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MOSSBAUER EFFECT IN TELLURIUM AT PRESSURE UP TO 100 kbar

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A study of the influence of high pressures p on the parameters of the Mossbauer spectrum (the probability f of resonant absorption (emission) of gamma quanta by nuclei in crystals, the isomer shifts, or the hyperfine splitting) can yield additional information on the electron structure of a solid and on the nature of phase transitions.

The investigation of tellurium under pressure is of interest since this material is a semiconductor under normal conditions and becomes a metal at high pressure.

Figure 1 shows the p-T phase diagram of tellurium, constructed on the basis of [1 - 5]. The first phase transition occurs at a pressure 15 - 20 kbar, and the chain structure of tellurium A8 goes over there into a layered rhombohedral structure of type A7 (arsenic structure). The Te II - Te III transition is observed at 45 kbar, and in this case the tellurium becomes a metal, but the structure of the Te III phase has not yet been established.

Several authors have noted a Te III - Te IV transition at 70 kbar at room temperature [1, 5], but an x-ray structure analysis of Te, carried out in [4] up to 90 kbar, casts doubts on the existence of this phase.

In our experiments, we applied pressure to a tellurium source containing the radioactive isotope Te^{125m}. The resonant absorber of the 35.6-keV gamma quanta was $MgTeO_4$, and the tellurium was enriched with Te^{125} to 88%. The absorber was moved at equal acceleration by an electrodynamic vibrator. The system for registering the gamma quanta consisted of an SI-6R proportional counter and a multichannel analyzer operating in the time mode.

The pressure was produced in a high-pressure chamber between the flats of cemented tungsten carbide Bridgman anvils, compressed by a mechanical press [6]. The investigated sample, pressed in the form of a tablet 0.85 mm in diameter and 0.1 mm high, was placed inside a guard ring of amorphous boron of outside diameter 2 mm, inside diameter 0185 mm, and height 0.1 mm.

The compression was at room temperature, after which the press was placed in a Dewar with liquid nitrogen.

Since the electronic attenuation of the 35.6-keV gamma rays in the tellurium material was such that all the gamma quanta from the outer ring of a tablet, $\leq$ 0.1 mm deep were registered, the pressure was determined for that section of the sample. The pressure was measured by means of a calibration curve based on known reference points of the phase

transitions of Te (45 kbar) [1] and Fe (130 kbar [7].

Statistical data on each value of p were accumulated continuously for 10 - 15 days. As the result we obtained the Mossbauer spectra of Te at the pressures 0, 35 ± 10, 60 ± 10, and 90 ± 10 kbar. The spectra are shown in Fig. 2, and the parameters of the spectra are listed in the table.

№№	Te phase	Pressure p, kbar	Isomer shift rel. to Te I mm/sec	Half-width mm/sec	Quadrupole splitting mm/sec
1.	TeI	0	0	15	7,5
2.	TeII	35 ± 10	0 ± 0,5	13	7,5
3.	TeIII	60 ± 10	0,7 ± 0,5	8	0
4.	TeIV	90 ± 10	0 ± 0,5	14	7,5

Notice must be taken, first, that the probability has a negligible pressure dependence, within the limits of experimental errors. This is apparently due to the low compressibility of tellurium [8]. The value of f for Te at 80° K and p = 0 was found by us to be 0.18 ± 0.03, using the area method and the known values of f for the sources Sb^{125} (Cu) and Sb^{125} (Pd) [9].

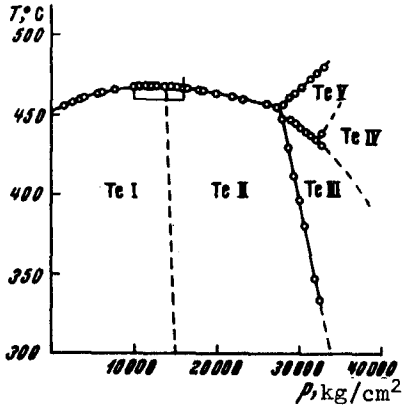

Fig. 1. Phase diagram of tellurium vs. temperature and pressure.

