STM SURFACE TOPOGRAPHY AND UV PHOTOCONDUCTIVITY OF InSe, GaSe LAYER SEMICONDUCTORS

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Photoconductivity spectra of InSe, GaSe layer semiconductor samples in the region of high energy ($h\nu >> E_g$) and surface topography receiving by Scanning Tunneling Microscope (STM) method of these samples have been investigated. The results both photoconductivity and STM investigation showed that surface and bulk electron behaviors not so different. These allow investigate electron transitions in depth of adsorption edge by simple photoconductivity method. STM surfaces topography unfolds new usage perspectives for layered crystals InSe, GaSe.

Layer semiconductors InSe, GaSe due to peculiarity of their crystalline structure are characterized by practical absence ragged chemical bounds on a surface. Due to this property their surface distinguishes weak adsorption ability. As consequence of before stated conditions the lower density of surface states allows to register high photosensitivity in a wide spectral range including ultraviolet (UV) area of spectra [1].

It is known that electronic properties of these crystals are not so anisotropy as their mechanical properties. These crystals are easily cleaved and almost without special technological processing it is possible to receive samples rather the big area surfaces with monolayer.

Researches of Auger spectra investigation have showed are that surface concentration of adsorbents on InSe and GaSe surfaces two or three order is lower than surfaces of "usual" semiconductors [2].

On the one hand the above-stated properties of crystals InSe and GaSe allow to create on their basis photosensitive devices in a wide spectral range, especially in short-wave area of a spectrum, and on the other hand to study of behaviors optical transitions in depth of absorption edge by means of a photoconductivity method, where $h\nu >> E_g$. Characteristic spectral dependences photoconductivity of layered semiconductors InSe and GaSe on fig.1 are resulted at the room temperature.

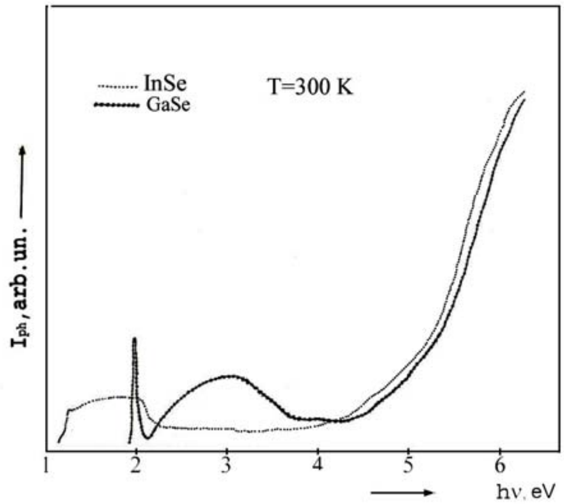

Fig.1. Photoconductivity spectra of InSe and GaSe layer semiconductors in the usual geometry (light being incident normally to the layer surface and contacts being installed upon the illuminated surfaces) of measurement in 1 – 6 eV region.

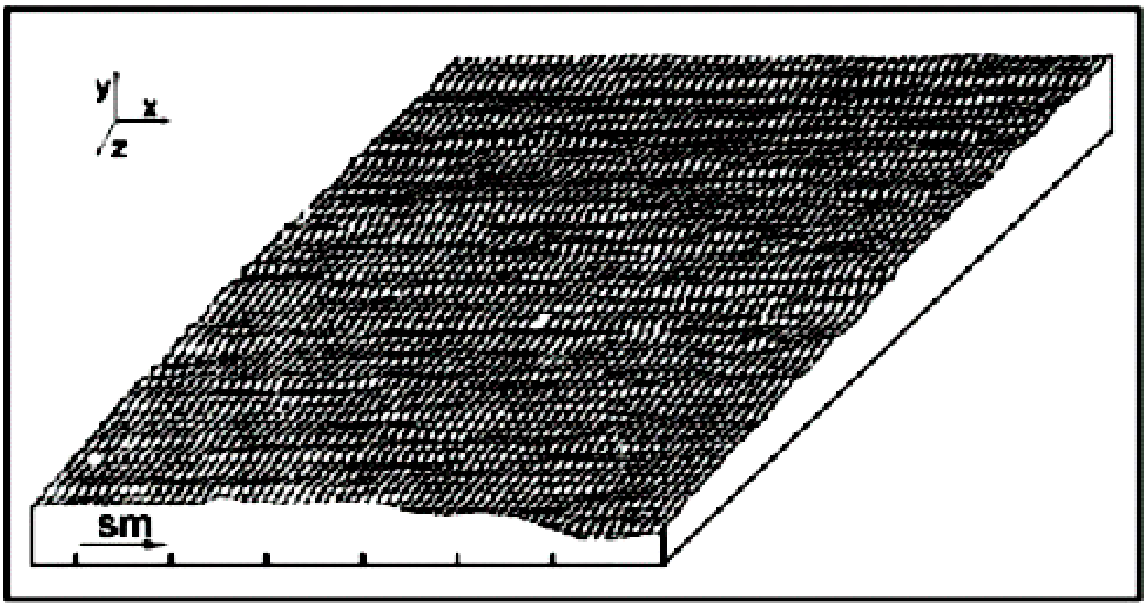

Fig.2. Scanning Tunneling Microscope method surface topography of InSe layer semiconductor samples in air. Size of image is correspondent to 280x280 A^o /cm on **x** and **y** direction, 60 A^o /cm on z direction.

