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GaAs Epitaxial Microrelief Layer

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***Abstract* – It is a report about an epitaxial GaAs relief layer with 3 µ of thickness growth in Ga – $AsCl_3$ – H_2 system on n-GaAs ($n=2x10^{18}cm^{-3}$) substrate with multiple crystallization centers. Crystalline lattice on substrate surface is crystallographic disorientated with 3-5° of (100) to (110), treated in $HCl:HNO_3:H_2O$ selective acid solution and thermally processed at 230-320 °C of temperature in vacuum 2 hours, then in inert medium with oxygen presence at 550-610 °C of temperature during 2-5 min. The epitaxial layer has a relief microstructure with 2,0-2,3 µ periodic dimensions and height from 80 nm to 180 nm, forming 110-120° at the top the angle. The relief layer morphology was studied with atomic force microscopy (AFM) and metallurgic microscopy MM500T. Reflection and absorption spectrum was obtained at variable incident angle (α=0; 5; 7; and 10°). In 0,54-1,22 µ spectrum range the perpendicular (α=0°) incident razes on micro-relief surface are reflected with 0,08-0,12%, absorption coefficient at λ=0,96 is 98 1/cm. A maximal jump of the reflected energy is observed at incident angle α=7° (11,06% la λ=0,65 µ and 39,05% la λ=1,12 µ), absorption diminishes up to 76,69 1/cm at incident angle α=10°. The micro-relief layer can be utilized in building of photovoltaic cells for concentrated solar energy.**

***Index Terms* – GaAs epitaxial micro-relief layer, morphology, light reflection.**

I. INTRODUCTION

One way to increase the photovoltaic cell (PVC) efficiency is elaborating the technology of the semiconductor with nanostructure controllable growing and optimal energy band. The perfect nanostructure is the semiconductor crystalline lattice itself, for example GaAs. Introducing defects into the crystalline lattice can form another structure of high or low order with positive effect, if the defects are array arranged and have small dimensions, which can change the electronic states of the surface. Two quantum effects can be utilized to modernize the PVC construction: the quantum effect of charge multiplication at one photon of sun energy reception [1] and the effect of light reflection multiplication from a micro-textured surface of PVC.

We know photovoltaic cells with micro-textured layers [2, 3], which increase the efficiency of the solar energy transformation. The positive effect depends on the construction and the technology of the micro-textured layer growth in the cycle of PVC production. Cornfeld A. and Varghese T. [3] created the micro-texture on the glass screen utilized in the protection of the active surface of light reception. The method can be utilized for PVC fabrication indifferent of semiconductor materials.

Textured PVC with silicon (Si) plane p-n junction [4] is meant to be used for space applications and is fabricated for commercialization. The first semiconductor layer of the cell is textured, that is to say, it is transformed into a three-dimensional layer, which contains small pyramids with 1-2 micron of height, obtained, for example, by pickling the Si (100) surface in anisotropic solution with 2-3% of NaOH. After the treatment are formed quadrilateral pyramid limited by (111) crystallographic surface forming at the top an angle of 70,5°. This is the textured layer. The p-n junction is formed by phosphor diffusion after the formation of the specific for silicon textured layer and it doesn't have a texture character.

The PVC textured surface diminishes the optic losses thanks to multiplication of the light reflection effect from pyramid surfaces. The silicon technology is inaccessible for binary compound semiconductors. In this work it is reported a GaAs relief epitaxial layer growing on a substrate with multiple centers of crystallization formed by chemical method.

II. EXPERIMENTAL

2.1. Crystallization centers formation

The experimental samples were carried out from n-GaAs plate (100) as a substrate with 400 µ of thickness and $2x10^{18}cm^{-3}$ of alloyed by tin. The crystal lattice on the plate surface is disorientated at 3-5° (100) to (110). The plate is degreased in organic solution, corroded in ammoniac solution and dried into a flux of hot air, then it is introduced in selective acid solution $HCl:HNO_3:H_2O$ for no more than 30 sec and it is abundantly washed with deionization water. The plate is subjected to thermal processing in the vacuum at the 230-320 °C of temperature during 2 hour then at 550-610 °C of temperature during 2-5 min in the inert condition with oxygen presence [5].

2.2. Epitaxial layer growing

A GaAs epitaxial layer with $n^o = 4 \times 10^{17}$ cm^{-3} of concentration and 3 µ of thickness was grown by utilizing the planar growing technology with reaction transport in Ga – $AsCl_3$ – H_2 system on GaAs substrate preparation by the described above method. The obtained layer has a three-dimensional morphology structure.

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2.3. Research methods.

Morphology study of GaAs relief layer was performed with the atomic force microscope (AFM) and metallurgic microscope MM500T utilization. Measuring of the optic properties was effected with the ZMR-3 monochromator at the room temperature in visible and infrared spectrum interval. Reflection spectrum was obtained at the same installation with variation ($\alpha=0^o$, 5^o, 7^o and 10^o) of the angle between incident and reflection razes. The GaAs semiconductor in the relief layer was identified by Roentgen razes diffraction.

