major role in the development of the breakdown.

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POSITRONS IN CRYSTALS WITH DEFECTS

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It is known that defects play an important role in the properties of a real crystal. Useful information on the microscopic properties of point defects of a crystal lattice can be obtained by the positron-annihilation method. The positive charge of the positron enables it to be captured by a cation vacancy to form the so-called A-center (Brandt's model [1]). The interaction of a positron with an F center can lead to the production of a positronium-like bound state in an anion vacancy.

Experimental investigations of the positron lifetimes in ionic crystals with defects have revealed the presence of long-lived components $\tau_2 \sim 0.5$ nsec and $\tau_3 \sim 1$ nsec, corresponding to annihilation of positrons captured by cation vacancies in F centers [2 - 6]. The intensities I_2 and I_3 of the long-lived components are determined by the concentrations of the corresponding defects. The presence of defects in the crystal causes also a narrowing of the curves of the angular correlation of the annihilation γ quanta [7, 8].

It must be noted that most studies were made on alkali-halide crystals, in which the relative concentration of the cation vacancies, estimated from the annihilation characteristics, did not exceed 10^{-5}. Yet to explain the positron-capture mechanism it is important to investigate crystals whose cation vacancy concentration is known beforehand and can be varied over a wide range.

We have investigated $Fe_{1-x}S$ crystals of stoichiometric (x = 0, sample 1) and non-stoichiometric composition (sample 2). The samples were prepared by the "ceramic" method described in [9]. The sample control was by measuring the spectra of the nuclear γ resonance and x-ray diffraction. The NGR spectrum of sample 1 revealed a simple structure of six hyperfine components, which is evidence of the stoichiometric composition of the sample [10]. The spectrum of sample 2 revealed a complicated structure consisting of a superposition of several sextuplets, thus evidencing a shortage of iron ions in the crystal lattice [10]. An analysis of the x-ray diffraction patterns has made it possible to determine quantitatively the concentration of the cation vacancies in sample 2, which turned out to equal $n_v = (2.5 \pm 0.2) \times 10^{21}$ cm^{-3} ($Fe_{0.92}S$).

The positron lifetime was measured by the standard procedure using "Ortec" apparatus with a model-437-A "time-amplitude" converter. The half-width of the peak of the prompt coincidences from Co^{60} was 0.4×10^{-9} sec, and the logarithmic slope of the sides of the peak did not exceed 0.7×10^{-9} sec. The contribution from positron annihilation in the source [11] was subtracted from the experimental spectra. The positron lifetimes were measured at room temperature; the results are given in the table.

Sample	$\tau_1, 10^{-9}$ sec	$\tau_2, 10^{-9}$ sec	I_2, %	n_v, cm^{-3}	$k, 10^9 sec^{-1}$
FeS	0.22 ± 0.01	–	–	$\lesssim 10^{20}$	0
$Fe_{0,92}S$	0.20 ± 0.01	0.48 ± 0.04	12 ± 1	$(2,5 \pm 0,2)\, 10^{21}$	0.35 ± 0.05

According to Brandt's model [4, 5], the rate of positron capture by cation vacancies is given by

$$k = n_v \sigma v = I_2 \left(\frac{1}{\tau_1} - \frac{1}{\tau_2} \right), \qquad (1)$$

where σ is the capture cross section and v is the velocity of the free positron in the crystal ($\sim 10^7$ cm/sec).

Starting from the experimental values of τ_1, τ_2, I_2, and n_v, we obtain from (1) $\sigma \simeq 10^{-20}$ cm^2. This is smaller by 5 - 6 orders of magnitude than the analogous cross section in alkali-halide crystals [4, 5].

Such a strong change in the cross section allows us to advance some hypotheses concerning the mechanism whereby positrons are captured by cation vacancies. First, in analogy with carrier capture by traps in semiconductors, the capture of positrons by cation vacancies should be regarded as a nonradiative process, since radiative processes have a cross section $\sim 10^{21}$ cm^2 [12]. There are two main models of nonradiative transitions in a solid: multiphonon transitions [12], and the Lax theory of the cascade (one-phonon) process [13]. For the multiphonon process, the capture cross section decreases sharply with increasing depth of the trap (binding energy), and this explains qualitatively the difference between the positron capture cross sections in iron sulfides and in alkali-halide crystals, for in the latter the effective charge of the cation vacancy is smaller and the traps should in general be shallow. To explain the positron capture mechanism, it would be of fundamental importance to measure the temperature dependence of the positron lifetime spectra in iron sulfides of non-stoichiometric composition. One can expect the capture cross section to increase with increasing temperature in the case of the multiphonon process [12], and, to the contrary, to decrease in the case of the cascade process [13]. For radiative processes, there is no temperature dependence at all.

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