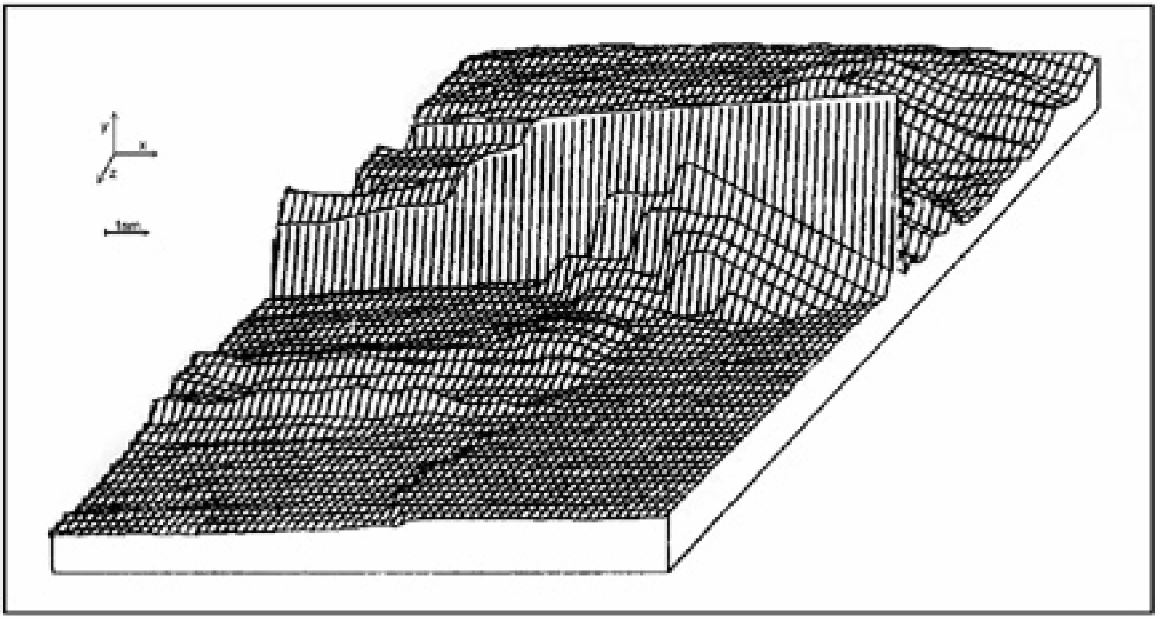

Fig.3. Scanning Tunneling Microscope method surface topography of InSe layer semiconductor samples in air where mechanical cleaving occurred in different layers far one from another. Size of image is correspondent to sizes on fig.2.

For present purposes the surface topography of samples InSe have been studied by the STM method in air. Before receiving topography images of given samples have been investigated of photoconductivity spectrums and were observed high photosensitivity, particularly in UV areas of a spectrum. On fig.2 the characteristic topography image of InSe samples surface is shown by STM method. These pictures distinctly show on reception favorable circumstance rather big areas of monolayer surfaces by the mechanical cleaved. On alongside with the assertion on surface of samples InSe crystal is absent significant inclusions, nevertheless in some places of topography images differences for scans are clearly visible. The height of these differences corresponds approximately to ~12–15 A^{o}. It can be concluded that on a surface can be have a place that defects of layers as a transition crystal lattice translation from one layer to another. Another event shown in Fig.3 where mechanical cleaving occurred in different layers far one from another and differences between scans much more than depth one or two layers.

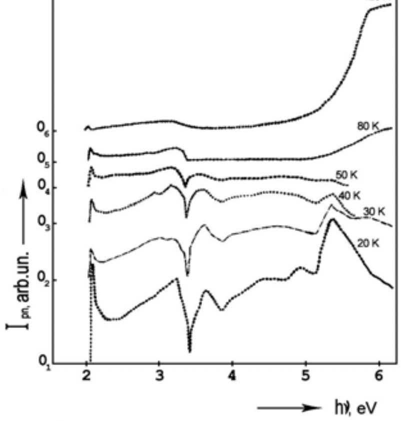

Fig.4. Photoconductivity spectra of GaSe layer semiconductors at different temperature.

Despite of the specified defects it is possible to observe separate sites of a surface with practical consisting of one monolayer. Due to opportunity STM it is easily possible to define on surface areas of layered semiconductors InSe and GaSe suitable for creation UV sensitive detectors and with manipulation simple technology it is possible to fabricate cheep UV devices.

