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GENESIS OF NANOSTRUCTURES FORMATION IN AMORPHOUS HYDROGENATED SEMICONDUCTORS A-SI1-X CX: H

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On the basis of the analysis of experimental data it is shown that at increase in the maintenance of carbon more, than on 50 % (x from above 0,5) there is a cardinal change of photoluminescent and photo-electric properties thin films a-$Si_{1-x}C_x$:H connected with nanoclusterization the films structures.

Keywords: thin films, nanoclusterization, semiconductors, exciting quantums, structurization.

Among amorphous semiconductors certainly are allocated amorphous hydrogenated silicon a-Si:H and its alloys, and also chalcogenide glasses [1]. Relative simplicity and the cheapness of the technology of fabrication of these semiconductors allow creating thin-film structures of the big area, the practical importance of which electronic properties opens prospects of numerous applications in various areas of electronics and optoelectronics, in particular, in the field of photoelectric transformation of energy.

The interest to amorphous semiconductors has sharply risen after observation by Spear W.E. and Le Comber P.G. in 1975 of an opportunity doping of amorphous hydrogenated silicon [2]. The prospect of their practical use stimulated wide scientific interest to studying fundamental properties amorphous hydrogenated silicon and its alloys.

In 1977 Anderson D.A. and Spear W.E. [3] have informed about amorphous hydrogenated silicon-carbon films a-$Si_{1-X}C_X$: H, received for the first time from a mix C_2H_4+SiH_4 by its decomposition in the glow decharge. In a year in [4] it has been shown, that a film a-$Si_{1-X}C_X$:H can find out a white photoluminescence at a room temperature if are prepared under corresponding conditions.

Alongside with the researches directed on understanding of fundamental physical processes, occuring in a film at various external influences, there were messages on successful application of the films a-$Si_{1-X}C_X$:H in optoelectronic devices and in solar tandem elements. So, for example, in [5] have found out visible light of an electroluminescence at a room temperature in a-$Si_{1-X}C_X$:H. Later in [1] application a-$Si_{1-X}C_X$:H aswide-gap windows in a multilayered solar element from amorphous silicon owing to what the efficiency of a solar element has raised from 5,5-6 % up to 10 % and as show researches of last years has been described, it was not a limit.

Concerning photo-electric properties films a-$Si_{1-X}C_X$:H it is necessary to note, that researches of these phenomena are intensively spent to last years in ultra-violet area (UV) of a spectrum [5]. This interest is caused as from the point of view of reception of the information on carry and a relaxation of "hot" carriers of a charge in amorphous semiconductors, and for creation of semiconductor thin-film photodetectors and devices UV of a range of a spectrum.

Researches of photoluminescent and photo-electric properties thin films a-$Si_{1-X}C_X$:H show their essential dependence on the relative maintenance of carbon [6,7].

It is established, that in the field of x <0,4 the structure of films a-$Si_{1-X}C_X$:H has homogeneous character. Photoconductivity and conductivity are observed in this range of x that testifies to the significant diffusion of nonequilibrium carriers of a charge. Photosensivity of photodetectors on the basis of films a-$Si_{1-X}C_X$:H with growth x moves in blue area of a spectrum that allows to recommend such a film as the photodetectors sensitive only in UV of area of a spectrum and "blind" to visible. The strongest shift of red border of photosensivity takes place for an alloy with x=0,2.

Behaviour of the photoluminescence (PL), strong temperature clearing, independence of width of spectrum PL on energy of quantum of excitation testifies to a significant role of diffusion of nonequilibrium carriers, rather slow (phosphorescence) kinetic of the decay that is well described within the limits of tunnel radiating recombination also.

At increase x from above 0,5 there is a cardinal change of photoluminescent and photo-electric properties of thin films a-$Si_{1-X}C_X$:H. In this range x conductivity and photoconductivity disappears. At increase in the maintenance of carbon over 50 % the width of an optical crack varies slightly, quantum

efficiency of PL, despite of increase of density of the defects caused by torn off communications of carbon, or is kept, or even grows, temperature clearing PL is sharply weakened, and speed of recession PL becomes very fast. It is possible to approve, that in the field of 40-50 % of the maintenance of carbon there is a change of mechanisms of the recombination: tunnel or exitonlike, described fast time de-exitation.

Experimental data allow to make a conclusion that at x above 0,5 system appears heterogeneous, including besides sp^3 phases, as well sp^2 a phase. The thermodynamics sp^2 phases is those, that it tends to cluster in nanogranules in the size 1- 10 nanometers. This phase defines optical absorption and luminescent properties of the films a-$Si_{1-X}C_X$:H with the greater maintenance of carbon. The nonequilibrium carriers born at absorption of quantum of exciting light, appear locked in sp^2 to a granule, and lose ability to diffusion, than and absence of photoconductivity speaks, i.e. optical absorption becomes not photoactive. Theoretical calculations [8] also confirm energetic advantage of the clusterization of graphite sp^2 granules.

In figure 1 are presented normalized spectra of a photoluminescence amorphous hydrogenated carbons, received at a room temperature at excitation by different quantums of laser radiation E_{exc} [4,9].

