INVESTIGATION OF ELECTROPHYSICAL AND PHOTOELECTRICAL PROPERTIES OF $Ge_{1-X}Si_X$ /Ge HETEROSTRUCTURES OBTAINED BY MOLECULAR-BEAM EPITAXY METHOD

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The structures investigated in this work were obtained by molecular beam epitaxy method on Ge substrates. The parameters of the samples were determined by the method of X – ray structural analysis. The method of spectroscopy of combinational light scattering was used to control the content. After irradiation the samples become more photosensitive in the regions 1.0 ≤hν≤1.11eV than the origin ones.

At modern stage of scientific and technological revolution special emphasis is placed on the advancement of those fields of science the achievements of which define the wide prospect of technological development. These fields of science include semiconductor physics, one of the main tasks is search, study and modification of crystal properties with high values of applied – physics characteristics in order to develop new materials promising different technological applications.

Solid solutions of Ge and Si are of great interest from scientific and technological aspect. This interest is conditioned by multiple unique properties: complete solubility, continuity of electrical properties' change, resistance against thermal actions, large energy gp width, high fusion temperature, mechanical strength, resistance against the effect of highenergy particle bombardment and others.

At present it was experimentally shoved that Ge and Si really from solutions not only in liquid state but also in solid state and the quantity of lattice parameter of $Ge_{1-x}Si_x$ solid solutions change almost linearly with the change of solution and alloy composition.

Practically, all the investigations carried out dealing with practical realization of atom layer epitaxy of $Ge_{1-x}Si_x$ structures have been based upon molecular beam epitaxy method during the recent years.

In the present work structural characteristics of thin films Ge/$Ge_{1-x}Si_x$ obtained by molecular ray epitaxy (MRE) method with (100) and (111) orientation oas been tidied. Epitaxial layers $Ge_{1-x}Si_x$ had thickness from 50Å to 1 mcm and Si contend x=0,05÷0,15 (fig.1).

$Ge_{1-x}Si_x$/Ge solid solutions are considered one of perspective materials used in modern electronics. As the band-gap energy in these solutions is less than that of Si, but mobility of charge carriers is more than that of Si, these solutions are used to prepare heterostructure.

Nowadays transistors, anodes and integrated circuits distinguishing by their accuracy, mobility and restlessness have been developed on the base of $Ge_{1-x}Si_x$ solid solutions. $Ge_{1-x}Si_x$ solid solutions have been obtained by Czochralski method.

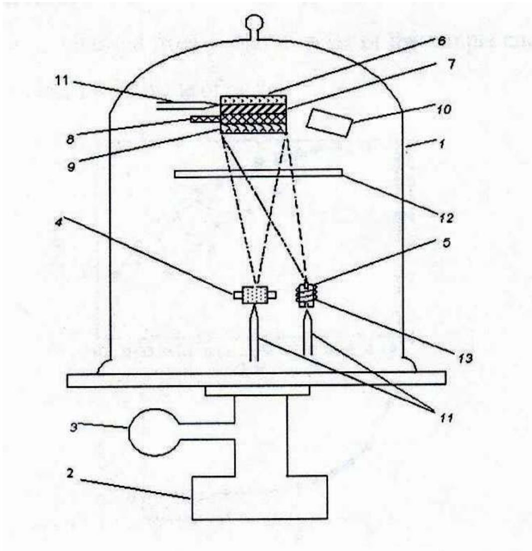

Fig. 1. UVP – 71P3 grade vacuum assembly and used facilities:
1 – cover; 2 – high vacuum pump; 3 – ion lamp;
4 – Knudsen cut; 5- effusion cut; 6- substrate heater;
7 – substrate; 8 – floating mask;9 – mask – kepper;
10 – quartz thickness gage; 11 – thermopair;
12 – cross – section; 13 – effusion cut heater.

During the process the crystals were detected (alloyed) by boron and phosphorus. Crystals were cut into perpendicular boards from 30 up to 42 in diameter in <110> direction.

P-type $Ge_{1-x}Si_x$ boards polished like plate glass were used to develop diode structures. Here specific resistance of p-type $Ge_{1-x}Si_x$ boards was ρ=4.8 Ohm·cm, but specific resistance of n-type Ge boards was ρ=5÷4.5 Ohm·sm, лthickness of the boards ≈ 400 mcm.

