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Figure 1

Figure 1: Figure 1

Abstract

Full Text

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PHYSICAL CHEMISTRY

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THE MÖSSBAUER EFFECT IN SOLID SOLUTIONS BASED ON TIN

(Presented by Academician G. V. Kurdyumov, 7 VII 1964)

One of the characteristics of interatomic interaction in metals is the characteristic temperature θ ⁽¹⁾. Until recently it has been determined from measurements of elastic constants, heat capacity, and the intensity of x-ray reflection. On the basis of the determination of elastic constants and of the thermal scattering factor of x-rays, definite conclusions are drawn about the nature of changes in the crystal lattice of alloys (root-mean-square displacements of atoms, Debye temperature, etc.) ⁽²⁻⁷⁾. The x-ray method of determining the thermal scattering factor gives a composite picture from the atoms of the matrix and the atoms of the impurity. It does not permit separate determination of the root-mean-square displacements of impurity atoms and matrix atoms. In addition, static displacements must also be taken into account. The method of determining the thermal scattering factor of x-rays that is based on the use of the effect of resonance absorption of gamma quanta by the nuclei of atoms without recoil ⁽⁸⁾ is free of these shortcomings. Owing to the selectivity of the nuclei of the atoms of the crystal lattice of a solid solution with respect to resonance absorption of gamma quanta of radioactive isotopes, this method makes it possible to determine separately the root-mean-square displacements of matrix atoms and impurity atoms, depending on whether the Mössbauer isotope is the matrix or the impurity. In this case only the dynamic displacements of atoms are taken into account.

Fig. 1. Resonance absorption spectra at temperature $T = 155^\circ \text{ K}$: 1 —absorber made of tin with a thickness of $16.3 \cdot 10^{-4} \text{ g/cm}^2$ in tin-119 isotope; 2 —absorber made of the solid solution tin + 11 at.% bismuth with a thickness of $16.7 \cdot 10^{-4} \text{ g/cm}^2$ in tin-119. On the abscissa axis is the source velocity; on the ordinate axis is the intensity of the gamma-quanta flux in relative units.

Fig. 2

Figure 2: Fig. 2

The thermal scattering factor is related to the probability of emission or absorption of gamma quanta without recoil by the relation:

$$f = \exp(-2w),$$

where $2w$ is the thermal scattering factor, depending only on the dynamic displacements of atoms, and f is the probability of recoil-free absorption (emission) of gamma quanta, determined from Mössbauer-effect experiments.

In works ^(9, 10) the quantity f' (the probability of recoil-free absorption of gamma quanta) was determined for tin impurity atoms in matrices of vanadium, gold, platinum, and thallium in the solid-solution region. No concentration dependence of f' was found, and the assumption was made that the change in force constants in substitutional solid solutions is insignificant.

In the present work, the magnitude of recoil-free absorption of gamma quanta f' was determined in disordered solid solutions tin–bismuth, tin–indium, tin–cadmium, tin–antimony, and in pure tin. The tin atoms in the listed alloys are matrix atoms. Absorbers were prepared from alloy powder by deposition on aluminum foil. Measurements were carried out on a series of absorbers of different thicknesses (from 15 to 80 mg/cm²) for each alloy. Tin dioxide, SnO₂, containing the isomer Sn^{119m} with $E_\gamma = 23.8$ keV, was used as the gamma-quantum source. In all experiments the radiation source was at room temperature.

Measurements of the resonance-absorption spectra were made on an apparatus in which the source was given a constant velocity relative to the absorber by means of a three-sector eccentric. The sectors of the eccentric correspond to positive, negative, and zero source velocity. The detector of gamma quanta that had passed through the absorber was a scintillation counter with a NaJ(Tl) crystal about 1 mm thick. In measurements below room temperature the absorber was placed in a cryostat, the temperature in which could be varied smoothly. Temperature measurements were made with an accuracy of $\pm 3^\circ$.

Fig. 2. Probability of absorption of 23.8-keV gamma quanta without recoil by Sn¹¹⁹ nuclei: 1 –tin (solid curve calculated theoretically at $\theta = 138^\circ$), 2 –tin + 6 at.% Bi ($\theta = 126^\circ$), 3 –tin + 13 at.% Bi ($\theta = 106^\circ$)

The resonance-absorption spectra were recorded in the temperature interval 130 ÷ 300°K for alloys with different impurity concentrations (1.45; 2.9; 11; 13 at.% bismuth, 6 at.% indium, 0.8 at.% cadmium, 3.3; 7 at.% antimony). In addition, bismuth concentrations above 5 at.% were fixed by quenching in liquid nitrogen. The magnitude of the maximum absorption effect E , the width of the

resonance line Γ_{exp} , and the line position were determined. Typical resonance-absorption spectra are presented in Fig. 1. The spectra of all the alloys studied had the form of a single symmetric line; no influence of impurities was found on the line shape, its position, or the width Γ_a in comparison with pure tin.

Table 1

Alloy	θ	$\sqrt{x^2}$, Å
Tin	138 ± 4	0.0225
» +1.44% Bi	134 ± 4	0.0232
» +2.9% Bi	130 ± 4	0.0239
» +5.94% Bi	126 ± 4	0.0246
» +11% Bi	118 ± 5	0.0263
» +13% Bi	106 ± 10	0.0294
» +0.9% Cd	133 ± 5	0.0233
» +6% In	132 ± 5	0.0235
» +3.3% Sb	127 ± 6	0.0246
» +7% Sb	122 ± 6	0.0254

The probability of the recoil-free resonance absorption effect of gamma quanta was determined by the method proposed in works ^(11,12). The accuracy of determining f' was 6-10%. It was found that the value of f' for matrix atoms in the alloys studied differs from f' for pure tin. The change is especially large in the solid solution tin-bismuth. The dependence of f' on temperature for matrix tin atoms in the tin-bismuth alloy at different bismuth concentrations is shown in Fig. 2. Similar dependences were also determined for other alloys. In the one-parameter approximation the temperature dependence of f' is well described by characteristic tem-

peratures given in Table 1. From the found values of f' , the mean-square displacements of tin atoms were determined for the alloys investigated. As is seen from the data of Table 1, the impurity increases $\overline{x^2}$ of the matrix atoms for these alloys. The change in the mean-square displacements of tin atoms with increasing impurity concentration may be attributed to a change in the forces of interatomic interaction. Table 2 gives the values found and the quantities $\overline{x^2}$ and the ratios of the parameters c/a for the solid solution tin-bismuth at 300° K for various impurity concentrations ⁽¹³⁾.

Table 2

Bi concentration, at. %	c/a	$\sqrt{x^2}$, Å
0	0.54540	0.0308
1.44	0.54522	0.0316
2.9	0.54506	0.0320
5.94	0.54473	0.0332

Bi concentration, at. %	c/a	$\sqrt{x^2}$, Å
11.0	0.54324	0.0365
13.0	0.54303	0.0400

The different degree of change of $\sqrt{x^2}$ with concentration for different alloys is apparently connected with the peculiarities of the interatomic interaction in the systems investigated. The results obtained indicate that the assumption of an insignificant change in the force constants upon introduction of an impurity atom requires refinement⁽⁹⁾. If it is assumed that the concentration dependence of f' is connected with a change in the forces of interatomic interaction, then the force constants of some solid solutions change appreciably with increasing impurity concentration.

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Note: Figure translations are in progress. See original paper for figures.

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