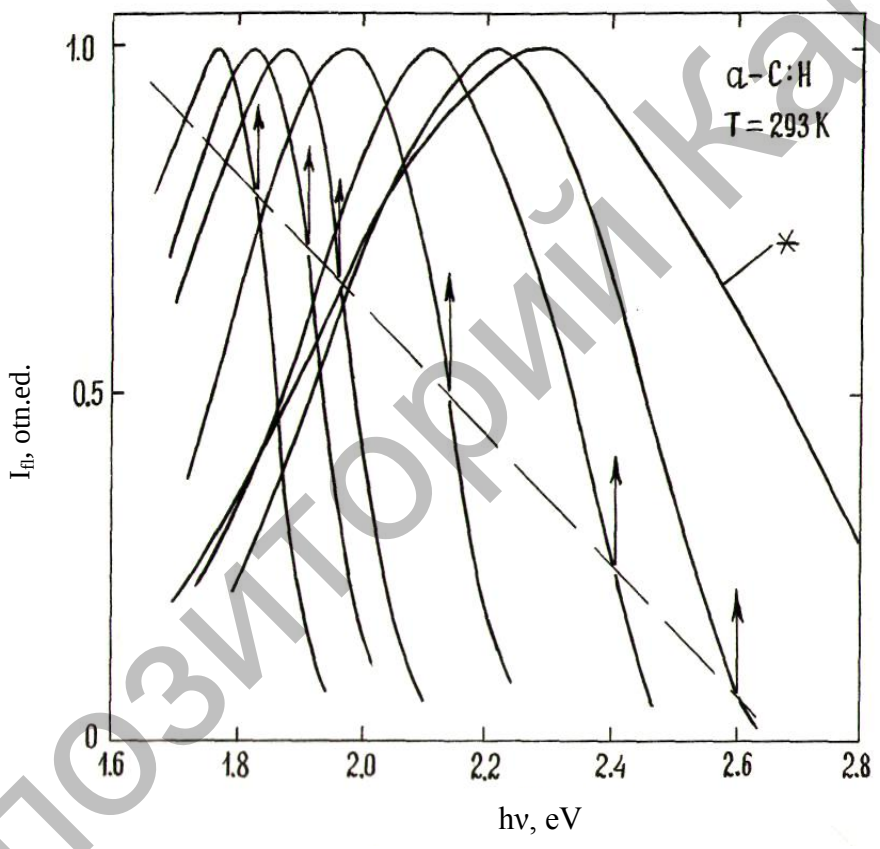

Fig. 1. Spectra PL a-C:H at various energies of exciting quantums ($E_{exc.}$) are shown by arrows. Normalized intensity anti-Stokes radiations near to a line of excitation [9] is shown by a dashed line

The spectrum designated by an asterisk (*), corresponds E_{exc} = 3,68 eV. It is seen, that with decreasing E_{exc}. the width of a band of a luminescence is narrowed, thus the long-wave border remains constant. Such behaviour of spectra is characteristic for a photoluminescence of eximer nature [10]. In figure 2 spectra of a photoluminescence a-$Si_{1-X}C_X$:H layers are presented at a stationary condition of excitation.

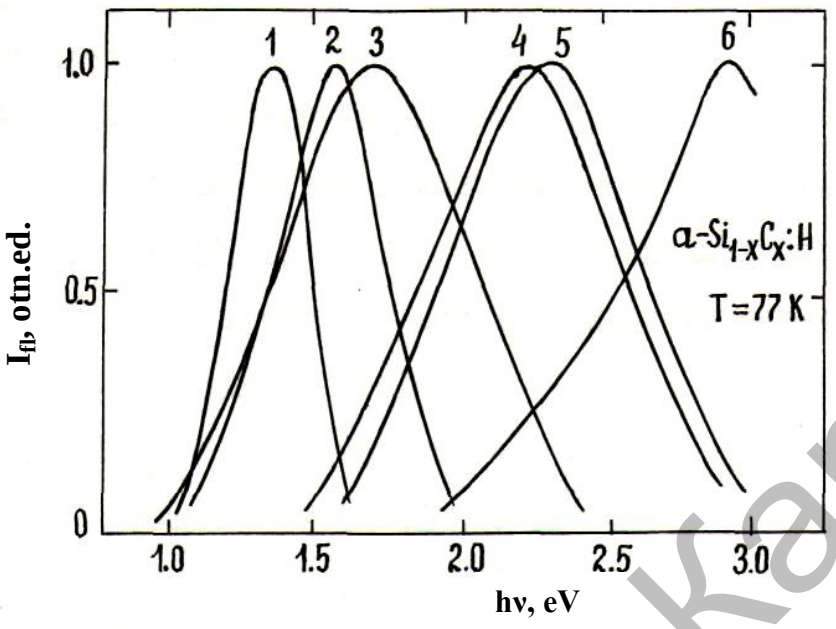

Fig. 2. Spectra of a photoluminescence a-$Si_{1-X}C_X$:H layers with various X: 1 - 0; 2 - 0,19; 3 - 0,35; 4 - 0,58; 5 and 6 - 1,0 at different energy of excitation quantum

Measurements were conducted at temperature of liquid nitrogen. From the analysis of spectra follows, that in the field of samples at X <0,4 the halfwidth of a spectrum linearly grows with X, and at X> 0,4 the halfwidth practically remains constant. the Halfwidth at X> 0,4 it is compared with the halfwidth of a spectrum observed for a-C:H. Such behaviour of spectra, apparently, is connected with кластеризацией alloys a-$Si_{1-X}C_X$:H with formation of graphitelike phases nanogranules. The spectra of a photoluminescence, the kinetic its decay, and also anti-Stokes radiation having fast fluorescent character, testify too about eximer nature of PL [10.] Eximerlike luminescence of graphitelike sp^2 structures, having similar with observable in a-$Si_{1-X}C_X$:H layers (with> 0,5) luminescent characteristics, was observed earlier [11, 12].

Thus, the analysis of experimental data of photo-electric and photoluminescent characteristics a-$Si_{1-X}C_X$:H layers allows to make the conclusion about structurization in a-$Si_{1-X}C_X$:H layers (with> 0,5) with formation of graphitelike nanoclusters.

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