After the heterostructure had been obtained, p^+ and n^+ layers of boron and phosphorus 8-10 mcm in depth were obtained from p- and n- sides of the sample and silicate glass by diffusion. The contact pieces were made of nickel.

Diode structures with the field ≈ 1cm^2 were cut from the obtained samples. Current-voltage characteristic of the samples were measured at room temperature at constant current. In order to obtain thin $Ge_{1-x}Si_x$ (x= 0.10) on Ge substrate the sample from the side of $Ge_{1-x}Si_x$ was mechanochemically polished, so $Ge_{1-x}Si_x$ solution with ≈ 400 mkm density was obtained on thick Ge substrate. Elastic voltage and defects of the crystal structure were studied by X-ray topography method using continuous synchronous radiation.

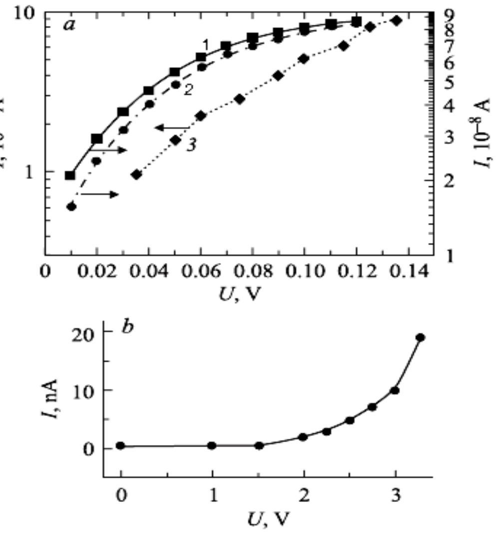

Fig. 2. 1 –proportional current-voltage characteristic,
2 – not proportional current- voltage characteristic;
a – current-voltage characteristic for proportional street,
b – for not proportional street: 1 – before radiation,
2 –after radiation 30 krad, 3 –100krad

It was revealed that variety of thermal expansion coefficients and parameters of $Ge_{1-x}Si_x$ and Ge crystal lattices leads to considerable increase of tension. At the result of this tension crystal lattice is exposed to elastic and plastic deformation.

Current-voltage characteristic of the samples obtained was measured before and after radiation.

As it seems from fig. 2 resistance of the samples increases after radiation and the current passing through the sample decreases.

It was determined that during radiation of $Ge_{1-x}Si_x$ (x=0÷0.15) solid solution linearity of current-voltage characteristic deteriorates and three fields are observed. These dependence shows that there are deep donor layers in restricted band of $Ge_{1-x}Si_x$ solid solution.

During the experiment after radiation defects generate in restricted band and their concentration increases simultaneously with the increase of radiation dose. n-$Ge_{1-x}Si_x$ solid solution is compensated after radiation and this provides its light-sensitivity.

For additional information photoconductivity of the samples at room temperature was measured.

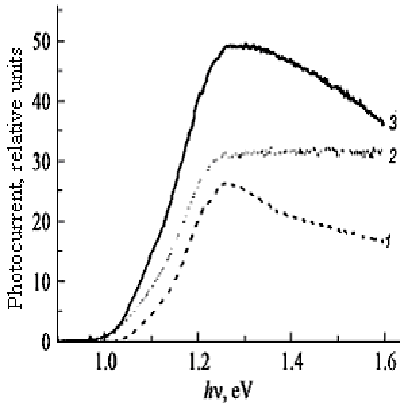

Fig. 3. Photoconductivity of $Ge_{1-x}Si_x$ samples before and after radiation at room temperature; 1 –before radiation, 2, 3 – after radiation.

As it seems from fig. 3 light-sensitivity of the samples in heterostructures after radiation in 1.0 ≤ $h\nu$ ≤ 1.11 eV field has increased. The sensitivity of heterostructures increase more in comparison with that of solid solutions. The generation of this additional sensitivity can be manifested by deformation of crystal lattice as hypothesis in the meantime.

It is clear that the presented experimental data don't allow to elucidate the nature of given complex. Considering the analogy between silicon and germanium and eventually bearing in mind the coincidence of basic properties of Ge and $Ge_{1-x}Si_x$ with x=0.05….0.15 we made an attempts to exsplain the structure of this defect [3].

