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YEREVAN PHYSICS INSTITUTE

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INVESTIGATION OF CRYSTAL PERFECTION BY MEASURING OF COLLIMATIG SLIT IMAGE WIDENING IN DIFFRACTED SYNCHROTRON RADIATION

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ԲՅՈՒՐԵՂՆԵՐԻ ԿԱՏԱՐԵԼՈՒԹՅԱՆ ՈՒՍՈՒՄՆԱՍԻՐՈՒԹՅՈՒՆԸ ԿՈԼԻՄԱՑՈՐԻ ՊԱՏԿԵՐԻ ԼԱՅՆԱՑՄԱՆ ԵՂԱՆԱԿՈՎ ԴԻՖՐԱԿՑՎԱԾ ՍԻՆՔՐՈՏՐՈՆԱՅԻՆ ՃԱՌԱԳԱՅԹԻ ՓՆՏՐՈՒՄ

Ներկայացված է ստեղծված մի մեթոդ, որի միջոցով կարելի է որոշել բյուրեղների մակերևույթի և ծավալի կատարելությունը: Այն հիմնված է կոլիմատորի անցքի պատկերի լայնացման վրա, որը արտահայտվում է սինքրոտրոն ճառագայթման դիֆրակցիայի երկբյուրեղ (n, +n) սպեկտրաչափի միջոցով:

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INVESTIGATION OF CRYSTAL PERFECTION BY MEASURING OF COLLIMATIG SLIT IMAGE WIDENING IN DIFFRACTED SYNCHROTRON RADIATION

The design and experimental study of a method for determination of surface and volume perfection degree of crystalline samples by means of measuring the widening of the collimating slit image in diffracted by (n,+n) spectrometer SR beam are presented.

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Yerevan 1988

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Н.Н.КАРАБЕКОВ, Д.Л.ЕНИКЯН

ИССЛЕДОВАНИЕ РАСШИРЕНИЯ ИЗОБРАЖЕНИЯ КОЛЛИМИРУЮЩЕЙ ЩЕЛИ В ДИФРАГИРОВАННОМ РЕНТГЕНОВСКОМ СИНХРОТРОННОМ ИЗЛУЧЕНИИ ОТ СТЕПЕНИ СОВЕРШЕНСТВА КРИСТАЛЛОВ

Представлены результаты разработки и экспериментального исследования метода определения степени нарушенности поверхности и об"ема кристаллических образцов путем измерения расширения изображения коллимирующей щели в дифрагированном двухкристальным (n , +n) спектрометром пучке синхротронного излучения

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One of the most important tasks of investigation of X-rays diffraction from crystalline structures is determination of quantitative relation between the diffraction parameters and the degree of the crystalline structure perfection. Here most interesting for modern industry are the methods allowing to obtain required information quickly and with high resolution.

With this purpose a number of nondestructive methods of identification of the structural perfection of monocrystals such as topography [1,2], measurement of the diffraction parameters [3,4], secondary electron processes in solids [5] , etc are used. But, all the methods listed are not quick because the comparativly long time is necessary for measurement and compute of a great number of parameters, using special programs [6], and for preparing of samples, especially, for the vacuum conditions [7].

In the present paper the results of design and experimental study of a method for determination of the degree of surface and volume structural perfection of crystalline samples by means of measuring only one parameter of photons spatial distribution at X-ray diffraction are presented.

Realization of the proposed method, using SR of dedicated sources [8] with the usual beam emittances and intensities, will allow to obtain high quickness and resolution.

The method lies in the following. The SR beam, collimated by a h_o- wide slit, is directed on a double-crystal spectrometer (DCS) with antiparallel dislocation of crystals and located at L distant from the collimator's plane. The width, h of the diffracted beam after DCS, as it is seen from the Du-Mond's diagram [9] (see Fig.1), in a general case, when the crystals have a different structural parameters, is defined by

$$h = h_o + \frac{\varepsilon_1 ctg\theta_1 tg\theta_2 + \varepsilon_2}{1 + ctg\theta_1 tg\theta_2} L \qquad (1)$$

where θ_1, θ_2 -diffraction angles, and $\varepsilon_1, \varepsilon_2$ are the widths of the rocking curves of the used crystals.

