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**ЕРЕВАНСКИЙ ФИЗИЧЕСКИЙ ИНСТИТУТ**

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**БФН-588(75)-82**

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**INVESTIGATION OF BENT MONOCRYSTALS STRUCTURAL PERFECTION**  
**USING SYNCHROTRON RADIATION DIFFRACTION PECULIARITIES**

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INVESTIGATION OF BENT MONOCRYSTALS STRUCTURAL PERFECTION  
USING SYNCHROTRON RADIATION DIFFRACTION PECULIARITIES

The results of the investigation of synchrotron radiation (SR) diffraction peculiarities from distorted monocrystalline plates are presented. The possibilities of SR diffraction peculiarities for the definition of monocrystals structural perfection are discussed.

Yerevan Physics Institute

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ИСПОЛЬЗОВАНИЕ ОСОБЕННОСТЕЙ ДИФРАКЦИИ СИНХРОТРОННОГО  
ИЗЛУЧЕНИЯ ОТ ИЗОГНУТЫХ МОНОКРИСТАЛЛОВ В ИССЛЕДОВАНИИ  
СТРУКТУРНОГО СОВЕРШЕНСТВА

Представлены результаты исследования особенностей дифракции синхротронного излучения от деформированных монокристаллических пластин. Обсуждается возможность использования особенностей дифракции СИ для определения структурного совершенства монокристаллов.

Ереванский физический институт

Ереван 1982

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The structural perfection investigation of semiconductor substrates, which are the basic elements of modern microcircuits, and the development of quick test methods of identification of disturbances is an urgent problem, the solution of which will permit to essentially increase the industrial yield and the quality of produced devices. A number of publications using all wide spread methods of investigation, including the X-ray topography are carried out in this direction [1,2]. This method is the most promising compared with the others, since being non-distorted it permits to identify the type of disturbances and the real picture of defects distribution in volume and on the sample surface. The investigation technique using the X-ray topography method is commonly connected with X-ray tubes. To intensify these investigations and to achieve quick-testability, X-ray devices have been developed with ultimate attainable parameters [3].

However, even using this technique the exposure time for typical cases makes several hours. The use of SR [4] allows to reduce by 3 + 4 orders [5] the exposure time for similar cases. Moreover, the high angular and spectral density of photon flux,

the spectrum continuity and almost total linear polarization of the radiation additionally increase the possibilities of X-ray topography method.

In this connection, using semiconductor substrates of electronic devices the structural perfection investigation was carried out by the method of two-crystal topography in the Bragg geometry using SR [6]. This research showed the high sensitivity of the method to various disturbances and the possibility of developing on its basis a commercial quick test method. As has been shown, the one peculiarity of all the topograms obtained in the first (III) order of reflection of monocrystalline substrates with microcircuits and devices (see fig. 1), is the origin of a narrow illuminated strip, "glitter" directed along the vertical axis of the spectrometer collimating system. The origin of such a "glitter" may be accounted for by the complex curve of the substrate arising at its technological processing [7]. The degree and form of the curve of each element of the plate surface is determined by its mechanical parameters which may vary depending on the density and type of defects [8]. This is convincingly shown on fig. 1a,b (III) which presents topograms of the sample region with strong disturbance. The straight-line "glitter" with equal boundaries is obtained from the region with no disturbance (see fig. 2). Thus the two-crystal topography using SR acquires one more criterion allowing to develop a quick test method of analysis of the structural perfection of semiconductor substrates designed for the production of microcircuits.

The validity of the accepted explanation of the "glitter"

origin was confirmed by a number of experimental tests. First, the width of the "glitter" is independent of the output collimator dimension, i.e. of the width of the illuminated region of the sample surface. Second, the rotation of the sample in azimuthal plane doesn't lead to any essential change in the position of the "glitter" vertical axis. Third, there is no "glitter" on topograms from the plates that have not undergone technological operations of applying the microcircuits. The "glitter" is also lacking after the mechanical polishing of the plate surface layer from both sides. Finally, the "glitter" practically of the same width arises from both sides of the substrate.

The conditions of the "glitter" origin and its width may be obtained from the following simple relations. For the selected value of the Bragg angle  $\theta_B$  the reflection from the bent in the radius R crystal appears when the central angle of the plate illuminated region  $\Delta S$  and the incident beam divergence  $\Delta \psi$  are equal:

$$\Delta S / R = \Delta \psi \quad (1)$$

The divergence of the beam without consideration of the source transverse dimensions may be presented by the relation of the collimator width  $h$  to the distance  $L$  between the collimator and the source. Hence, (1) may be rewritten as

$$\Delta S / R = h / L \quad (2)$$

or

$$\Delta S = h \cdot R / L$$

The experimental testing of the expression (2) validity is accomplished using bent quartz monochromator included in the set

of the installation DRON-2.0. The radius of the crystal curve is  $R = 2.56\text{m}$ , the distance up to the source is  $L = 25.75\text{m}$ . The width of the "glitter" topogram in this case is  $0.19\text{mm}$  which is in a good agreement with (2) at  $h = 2\text{mm}$  and at the angle of the beam incidence on crystal  $\theta_B = 14^\circ$ . The width of the topogram of this crystal taken out of the frame determining the required curve radius corresponded to the width of the surface illuminated by SR beam. It is seen from (2) that to observe the "glitter", the ratio  $R/L$  should be  $\approx 1$ . Such a condition, easy to fulfil with SR beams ( $L \gg R$ ), is practically impossible in setups using traditional X-ray tubes. Hence the use of "glitter" characteristics for the quick test analysis of structural perfection is possible with SR beams only. To identify the type and concentrations of disturbances by analysing the "glitter" boundary form and the picture of the intensity distribution in it, further experimental and theoretical investigations are required.

