10 microns is carried out;
- The photoresistive layer is deleted and on all surface of a crystal the anodi oxide layer is constructed, and then by vacuum raising method the argentum layer with the thickness ~ 0,3 microns, having reflection coefficient ~99 % is brought;
- The plate is pasted by the manufactured side on a germanium substrate;
- After a desiccation of a glue the thickness of a semiconductor plate is transformed up to the thickness ~ 40 microns by a method of a chemical-mechanical polishing;
- The chemical etching of a plate before exposure of fiducial points created earlier on its inverse side is carried out;
- The topology of photosensitivity elements is formed by the photoengraving and vacuum raising;
- The finish machining is carried out on the installation of ion etching "Imsid", then, on installation of diamond kerf partitioning off-the-shelf units of photosensitivity elements are carried out,that have the form given on figure 1.

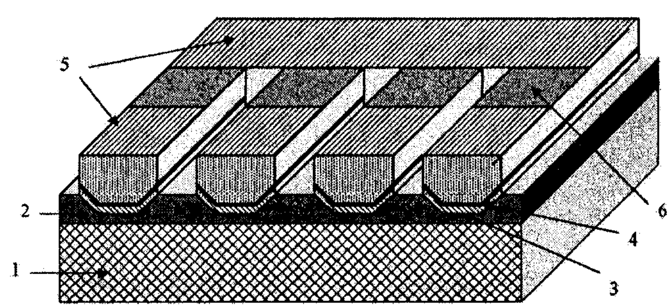


*Figure 1.* General view of a photosensitivity element:
1 - germanium substrates; 2- glues; 3- layer of argentum; 4 - anodi oxide layer; 5 - bonding contact pads; 6 - photosensitivity site.

Further on obtained samples the measurings spectral and pulse characteristics of the photoconduction are made.

As it is known, linear photoconduction for thin samples is described by the formula [2]:

$$\Delta\sigma_{pc} = e\eta\mu\tau I_0[1-\exp(-\alpha d)]h/l \quad , \qquad (2)$$

where $\alpha$ - absorption coefficient, $I_0$ – incident radiant flux on the photosensitivity site of the detector, h and $l$ are width and length of a photosensitivity site of the detector.

The obtained results for both photoresistors and spectral characteristic of a photoconduction of an initial monocrystal are given in a figure 2. Comparing the obtained results it is

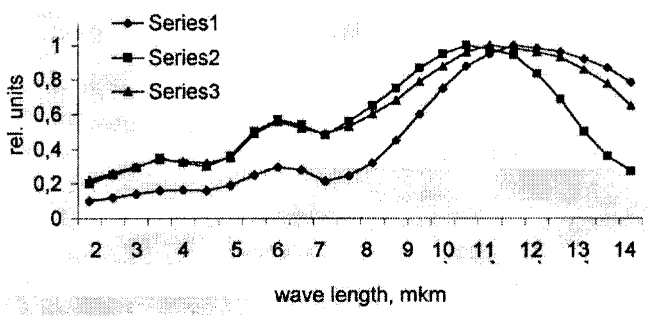


*Figure 2.* Relative spectra.
Series 1 – initial monocrystal;
Series 2 – traditional technology;
Series 3 – presented technology.

possible to note, that the maximum and long-wave boundary of sensitivity are shifted in more short-wave region respect of initial monocrystal ones. This fact is connected with absorption coefficient decrease and it gives to that the long-wave radiation with absorption coefficient less than $10^3$ см$^{-1}$ transits through the semiconductor not interaction with it. At the same time for a device manufactured on the presented technological plan, the maximum of sensitivity is shifted respect of one manufactured on traditional technology on 0,5 mkm, and long-wave decrease of a photoconduction has more smooth form.

The pulse measurings are carried out on installation assembled on the basis of the $CO_2$ laser with the electrooptical modulator, permitting to gain pulses by duration ~$10^{-3}$ - $10^{-7}$ seconds, with front of the increase and decrease no more than $10^{-8}$ seconds. The obtained results are given in a figure 3. This curves are analyzed according to a procedure and formula given in [2]:

$$\eta = 2tg\varphi/e\mu\alpha I \quad , \qquad (3)$$

where $\varphi$ - is the angle of the slope of an initial region of a pulse photoconduction.

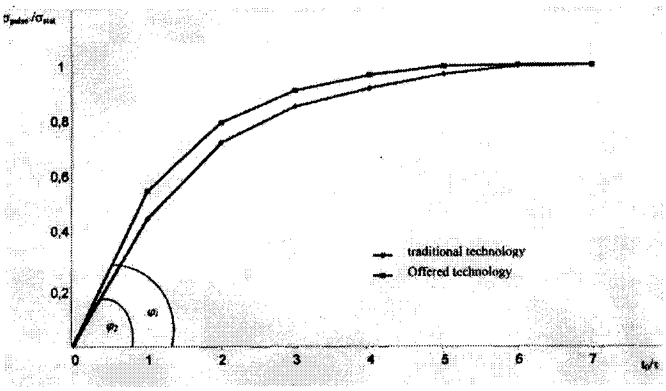


*Figure 3.* Pulse photoconduction.

For exact definition $\eta$, it is necessary also separately to measure mobility, absorption coefficient and absorbed light energy. But in our case for the proof that the delivered problem of the increasing of a quantum yield is reached, it is enough to obtain the relation $tg\varphi_1/tg\varphi_2$ , where $\varphi_1$ and $\varphi_2$ are angles of the slope initial sections of the pulse photoconduction of elements, manufactured by the presented technology, which that is equal ~1.2 e.g. the quantum yield increases up to ~20 %.

Thus the presented construction and technological plan of manufacturing IR-radiation detector photosensitivity elements allows to increase their quantum yield up to 20 %.


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## İQ-DETEKTORLARIN KVANT ÇIXIŞININ ARTIRMA İMKANI HAQQINDA

İQ-detektorların kvant çıxışının artırılmasına yönələn konstruksiya və hazırlanma texnoloqiyası tədqiq olunmuşdur. Ən'ənəvi planar texnoloqiyası və təqdim edilən hazırlanma sxemi ilə istehsal olunmuş $Cd_{0,2}Hg_{0,8}Te$ əsaslı detektorların spektral və impuls xarakteristikaların müqahisəli analizi keçirilmişdir. Alınan nəticələr təqdim olunan texnoloci sxemin ən'ənəvi planar texnoloqiyasından üstünlüyünü təsdiqləyərək, kvant çıxışının 20%-dək artırmaq imkanını göstərir.

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## О ВОЗМОЖНОСТИ УВЕЛИЧЕНИЯ КВАНТОВОГО ВЫХОДА ДЕТЕКТОРОВ ИК-ИЗЛУЧЕНИЯ

Предложена конструкция и технологическая схема изготовления детекторов ИК-излучения, способствующая увеличению квантового выхода. Проведен сравнительный анализ спектральных и импульсных характеристик детекторов изготовленных на основе монокристалла $Cd_{0,2}Hg_{0,8}Te$ по традиционной планарной технологии и предложенной схеме. Полученные данные подтверждают преимущества предложенной конструкции и технологической схемы, которая позволила увеличить квантовый выход до 20%.

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