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ЕФИ-587(74)-82

I.P.KARABEKOV, D.L.EGHIKYAN, R.A.MIKAELYAN,
V.G.BAGHDASARYAN, M.A.MARTIROSYAN, A.M.KOTSINYAN,
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INVESTIGATION OF MONOCRYSTAL SURFACE STRUCTURE DISTURBANCES USING SYNCHROTRON RADIATION

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INVESTIGATION OF MONOCRYSTAL SURFACE STRUCTURE DISTURBANCES USING SYNCHROTRON RADIATION

Results of the investigation of monocrystal surface layers defected structure by means of two-crystal topography in the Bragg geometry using synchrotron radiation are presented. Topograms obtained in high orders of reflection are shown to contain information on the structure perfection of monocrystal surface layers with thickness of several up to hundreds microns.

Yerevan Physics Institute
Yerevan 1982

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И.П.КАРАБЕКОВ, Д.Л.ЕГИКЯН, Р.А.МИКАЭЛЯН,
В.Г.БАГДАСАРЯН, М.А.МАРТИРОСЯН, А.М.КОЦИНЯН,
С.Л.ХАЧИКОГЛЯН

ИССЛЕДОВАНИЕ ПОВЕРХНОСТНЫХ НАРУШЕНИЙ МОНОКРИСТАЛЛОВ С ИСПОЛЬЗОВАНИЕМ СИНХРОТРОННОГО ИЗЛУЧЕНИЯ.

Представлены результаты исследования дефектной структуры поверхностных слоев монокристаллов с помощью двухкристальной топографии в геометрии Брэгга с использованием синхротронного излучения. Показано, что топограммы высоких порядков отражения несут информацию о структурном совершенстве поверхностного слоя, толщиной от нескольких до сотен микрон.

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Ереван 1982

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As is known [1] the quality of semiconductor electronic devices, defined by the conformity of their parameters to the predetermined specifications, depends greatly on the structural perfection of the silicon crystalline substrate. In the process of formation of the parameters of devices and microcircuits a small depth of the surface is involved. Thus the development of quick test method of the definition of surface layers structural perfection is very urgent and its application will permit to increase the industrial yield and quality of electronic devices.

At present indestructible methods of the investigation of monocrystal structure [2-6] using traditional X-ray sources cannot provide quick test investigations, since in order to obtain one topogram one needs many-houred exposure time [4,5].

This paper presents the results of the investigation of possibilities of defining the structural perfection of monocrystal surface layers by means of topography in the Bragg geometry, using the synchrotron radiation of the Yerevan Physics Institute accelerator [7]. The method is based on the phenomenon of primary extinction and allows to define the picture of defects distribution in surface layer at a depth of several up to dozens of microns by means of topograms obtained at various orders of reflection in a wide range of wavelengths.

To estimate the quick-testability, degrees of resolution and informativity of the method, topographic investigations have been carried out of the silicon monocrystal with specially introduced unit dislocations[8] and crystalline substrates with a diode matrix. Topograms were taken in two-crystal (n, +n) and (n, -n) spectrometers in (III), (333) and (444) orders of reflection. The topograms obtained are compared to those taken in the Laue and Bragg geometry in one-crystal spectrometer using the white SR spectrum. An experimental setup assembled on the basis of the goniometer GUR-5[9] is arranged at the SR beam path at a distance of $\sim$ 25m from the radiation origin point. After the formation by means of collimators[10] the SR beam had transverse dimensions $4 \times 12 mm^2$ and divergence in the horizontal and vertical planes $\Delta\varphi = 0.75 \; 10^{-3}$ and $\Delta\psi = 2.4 \; 10^{-4}$ rad , respectively. As an SR monochromator a perfect monocrystal of silicon was used with a dislocation density $Nd \sim 10 cm^{-2}$, whose reflecting surface is cut parallel to the crystallographic plane (III) with an accuracy no more than 2 angular minutes. The choice of a perfect monochromator is induced by the necessity to exclude the overlapping of the monochromator defects image on the diffractional picture of the investigated sample. Topograms were taken on a photoplate with MK type emulsion. The photoplate was located parallel to the investigated sample which allowed to preserve the scale of images when taking topograms at different orders of reflection as well as to avoid geometric distortions of the image.

Fig. 1 presents the topograms obtained in (III), (333), (444) orders of reflection for (n, +n) (a) and (n, -n) (b) spectrometers. The comparison of topograms shows that images of disturbance fields substantially differ depending on the order of reflection, i.e., depending on the depth of extinction.

