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Study of X-Ray Surface Backscattering

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Interest in X-ray backscattering (BS) (the limiting case of the Bragg diffraction at $\Theta_B \approx \pi/2$) is attributed to such peculiarities of this geometry as a large angular width of reflection and an extreme sensitivity to the radiation wavelength and the value of the crystal parameter.

So far the great majority of studies have treated the BS effects in the Bragg geometry. In the Laue geometry, BS takes place only for diffraction planes which are normal to the crystal surface with an accuracy $|\gamma| \lesssim 10^{-3}$ rad. In this case diffracted beams glance with respect to the surface, i.e. surface backscattering (SBS) is realized which may be regarded as a limiting case of diffraction in the grazing geometry /1, 2/. The SBS scheme has been suggested in /3/, a lengthy theoretical treatment has been given in /4/ and a coplanar variant has also been considered in /5/.

In the present note the SBS effects have first been studied experimentally. The measurements were carried out on the specularly reflected beam under $CoK\alpha_1$ radiation diffraction conditions by the (620) planes of a Ge crystal with the (001) surface orientation. The experimental layout is presented in Fig. 1. An X-ray beam from the 1.3 kW source with focus 400x800 μm^2 was collimated on the horizontal plane within $\delta\Theta_\parallel \approx 0.5'$ by the two crystal monochromators 1 and 2, respectively Ge (111) and Si (333). Collimation in the vertical plane (with respect to the incidence angle ϕ_0) within $\approx 3'$ was performed by slit 3, 180 μm in width. The collimating system cut the radiation with a fixed wavelength accurate to $\Delta\lambda/\lambda \approx 0.9 \times 10^{-5}$. We could vary λ within the $CoK\alpha_1$ line by turning crystal 2. The specularly reflected beam was counted by detector 4. The backscattered beam was not detected.

While adjusting the sample orientation we kept in mind that (620) backscattering is a four-wave one with excitation of additional $(2\bar{2}0)$ and (440) reflections whose intensity was recorded by detectors 5 an 6. The fulfillment of the BS condition $|\varepsilon = 1-\lambda/2d| \lesssim 10^{-5}$ was achieved through the variation of the sample temperature.

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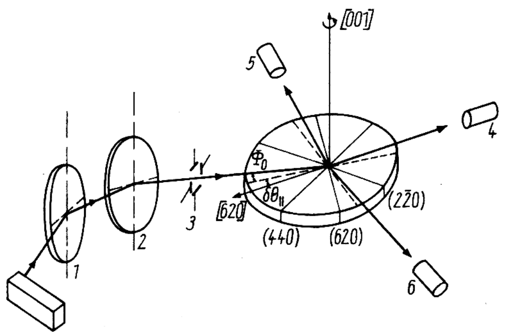

Fig. 1. Experimental layout

It was checked by the coincidence of the angular positions of (2$\bar{2}$0) and (440) peaks. Coincidence was reached at T = 17 °C.

Fig. 2 presents angular dependences of the specularly reflected beam intensity on $\delta\theta_{\parallel}$ at ϕ_o = 21$'$ and various λ within the width of the CoKα_1 line with the step $\Delta\lambda/\lambda = \Delta\varepsilon = 1.5\times10^{-5}$ (curves 1 to 4). The dashed lines show theoretical curves computed based on the theory proposed in /4/ in the two-wave approximation with due account of the averaging over $\varepsilon \approx 0.9\times10^{-5}$ as well as the surface amorphous layer 4 nm thick and the angle of misorientation of the (620) planes $\gamma = -3'$. The experimental curves 1 to 4 display a large angular width predicted in /4/ which is several orders of magnitude broader than multiwave drops in the central region.