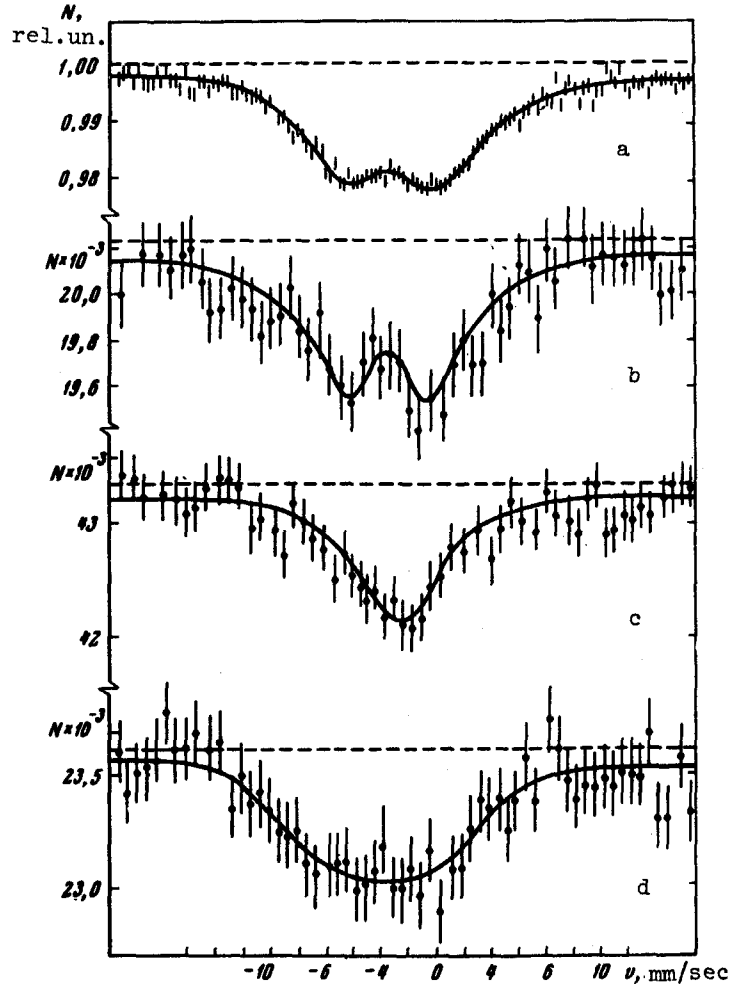

Fig. 2. Mossbauer spectra of tellurium at pressures 0 (a), 35 ± 10 (b), 60 ± 10 (c), and 90 ± 10 kbar (d).

The most sensitive to the pressure change turned out to be the form of the resonance-absorption spectrum. In the region up to 45 kbar, quadrupole splitting of the spectrum into two components was observed (Figs. 2a and 2b). The magnitude of the splitting was the same for Te I and Te II. According to [5], a bond of the covalent type is retained in the new structure. The asymmetry of the quadrupole-splitting peak, resulting from the Gol'danskii-Karyagin effect [10], can be estimated only for p = 0. The ratio of the intensities of the components is 1.05:1, which coincides with our measurements for tellurium as an absorber [11].

At pressure 60±10 kbar, an unsplit single line is observed (Fig. 2c), which corresponds, when allowance is made for the absorber thickness, to the natural emission line width of Te III, thus indicating that the electric charge distribution around the Te^{125} nucleus has spherical symmetry. This gives grounds for assuming that the metallic phase of Te III, which arises at p = 45 kbar, has apparently a cubic symmetry. The type A7 structure, which occurs at a lower pressure, is only a slight deviation from the primitive cube, and the high pressure eliminates the distortion of the A7 structure which possibly then goes into the primitive cubic cell.

This conclusion agrees with the assumption made in the review [12], on the basis of an analysis of p-T diagrams of various substances.

With further increase of the pressure, to 90 kbar, the width of the Mossbauer spectrum increases, and this is possibly due to the appearance of quadrupole splitting (Fig. 2d). Such a change in the form of the spectrum is obviously connected with the realignment of the crystal structure of the tellurium during the Te III - Te IV, which was first observed by Bridgman [1].

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