The case of identical crystals brings eq. (1) to the form:

$$h = h_o + \frac{\varepsilon_1 + \varepsilon_2}{2} L \qquad (2)$$

As it is known (see, e.g., Ref [3,4]), the rocking curve width and shape are sensitive to the lattice disturbances and hence, the value $\Delta h = \frac{\varepsilon_1 + \varepsilon_2}{2} L$ defines the degree of perfection of crystals using in the given diffraction.

Let the first crystal in DCS, serving as a monochromator, for which ε_1 is known, when the second crystal, to be searching sample, is substituted during the experimental. The value of Δh, measured for each sample, will be proportional to the rocking curve width ε_2 of searching sample and hence will determine the degree of its perfection..

The method was experimentally investigated using SR beam of the Yerevan Physics Institute accelerator ARUS. The SR beams necessity for the performing of the idea based on the fact, that the absolute value of Δh and hence, resolution too, are defined by the distance L, which in case of SR, can reach tens of meters. For example, for L=100 m the method's resolution is up to 0.05", when the slit's width measurement accuracy is $\sim 1\mu m$.

The experimental facility consists of a double-crystal spectrometer based on a ordinary goniometer type GUP-5, a collimating system, dislocated on the beam line at 8m distant from the first axis of DCS, a vacuum beam pipe and a detection system.

The shape of the diffracted beam was pectured using R3-1 type film, placed perpendicularly to the beam axis with a precision better than 2'. The experimental facility is schematically shown in Fig.2. The Experiment was performed in Bragg-Bragg and Bragg-Borman geometries, which allowed to investigate the sensitivity of the method to surface and space disturbances. To provide ATXR conditions ($\mu t > 6$) at investigations in Bragg-Borman geometry, the wavelength was chosen to be $\lambda \sim 0.5$Å, which simultaneously allowed to avoid the effect of harmonic components in the SR photons flux. The width of the slit was chosen to be 500 μm. As a samples for the research the Ge monocrystals with Ga, As and Cu admixtures in concentrations of $\sim 10^{18}$ atom.cm, and Si monocrystals polished by 7, 20 and 50μm -grained abrasive powder were used.

Fig.3 represents the images, obtained from the samples under investigation. The widths of the slit images, measured by

means of comparator having 1μm resolution are given in the Table.

The results presented in the Table indicate to high sensitivity of the method suggested. Ibidem, the widths of the rocking curves of the samples under investigation are presented, which are measured on the (n - n) spectrometer using SR. Comparison of the results of measurements of ε and Δh confirms that the interpretation of the slit's image widening mechanism is correct and it is possible to use the method under discussion to identify the degree of monocrystals disturbance.

Using instead of the film another more sensitive detector will allow to attain high quickness of the method.