The received results for samples from InSe layer crystals one can say with confidence can be attributed to samples of GaSe layer crystals.

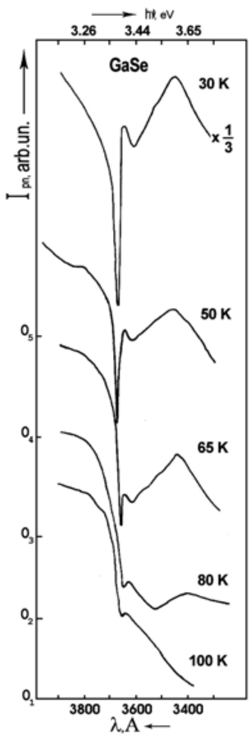

Fig.5. Photoconductivity spectra of GaSe layer semiconductors near deep exciton state.

It has been marked, that high photosensitivity in depth of absorption edge allows to studies the nature of optical transitions in this spectrum region. The spectrum of photoconductivity registered on sample GaSe are shown on fig.4 at various temperatures. Apparently from fig.1 and fig.4 photoconductivity spectrums of samples InSe and GaSe despite of increase adsorption coefficient factor photoconductivity signal decrease (~2-3 eV in InSe, ~3-4 eV in GaSe) is observed. Energy interval of this spectrum area coincides with spectrum area which optical transitions have excitons nature. Temperature influences research on photoconductivity spectra of InSe and GaSe layer semiconductors samples show an opportunity rather precise registration deep excitons transitions in these crystals for estimate their binding energy and Bohr radii. Temperature dependence photoconductivity spectra of these GaSe samples are shown on fig.4.

Thus in InSe and GaSe layered semiconductors were observed two types exciton states. One are formed between absolute extremes of a conductivity and a valet zone and it is typical Wannier-Mott type excitons, others correspond to excitations localized near the atomic site, possess the great binding energy (~90-100 meV), in small Bohr radii (~8 A^o), poorly participate in photoconductivity, and can be attributed to intermediate type excitons. Photoconductivity spectra of GaSe near deep exciton state at the different temperatures are resulted on fig.5. Deep exciton states originate from direct transitions between states which have atomic-like wave functions. It is easy to annihilate these excitons mainly at the low temperature than rather dissociate and consequently their contribution on photoconductivity registered as deep minima.

The photoconductivity and STM investigation of layer semiconductors InSe, GaSe are show that bulk and surface electron behavior of given crystals is approximately identically, more conclusions for bulk behaviors almost can be attributed to surface. At least monolayer surface of InSe, GaSe layer crystal can be utilized as easy prepare natural semiconductor plane surface for building on this a new nanometer devises and these blocks.

[1] *O.Z. Alekperov, M.O. Godjaev, M.Z. Zarbaliev and R.A. Suleymanov*. Solid State Commun. 1991, vol. 77, pp. 65-67.

[2] *E.Y. Salaev, M.O. Godjaev, G.L. Belenkii and L.N. Alieva.* Doklady Academii Nauk Azerb. SSR. 1986, 42, 15.

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InSe, GaSe LAYLI YARIMKEÇİRİCİLƏRİNİN STM SƏTH TOPOQRAFİYASI VƏ SPECTRİN ULTRABƏNÖVŞƏYİ OBLASTINDA FOTOKEÇİRİCİLİYİ

InSe, GaSe laylı yarımkeçirici nümunələrin yüksək enerji oblastında ($hv>>E_g$) fotokeçiriciliyi və həmin nümunələrin Skanirəedən Tunel Mikroskopu (STM) metodu ilə səth topoqrafiyası tədqiq edilmişdir. STM və fotokeçiricilik metodlarının hər ikisindən alınan nəticələr göstərir ki, səthi və həcmi elektron xassələri bir-birindən çox fərqlənmir. Bu da udulma kənarından dərin oblastda elektron keçidlərinin təbiətini sadə fotokeçiricilik metodu ilə öyrənməyə imkan verir. STM səth topoqrafiyası InSe, GaSe laylı kristallarının yeni məqsədlər üçün istifadəsinə yollar açır.

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ПОВЕРХНОСТНАЯ ТОПОГРАФИЯ ПО МЕТОДУ СТМ И УФ ФОТОПРОВОДИМОСТЬ СЛОИСТЫХ ПОЛУПРОВОДНИКОВ InSe, GaSe

Исследованы спектры фотопроводимости образцов слоистых полупроводников InSe, GaSe и поверхностная топография этих же образцов методом Сканирующей Туннельной Микроскопии (СТМ). Результаты, полученные обоими методами показывают, что электронные свойства поверхности и объема не сильно отличаются. Это позволяет изучать электронные переходы в глубине края поглощения простым методом фотопроводимости. Поверхностная топография по методу СТМ открывает возможности использования этих кристаллов в новых других целях.

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