At the same time, of certain interest is the investigation of parameters of angular and space distribution of photons in "glitter" with the aim of their possible use in X-ray optics. Rocking curves of bent substrates and the form of the photon space distribution in diffracted beam are measured. Appropriate diffractograms are depicted on fig. 3a. Here are also diffraction curves and curves of the space distribution of photon density obtained from control non-bent substrates (see fig.3b). Rocking curves are taken with an X-ray spectrometer using the goniometer GUR-5. Curves of photon density distribution are obtained by means of a  $50\text{mm}$  wide collimating slit. As is seen

from these curves, the diffraction maximum of the bent crystal is much wider than the corresponding curve of the plane substrate. On the other hand, the space density of photons in "glitter" is approximately 1.5 times higher than in the beam diffracted from the crystal plane. Such an increase in the space density of photons reflected by a bent crystal is observed from both surfaces of the sample. These characteristics of "glitter" may be used to form SR beams with a high density of photon flux, which is very important for investigations carried out using methods of small-angle scattering, topography etc. and also as a method of slitless collimation.



b



a

FIG. 1

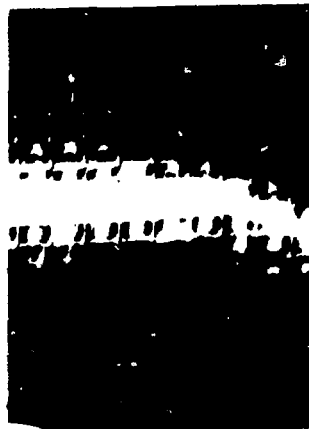


FIG. 2

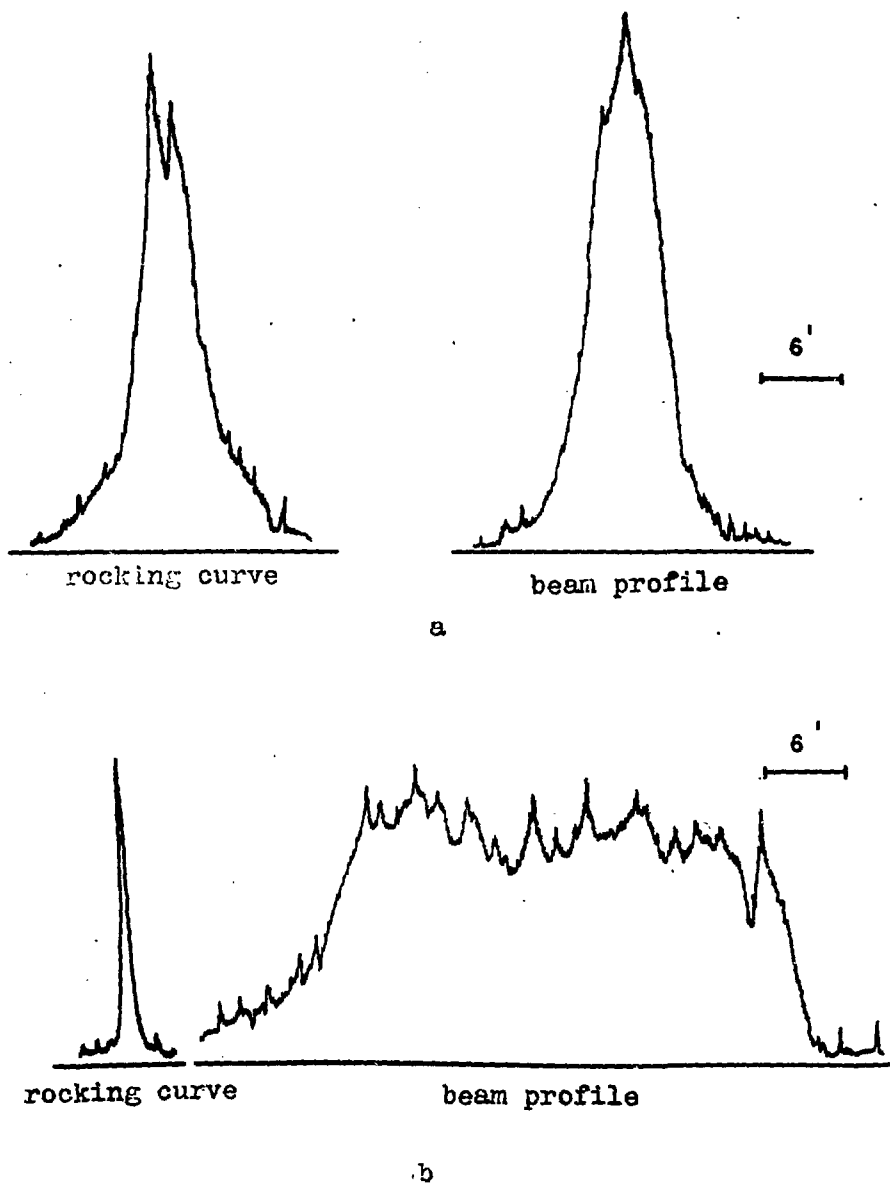


Fig. 3

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## Figure Captions

- ig. 1 Topograms of the disturbed region of the substrate with a diode matrix in the first(III) order of reflection  
a) at antiparallel disposition of spectrometer crystals;  
b) at parallel disposition of spectrometer crystals.
- Fig. 2 Topogram of the substrate with a diode matrix in undisturbed region.
- Fig. 3 a) Rocking curve and space distribution of photon density from the substrate with a diode matrix.  
b) Rocking curve and space distribution of photon density from control non-bent sample.



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