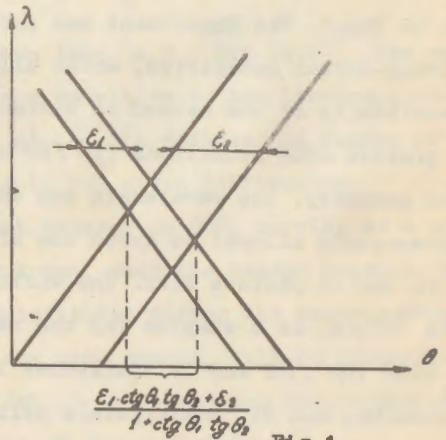

Fig.1

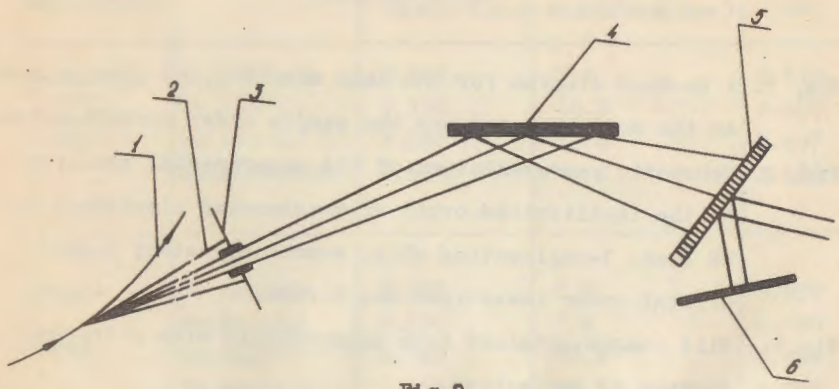

Fig.2

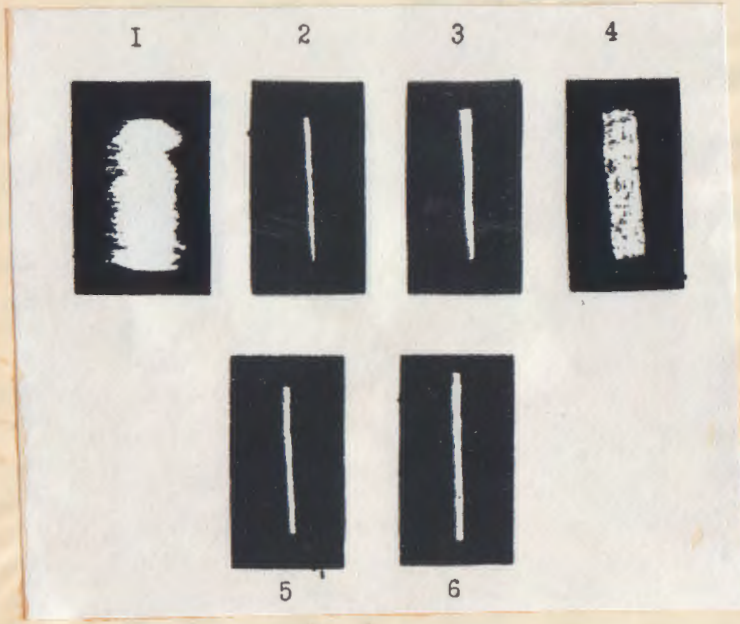

Fig.3

Figure Captions

Fig. 1. A Du-Mond diagram for the case with (n,+n) arrangement of the monochromator and the sample under investigation.

Fig. 2. Schematic representation of the experimental facility: 1- the iquilibricem orbit of accelerated electrons; 2- SR beam; 3-collimating slit; 4-monochromator; 5-monocrystal under investigation; 6-film.

Fig.3. Slit images,obtained from monocrystals with different degrees of perfection

1.- The collimated SR beam cross section image behind of the Be window.

2.- Perfect Si , Bragg-Bragg geometry.

3.- Anperfect Si, Bragg-Bragg geometry.

4.- Polished Si (5:0μm grains), Bragg-Bragg geometry.

5.- Perfect Ge, Bragg-Bragg geometry.

6.- Perfect Ge, Bragg-Borman geometry.

Table

Geometry of experiment	Sample	Diffracted width h (mm)	Rocking curve width(ang.sec)	$\Delta h = h - h_o$ (mm)
Bragg-Borman	Ge perfect	0.610	7.0	0.110
	Ge (As)	1.100	10.2	0.600
	Ge(Ga)+Cu	1.397	7. 6	0.897
	Si anperfect	1.989	11.8	1.489
Bragg-Bragg	Ge perfect	0.539	7.0	0.039
	Ge(Ga)+Cu	0.600	7.6	0.100
	Ge (As)	0.962	10.2	0.462
	Si perfect	0.525	6.5	0.025
	Si polished (7μm)	0.887	12.0	0.387
	Si polished (20μm)	1.767	91.5	1.267
	Si polished (50μm)	2.372	169.0	1.872
	Si anperfect	0.887	11.8	0.387
Collimator width			h_o = 0.500 mm	

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ИССЛЕДОВАНИЕ РАСШИРЕНИЯ ИЗОБРАЖЕНИЯ КОЛЛИМИРУЮЩЕЙ ЩЕЛИ В ДИФРАГИРОВАННОМ РЕНТГЕНОВСКОМ СИНХРОТРОННОМ ИЗЛУЧЕНИИ ОТ СТЕПЕНИ СОВЕРШЕНСТВА КРИСТАЛЛОВ

(на английском языке, перевод Папяна Г.А.)

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