As is seen from Fig. 2, SBS can be exploited for taking precise measurements of ε thereby determining the lattice parameter in a thin surface layer ($\lesssim$ 10 nm thick) of a crystal with an accuracy $\Delta d/d \approx 10^{-5}$ to 10^{-6} which is an order of magnitude higher than the accuracy provided by the multiwave method /6/. For example, under experimental conditions the variation of the lattice parameter resulting from the Ge crystal cooling by 2 K brought about a transformation of curve 4 into curve 3 (Fig. 2). An additional broadening of the experimental curves as compared to the theoretical ones in Fig. 2 is indicative of a spread $\Delta d/d \approx 5\times10^{-5}$ in the crystal surface layer. The possibility of taking measurements on a specularly reflected beam without recording a backscattered wave considerably simplifies the experimental scheme in comparison with the scheme of the method realized in /7/.

Measurements of a backscattered wave planned for the future are of an independent interest. First, the increase in the angular width of diffraction curves

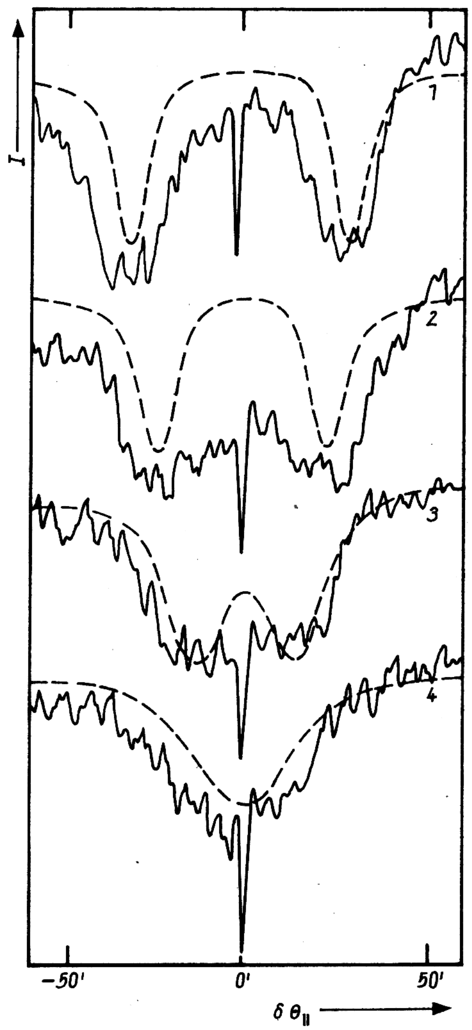

Fig. 2. Specularly reflected beam intensity as a function of the azimuthal angle at different ε: (1) $5x10^{-5}$, (2) $3.5x10^{-5}$, (3) $2x10^{-5}$, (4) $0.5x10^{-5}$. Solid lines indicate experimental data, dashed lines show theoretical computations

close to the SBS conditions by 2 or 3 orders of magnitude allows a precise check of the theory of grazing incidence diffraction /1, 2/. Secondly, based on the SBS theory /4/ one may predict a specific SBS effect: a backscattered wave will leave a crystal in a strictly limited cone of diffraction angles $\phi_o^2 + 2\delta\theta_{\parallel}^2 \lessapprox 4\varepsilon + 2\gamma^2$. An experimental study of this effect may prove to be useful for the collimation of X-ray beams.

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References

/1/ V.G. BARYSHEVSKII, Zh. tekh. Fiz., Pisma 2, 112 (1976).

/2/ A.M. AFANASEV and M.K. MELKONYAN, Acta cryst. A39, 207 (1983).

/3/ S.A. MAKSIMENKO, phys. stat. sol. (a) 85, K23 (1984).

/4/ S.A. STEPANOV and E.A. KONDRASHKINA, Poverkhnost (1989), in the press.

/5/ A.P. BEZIRGANYAN and P.A. BEZIRGANYAN, phys. stat. sol. (a) 105, 345 (1988).

/6/ A.L. GOLOVIN, R.M. IMAMOV, and E.A. KONDRASHKINA, phys. stat. sol. (a) 89, K5 (1985).

/7/ YU.P. STETSKO, S.A. KSHEVETSKII, and I.P. MIKHAILYUK, Zh. tekh. Fiz., Pisma 14, 29 (1988).

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