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ANISOTROPY OF THE MOSSBAUER EFFECT IN SINGLE CRYSTALS OF β-Sn *AND CASSITERITE* (SnO_2)

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The anisotropy of the resonance absorption probability f′ of 23.8-keV γ quanta in single-crystal specimens of β-Sn and cassiterite (SnO_2) was investigated at different temperatures. In β-Sn single crystals anisotropy decreases as the temperature drops from 400 to 77°K, and becomes barely noticeable near the boiling point of nitrogen. $f'_{(001)}/f'_{(110)} = 1.3$ in single crystals of SnO_2 at temperatures from 293 to 810°K. The centers of gravity of the cassiterite absorption spectra, plotted for samples with different orientations, are noticeably displaced relative to one another, possibly because of the presence of weak quadrupole splitting of the 23.8-keV line in $Sn^{119m}O_2$.

To study the dependence of the resonance absorption probability of γ quanta on the crystallographic orientation for different temperatures, specimens cut in the (001) and (110) planes from single crystals of white tin and from natural single crystals of cassiterite (SnO_2) were used. Relatively large SnO_2 single crystals were cut by ultrasonic means into slabs, which were then polished. This yielded several samples 20—30μ thick with transverse dimension 6—8 mm. The β-Sn slabs were cut by electro-erosion with subsequent electro-polishing. X-ray investigations made before and after the experiment confirmed that the produced samples were single crystals.

Single-crystal absorbers with a collimator were placed in an oven whose temperature was varied from 293 to 393°K for β-Sn and from 293 to 810°K for SnO_2. The measurements on the β-Sn samples were made also at liquid-nitrogen temperature. The temperature was measured with a chromel-alumel thermocouple.

The Sn^{119m} 23.8-kev γ quanta source, in the form of a polycrystalline SnO_2 powder, was kept at room temperature. The measurements were made with apparatus described previously[1], in which the absorber could be moved at a constant speed. The profile of the cam which converted the rotary motion into translation included a constant-radius section (zero-velocity sector). This made it possible to monitor the counting date during the course of the experiment.

A characteristic feature of the absorption spectra obtained with single-crystal cassiterite is that at room temperature their centers of gravity are shifted relative to the point v = 0 in the following fashion: for the (001) absorber—quite noticeably (0.10 mm/sec) towards positive velocities, and for the (110) absorber—less noticeably (0.03 mm/sec) towards negative velocities.

This feature is obviously connected with the presence of weak quadrupole splitting of the 23.8-keV level. Indeed, the ratio of the intensities of the absorption-spectrum components, corresponding to the Sn^{119m} spin projections on the fourfold symmetry axis of the tetragonal crystal lattice of cassiterite $\pm 3/2$ and $\pm 1/2$, is equal to 3:1 for the (001) absorber and 3:5 for the (110) absorber, in qualitative agreement with the observed displacement values. The observed difference in the positions of the minima of absorption, amounting to 0.13 mm/sec for these absorbers, yields for the quadrupole splitting a value $\Delta \sim 0.22$ mm/sec. The signs of the observed shifts indicate that the sublevel with spin projection $\pm 3/2$ has a larger energy than the sublevel with spin projection $\pm 1/2$. It follows therefore that the quantity Qq_{zz} (Q — observed quadrupole moment of the nucleus and q_{zz} —component of the electric-field gradient along the symmetry axis) is positive (in analogy with the case of SnO[2] and contrast to the case of β-Sn[3]). With increasing temperature, the centers of gravity of the absorption spectra of absorbers with either orientation naturally shift towards negative velocities, and the distance between the centers of gravity remains constant within the limits of experimental error (Fig. 1). The temperature shift for the samples of both orientations depends linearly on the temperature.

Table I

Orientation	293° K		470° K		635° K		810° K	
	ε	f'	ε	f'	ε	f'	ε	f'
(001)	20.9	0.69±0.07	19.6	0.55±0.06	18.3	0.46±0.05	14.7	0.30±0.03
(110)	18.6	0.54±0.05	17.1	0.45±0.05	15.4	0.36±0.04	12.1	0.22±0.02

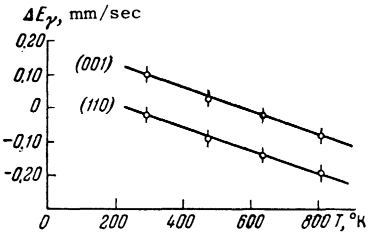

FIG. 1. Temperature shifts for single-crystal SnO_2 absorbers.