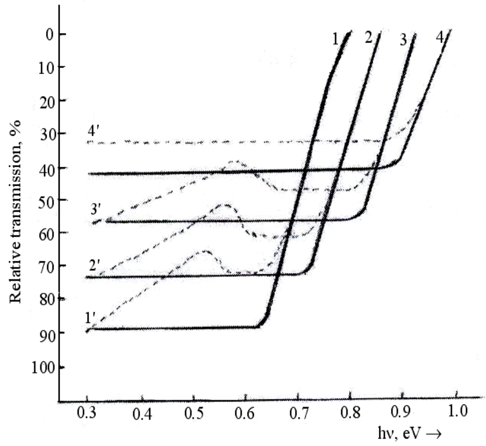

Fig. 4. Spectra of absorption bands of p - $Ge_{1-x}Si_x$ samples prior (1-4) and after (1'-4') irradiation by electrons with energy 4.5 MeV. Φ. см$^{-2}$;1 - 5·10^{16}, 2 – 4 -2·10^{17}, 1 – x=0; 2 –x=0,05; 3 –x=0,10 and 4 –x=0,15.

In [4,5] there have been carried out various investigations of irradiated Sin including the methods of EPR, photoconductivity and IR – absorption, on the basis of which there has been created a model of radiation defect responsible for absorption bands 1.8, 3.3, and 3.9 μm in the spectrum of IR – absorption of Si. These bands appear as a result of absorption in deviancy that may be in various charge states. It has been shown in these works that the absorption zone at 1.8 μm is due to electron transition that is possible only in divacancy at neutral or single – charge negative state whereas the absorption zone 3.9 *μm* appears only at single – charge negative state. Considering all above mentioned facts and the results of the previous electrophyisical and optical investigations of defects at various charge states [2] and assuming that many crystallographic and electrophyisical parameters of $Ge_{1-x}Si_x$ with x= 0.005…0.15 re similar, we suppose that it is deviancies that re responsible for absorption band in the range of 0.3 to 0.9 eV (fig. 4). As a zone was observed in n - $Ge_{1-x}Si_x$ samples only after n → p conversion as a result of irradiation [4] the most likely that divacancy might be only at to charge states: neutral or single – charge negative. As is shown above similarly to silicon in p - $Ge_{1-x}Si_x$ when divacancy is at neutral stet the absorption band appears in the range 0.3…0.9 eV.

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MOLEKULYAR DƏSTƏDƏN SƏPİLMƏ YOLU İLƏ ALINMIŞ $Ge_{1-x}Si_x$/Ge HETEROSTRUKTURLARIN ELEKTROFİZİKİ VƏ FOTOELEKTRİK XASSƏLƏRİNİN TƏDQİQİ

$Ge_{1-x}Si_x$ əsasında Ge altlıq üzərində molekulyar dəstədən səpilmə yolu ilə alınmış heterokeçidin parametrləri rentgenstruktur analiz və rekombinasiya olunmuş işığın səpilmə metodu ilə təyin olunmuşdur.

Şüalanmadan sonra heterostrukturlarda nümunələrin 1,0 ≤ $h\nu$ ≤ 1,11 eV oblastında isığın həssaslığı artmışdır və heterostrukturun həssaslığı bərk məhlula nisbətən yüksək olduğu aşkarlanmışdır.

Qüsursuz Ge/$Ge_{1-x}Si_x$ nazik təbəqənin alınması yüksək yürüklüyə malik tranzistorun hazırlanmasında böyük əhəmiyyət kəsb edir.

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ИССЛЕДОВАНИЕ ЭЛЕКТРОФИЗИЧЕСКИХ И ФОТОЭЛЕКТРИЧЕСКИХ СВОЙСТВ ГЕТЕРОСТРУКТУР $Ge_{1-x}Si_x$/Ge , ПОЛУЧЕННЫХ МОЛЕКУЛЯРНО – ЛУЧЕВОЙ ЭПИТАКСИЕЙ

Структуры, исследованные в настоящей работе, получены методом МЛЭ на Ge подложках. Параметры образцов определены методом рентгеноструктурного анализа. Метод спектроскопии комбинационного рассеяния света использовался для контроля состава. После облучения образцы становятся более фоточувствительными в области 1,0 ≤ $h\nu$≤ 1,11 eV.

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