III. RESULTS AND DISCUSSION

The n^+-GaAs epitaxial layer grown on the surface of substrate with defects in the Ga-$AsCl_3$-H_2 technological system takes the surface form of the substrate. Morphology of micro-relief epitaxial layer obtained on AFM is presented on image in fig. 1.

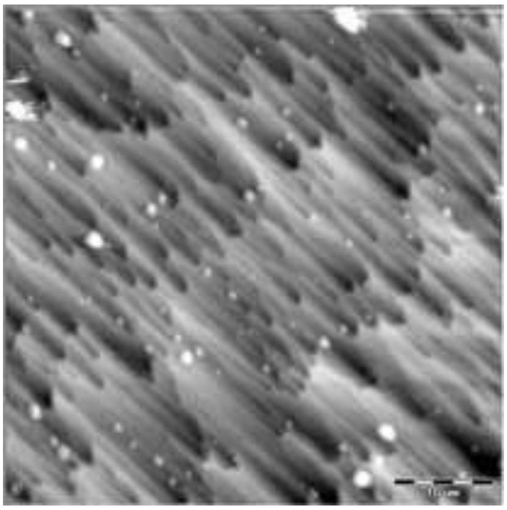

Fig. 1. GaAs epitaxial micro-relief layer

Probable, the defects on the surface of GaAs substrate formed by crystallographic disconcerting can be activated or decontaminated, can be developed by chemical method, so we have a control instrument for crystallization centers on GaAs surface. But the industrial plate surface contains other defects, remained after the mechanic processing of the semiconductor at cutting up the plates, at grinding or polishing the plates etc. Those defects are limited in accordance with the standard requirements of the product and form the metallurgical surface of the semiconductor, which determines the quality of subsequent technological operations. Influence of the uncontrollable defects on quality of the relief epitaxial layer remains an object of study for the future.

The objective of the presented study is to demonstrate the applicability of GaAs advanced epitaxy technology from gaseous phase in elaboration and manufacturing of the semiconductor device with nanostructure layer included in construction [6]. A transversal section of the GaAs relief epitaxial layer with textured dimensions on the surface measured by AFM is presented in fig. 2. In the image we observe that the epitaxial layer has a relief microstructure on a surface with 2,0-2,3 μ of periodical dimension and the height from 80 nm to 180 nm forming an angle of 110-120^o at the top.

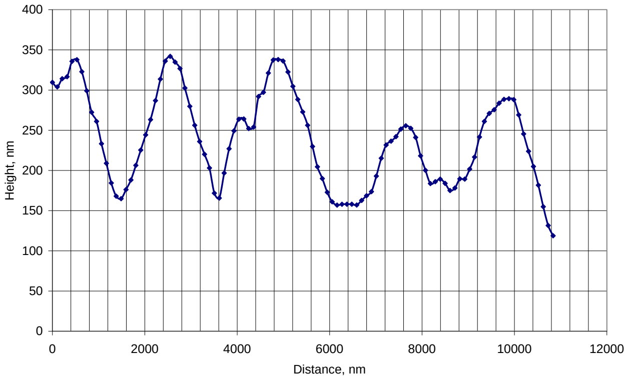

Fig.2. AFM measured cross section of GaAs epitaxial micro-relief layer.

The micro-relief on the surface changes the optical parameters of layer. Reflection spectrum of GaAs micro-relief is presented in fig. 3. for some values of incident angle.

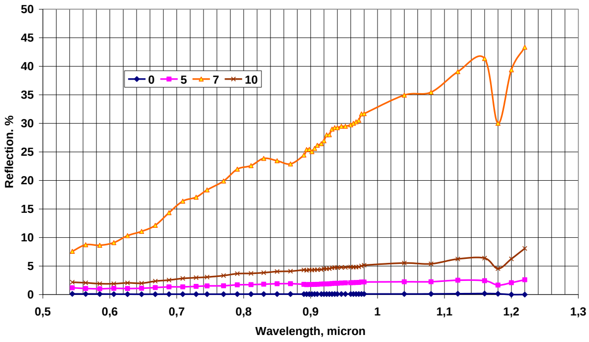

Fig.3. Reflection spectrum of GaAs relief layer in dependence of the angle α between incident raze and perpendicular axis on surface layer (α = 0, 5, 7 and 10^o).

As shown, from drawing in spectrum range 0, 54-1, 22 μ all incident raze perpendicular (α=0) on a micro-relief surface are absorbed by the GaAs layer (reflection 0, 08-0, 12%). The razes with incident angle $\alpha=5^o$ are reflected more intensively by the surface in the spectrum range, which increase from 1, 06% to 2, 59% to infrared range. A jump of energy reflection is observed at the incident angle $\alpha=7^o$ (11, 06% at λ=0, 65 μ and 39, 05% at λ=1, 12 μ). Further rising of the incident angle ($\alpha=10^o$) leads to diminishing of the reflective energy. The dependence of light reflection from micro-relief layer on the incident angle and on the light wavelength is shown in fig. 4.

