THE "THIN" AND "THICK" CRYSTAL APPROXIMATIONS IN ANOMALOUS X-RAY TRANSMISSION

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The possibility of transition from the "thick" crystal approximation to asymmetric transmission and to the "thin" crystal approximation by changing the structure parameters, the temperature, or purity of the crystal while retaining the geometric thickness constant is verified experimentally.

IT is usual to distinguish in the anomalous transmission of x rays two limiting cases depending on the value of the parameter $\mu_0 t$ where μ_0 is the normal absorption coefficient and t is the thickness of the crystal. If $\mu_0 t \ll 1$ (the region of the "thin" crystal approximation), then the intensity of the transmitted radiation at the Bragg angle decreases appreciably as a result of extinction. In a narrower sense of the word, anomalous transmission (a sharp decrease of the absorption) occurs when $\mu_0 t \gg 1$ (the region of the "thick" crystal approximation). The intermediate case $\mu_0 t \sim 1$ corresponds to asymmetric transmission—the angular dependence of the intensity transmitted through the crystal has both a peak and a dip.

However, the interaction of the radiation with the lattice can be influenced by changing the structure parameters of the crystal or the experimental conditions; one can, therefore, carry out the transition from the region in which the "thin" crystal approximation is valid to the region of the "thick" crystal approximation without changing the actual thickness of the crystal. Such a possibility is, for instance, clear from a consideration of the expression for the anomalous absorption coefficient μ [1] which contains the quantity $\epsilon = K\,|F''_{hkl}/F''_{000}|$ where K is the polarization factor and F''_{hkl}/F''_{000} is the ratio of the imaginary parts of the structure factor of the reflection hkl and of the transmitted beam. The value of ϵ depends on the indices of the system of planes (in particular, on the order of the reflection), on the temperature, and as shown by

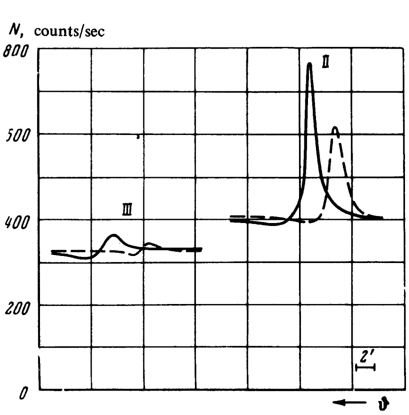

FIG. 1. Anomalous transmission of MoKβ radiation in tin. The crystal was 0.4 mm thick, (020) reflection; II, III–order of the reflection. Solid curve–T = 120°K, dashed curve–T = 293°K.

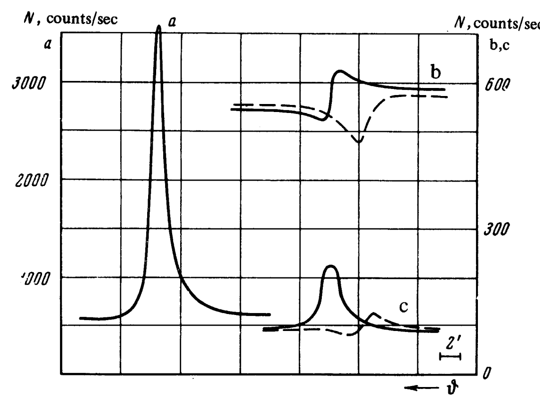

FIG. 2. Anomalous transmission of MoKβ radiation in tin. First-order reflection. Solid curves–T = 120°K, dashed curves–T = 293°K. a – (020) reflection, 0.4 mm thick crystal; b – (420) reflection, 0.4 mm thick crystal; c – (420) reflection, 0.6 mm thick crystal.

Hunter[2] on the various types of disturbances of the crystal structure.

We checked the possibility of transition from a "thin" crystal to asymmetric transmission and to a "thick" crystal without changing t experimentally using single crystals of tin. The experimental setup has been described in[3].

Figure 1 shows the dependence of the intensity of MoKβ (19.6 keV) radiation transmitted through a single crystal as a function of the angle of rotation of the crystal relative to the direction of the incident beam in the second and third-order reflections at temperatures of 120 and 393°K. The reflecting planes were the (020) planes. The crystal was 0.4 mm thick. As is seen from the figure, in the higher-order reflections there is a change in the nature of the transmission of the radiation by the crystal.

The transition from the peak to asymmetric transmission is also possible when a change is made of the reflecting planes [Figs. 2a and 2b, (020) reflecting planes—Fig. 2a and (420)—Fib. 2b, solid curves]. The anomalous transmission peak can be re-established by increasing the thickness of the crystal (Fig. 2c, solid curve). Increasing the temperature corresponds to a return to asymmetric transmission (Fig. 2c, dashed curve). Figure 2b also illustrates the transition from asymmetric transmission (solid curve) to the extinction dip (dashed curve) on increasing the temperature.

Figure 3 illustrates the effect of impurity defects of the crystal structure on the anomalous transmission. Without changing the crystal thickness (0.4 mm), the peak characteristic of a crystal with a rather perfect structure is replaced by asymmetric transmission[1)].

Thus, depending on the parameters of the reflecting planes, the degree of purity of the crystal and the temperature, not only does the intensity of the anomalously transmitted radiation change, but sharp qualitative changes in the nature of the transmission of the radiation through the crystal take place. Making use of this result, it is apparently possible by an optimal choice of experimental conditions to increase considerably the sensitivity of existing methods of controlling crystal perfection based on the quantitative investigation of the anomalous transmission of x rays.[5]

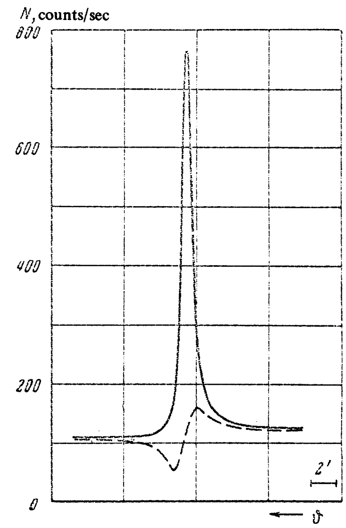

FIG. 3. Anomalous transmission of MoKβ radiation in tin. Crystal thickness—0.4 mm. (020) reflection. First-order reflection. Solid curve—crystal without impurities. Dashed curve—crystal with impurities of iron ($\sim 10^{-4}$), copper ($\sim 5 \times 10^{-4}$), aluminum ($\sim 10^{-4}$) and antimony ($\sim 10^{-4}$).

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[2]L. P. Hunter, Koninkl. Ned. Akad. Wetenschap. Proc. B61, 214 (1958).

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[4]G. L. Rogosa and G. Schwarz, J. Appl. Phys. 24, 954 (1953).

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[1)]We have observed the transition from a "thick" to a "thin" crystal due to an increase of the number of dislocations and of the related structural disturbances of the lattice in KCl crystals. [3] The effect of the degree of perfection of a LiF crystal on the nature of the anomalous transmission has been investigated in [4]. It was noted there [4] that an investigation of the anomalous transmission can yield an estimate of the dimensions of regions of perfect structure in large mosaic crystals.

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