The applicability of the two-crystal monochromatic Bragg topography method with the variation of extinction depth for investigating the defected structure of monocrystalline substrates for electronic devices is confirmed by topograms on fig. 2. It presents the images obtained from the substrates with diode matrix in (n, +n) and (n, -n) arrangement for the same orders of reflection, that were used in previous topograms. A strongly disturbed area was selected on the circuit for which were also taken topograms in the Bragg and Laue geometry using a polychromatic SR beam (figs. 3,4). As is seen from the topogram on fig. 4, in this region there is a fracture in the crystal depth. The topograms in the Bragg geometry for (444), (333) and (III) reflections show an increase of the contrast of the fracture image with the increase of extinction. The comparison of topograms obtained on a two-crystal spectrometer with that of the one-crystal spectrometer (see fig. 3) shows that the one-crystal topography is insensitive to the majority of disturbances which are distinctly manifested in two-crystal geometry.

The comparison with the topogram obtained in the Laue geometry (fig. 4) (fujiwaragrams) [6,11] shows that the latter gives less information on the plane structure compared to that on the volume structure of defects.

As is seen from the above topograms, the image in the first order of reflection carries the most information on the surface layer structure. Besides the topogram obtained at (n, -n) arrangement of crystals in (III) reflection has a greater resolution compared to (n, +n) arrangement. This is accounted for by the difference of diffracted beam formation mechanisms in these spectrometers. As is well known (see e.g. 12) in the case of (n, -n) spectrometer the maximum image contrast corresponds to the angular disorientation equal to the convolution of diffracted maximums of the investigated region of the sample. In the case of (n, +n) spectrometer the same contrast is manifested when the disturbance of the sample plane structure overcomes the angular divergence $\Delta\varphi$ of the SR incident beam. Therefore, in the case of (n, +n) spectrometer, in order to obtain a resolution comparable with that of (n, -n) spectrometer narrower collimated beams are needed [10] which leads to the waist of the illuminated region and to a corresponding increase of the total time required for the obtaining of the images of all the sample surface.

One characteristic of topograms depicted on fig. 2 is that the width of the (III) topogram for both cases of crystal arrangement is much less than the illuminated region and it has a brilliance modulation close to the colonlike with abrupt falls at the ends. The appearance of such a "glitter" may be accounted for by a complex curve of the substrate arising at technological treatment [1] . The topograms in fig. 2 show that the intensity distribution in the "glitter" width and its form along the vertical direction of collimating slit are sensitive to the disturbance of the surface structure.

These characteristics of "glitter" can as well be used to develop quick test methods of the analysis of the surface structural state.

The homogeneous direct "glitter" parallel to the collimating slit (fig. 5b) informs of a good structural perfection. The curves of the type shown in fig. 5a point out the presence of disturbance.

Hence the information obtained from the two-crystal spectrometer is sufficient to define the degrees of disturbance in the acting layer of the substrate.