As shown in fig.4, the graphic information demonstrates that the reflection coefficient of light with 7^o of incident angle from micro-relief layer enhances significantly in infrared range of spectrum. Being absorbed, this light might have warmed up the semiconductor. Another positive effect observed at the micro-relief layer application in PVC construction is the large moving interval of incident angle (+/- 5^o), when the reflection light from surface is minimal (R=0, 08 – 1, 82% at λ=0, 83 μ). Antireflective layers are applied for PVC with planar surface to obtain these performances in diminishing optical losses.

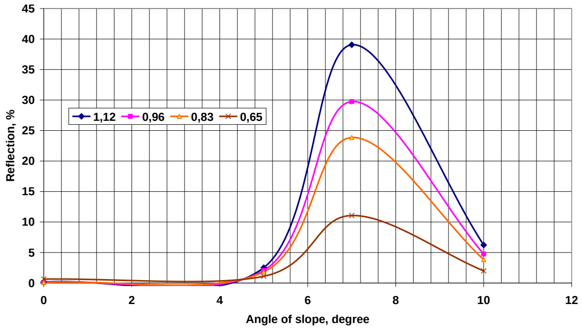

Fig.4. Light reflection dependence on GaAs micro-relief layer in function of incident angle at difference wavelength (o, 65μ, 0,83μ, 0,96μ, 1,12μ)

The absorption spectrum of GaAs micro-relief epitaxial layer is shown in fig. 5 for different value of the incident angle. Absorption after fundamental threshold of semiconductor on wavelength axis is stabilized as constant, but is changed in function of the incident angle of light. The absorption spectrum is presented in fig. 6. The absorption coefficient is diminished from 98 1/cm at λ=0, 96 μ when the light razes fall perpendicular on surface ($\alpha=0^o$) up to 76, 69 1/cm at the incident angle $\alpha=10^o$.

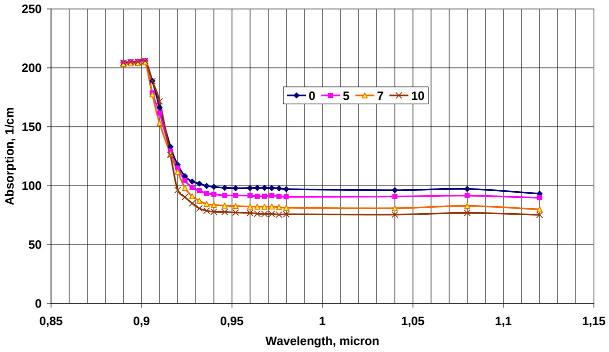

Fig.5. Absorption spectrum of GaAs micro-relief layer in dependence at angle α between incidents razes and perpendicular axe son surface layer (α = 0, 5, 7 and 10^o).

The optical research demonstrates that GaAs micro-relief layer obtained by the advanced epitaxial technology from gaseous phase has application expectations in photovoltaic cell construction as an element of light multiplication reflection in the semiconductor, also as diminishing of energy losses at the light reflection from the reception surface. The mechanism of growing the micro-relief layer by epitaxial technology on substrate with multiply crystallizing centers (substrate with defected surface) and crystallographic orientation of the obtained texture could be research objectives for the future.

One of the priorities of GaAs micro-relief layer growth technology method can be considered the possibility to multiply the layers with different impurity, other way said, the possibility to build relief p-n junctions, which can change the electric field at the border between layers.

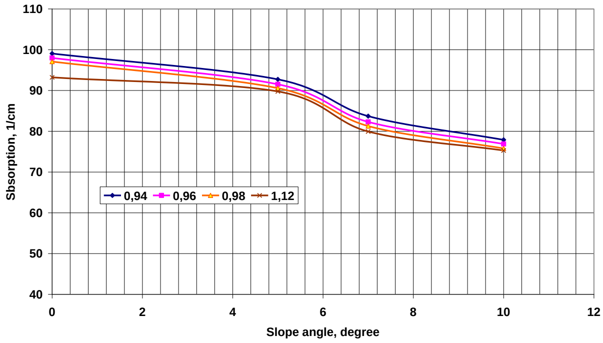

Fig.4. Light absorption dependence on GaAs micro-relief layer in function of incident angle at different wave-length (o,94μ, 0,0,96μ, 0,98μ, 1,12μ)

III. CONCLUSION

Technological experiments in this research demonstrated that GaAs epitaxial method with reactions transport in system Ga-$AsCl_3$-H_2 is valid for epitaxial layers growth on support with multiple micro-infirmities on the surface, which serves as crystallization centers in technological process. Probably the micro-relief layer is polycrystalline and the micro crystals form a structure, which realizes the effect of the light razes reflection multiplication.

The PVC textured surface [6] diminishes optical losses because of light multiple reflection from the inclined surfaces of texture. Charges generation area at the light action is approaching p-n junction thus enhancing charges collection efficiency.

Development this technology in diminishing epitaxial layer texture sizes up to appearance the quantum effects can lead (take) an essential increase of PVC converse efficiency.

IV. REFERENCES

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