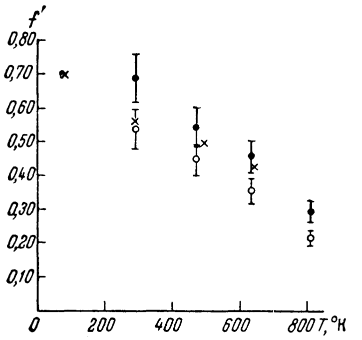

FIG. 2. Temperature dependence of the probability of the resonance absorption f' for SnO_2 absorbers of different orientations: × – polycrystal (data of[5]), ● – (001), o – (110).

The slope of the plots of these curves is -3.4×10^{-4} mm/sec-deg, which is in good agreement with the -3.48×10^{-4} mm/sec-deg obtained theoretically for high temperatures, when the dependence is governed only by the mass of the radiating nucleus.

The resonance absorption probability f′ was determined from the areas of the experimental absorption spectra (by a method proposed by Bykov and Pham Zuy Hien[4]). Table I lists the values of $\epsilon = [N(\infty) - N_{min}]/N(\infty)$, reduced to an SnO_2 absorber thickness 16.3 mg/cm², and the corresponding values of f′. The noticeable anisotropy of the quantity $f'(f_{(001)}/f'_{(110)} = 1.3)$ apparently remains constant in the investigated temperature interval. The temperature dependences of $f'_{(001)}$ and $f'_{(110)}$ are shown in Fig. 2 (for comparison we given also data for a polycrystalline absorber[5]).

We proceed to the results obtained with white tin. We have confirmed, using a stronger radiation source, the previously obtained data[3] on the anisotropy of the effect at room temperature. With increasing temperature, the anisotropy of the effect increases. The corresponding data are listed in Table II.

The results of the measurements at the temperature of liquid nitrogen differ from those previously published, namely, $f'_{polycr} = 0.34 \pm 0.03$; $f'_{(110)} = 0.32 \pm 0.03$; $f'_{(001)} = 0.35 \pm 0.04$. However, these data must be approached with great caution. The point is that the technology used to prepare the single-crystal β-Sn slabs does not guarantee their equal thickness over the entire area. Under low temperature conditions (close to saturation), in the case of geometrically thin absorbers (30–35μ), a local decrease in thickness, of small absolute magnitude can greatly distort the result. We can apparently merely state that the anisotropy of the effect decreases with decreasing temperature, and possibly disappears. The question can apparently be resolved experimentally by using at low-temperature measurements geometrically thick samples with reduced Sn^{119} content.

Figure 3 shows the temperature dependence of the Debye-Waller factor which we have measured for β-Sn absorbers of different orientation. The experimental points for the polycrystal fit satisfactorily the theoretical curve plotted by Boyle et al.[6] with account of the change in the Debye temperature Θ resulting from the anharmonicity of the lattice vibration.

Table II

Orientation	Values of f'			
	293° K	323° K	353° K	393 °K
Polycrystal	0.060±0.006	0.033±0.003	0.020±0.002	0.013±0.001
(001)	0.058±0.006	0.027±0.003	0.016±0.002	0.008±0.001
(110)	0.085±0.009	0.049±0.005	0.034±0.003	0.018±0.002

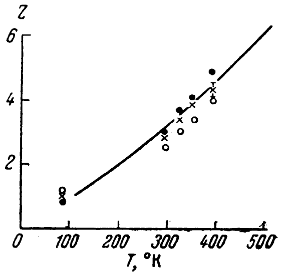

FIG. 3. Temperature dependence of the Debye-Waller factor Z for β-Sn absorbers of different orientations: × – polycrystal, ● – (001), o – (110); the continuous curve was calculated by Boyle et al.[6].

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