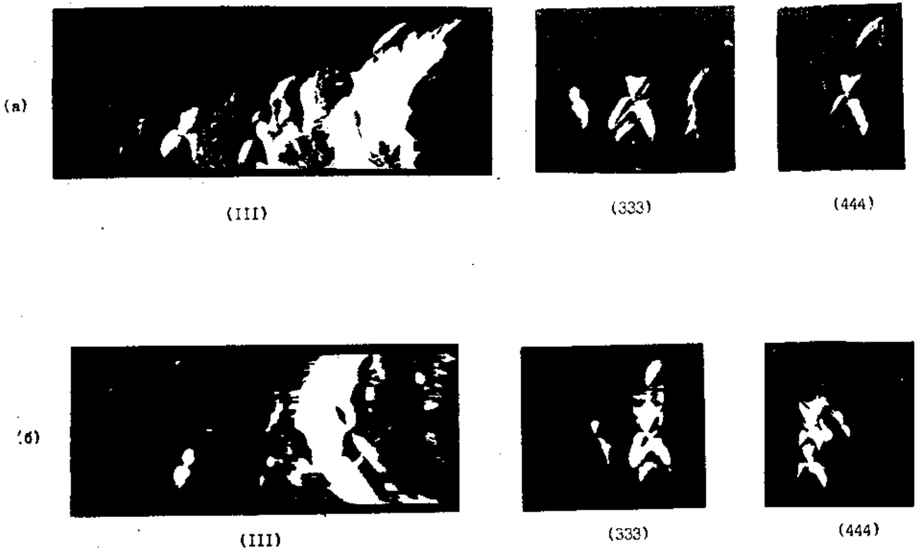


Fig. 7

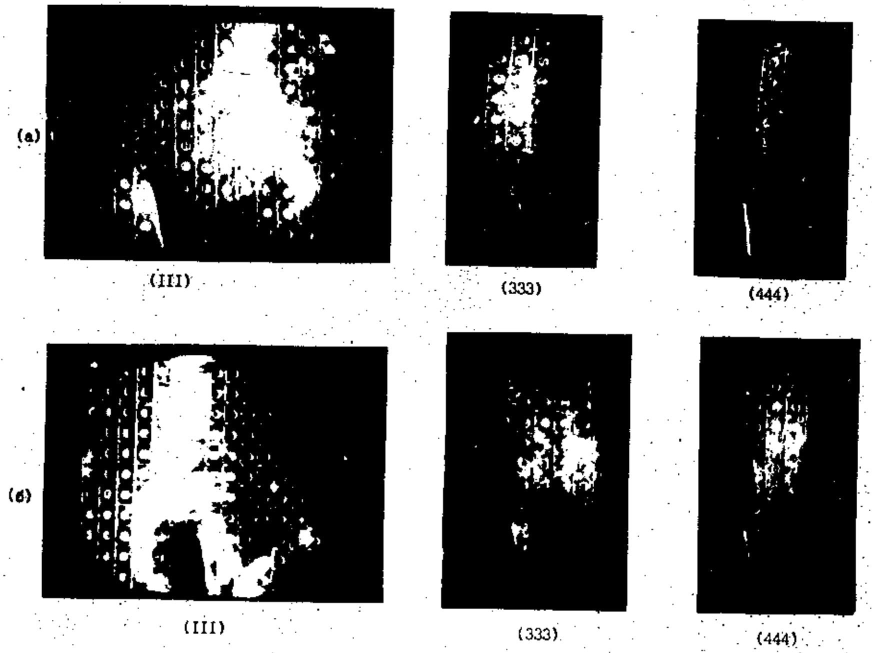


Fig. 2

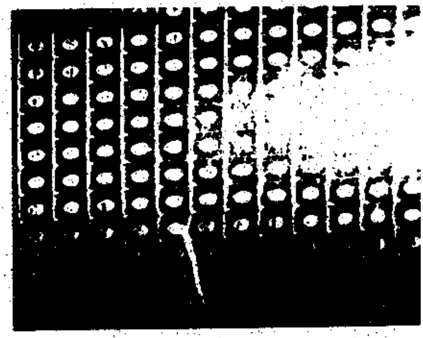


Fig.3

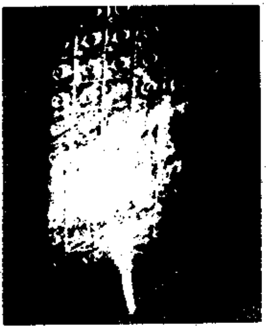
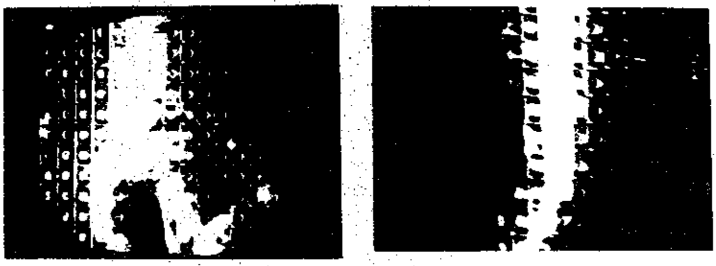


Fig.4



(a) (b)

Fig.5

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Figure Captions

Fig. 1 Topograms of Si sample with unit dislocations in (III), (333), (444) orders of reflection taken on a two-crystal spectrometer;

a) at (n, +n) arrangement of crystals;

b) at (n, -n) arrangement of crystals.

Fig. 2 Topograms of silicon substrate with a diode matrix in (III), (333), (444) orders of reflection taken on a two-crystal spectrometer;

a) at (n, +n) arrangement of crystals;

b) at (n, -n) arrangement of crystals.

Fig. 3 Topogram of a silicon substrate with a diode matrix taken on a one-crystal spectrometer.

Fig. 4 Topogram of a silicon substrate with a diode matrix taken in the Laue geometry on a one-crystal spectrometer.

Fig. 5 a) topogram of a silicon substrate disturbed region in (III) order of reflection taken on a two-crystal (n, -n) spectrometer.

b) Topogram of a silicon substrate undisturbed region in (III) order of reflection taken on a two-crystal (n, -n) spectrometer.

И.П.КАРАБЕКОВ, Д.Л.ЕГИКЯН, Р.А.МИКАЭЛЯН,
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С.Л.ХАЧИКОГЛЯН С.Л.

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(на английском языке, перевод Л.Н.Багдасаряна,А.М.Похсрарян)

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