EXPERIMENTAL OBSERVATION OF THE IONS $^{13}\mathrm{C}^{4+}$, $^{29}\mathrm{Si}^{4+}$, $^{77}\mathrm{Se}^{4+}$, S^{4+} IN THE DIAMOND LATTICE BY ELECTRON PARAMAGNETIC RESONANCE

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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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EXPERIMENTAL OBSERVATION OF THE IONS $^{13}C^{4+}$, $^{29}Si^{4+}$, $^{77}Se^{4+}$, S^{4+} IN THE DIAMOND LATTICE BY ELECTRON PARAMAGNETIC RESONANCE

(Presented by Academician L. A. Artsimovich, March 27, 1969)

It was reported earlier that the EPR spectrum of the ion N^{4+} had been observed in natural diamond (^{1}). From Fig. 1 of work (^{1}) it is seen that the spectrum of the ion N^{4+} in diamond consists of a set of lines of different intensity. The most intense lines in Fig. 1 are lines 1; lines 2–5 are weaker in intensity by a factor of 180–200. Lines 4, as indicated in that work, belong to the ion $^{15}N^{4+}$.

At the zero orientation of the specimen (Fig. 1 (^{1})), spectra 1, 2, 3, 5 are characterized by the following constants: spectrum 1, $K_C = 33.6$ Oe; spectrum 2, $K_S = 42$ Oe; spectrum 3, $K_{Se} = 75$ Oe; spectrum 5, $K_{Si} = 6$ Oe.

Fig. 1

An assumption was put forward explaining the origin of these spectra. Spectrum 1 was attributed to the ion N^{4+} located at the center of a carbon tetrahedron. Spectra 2, 3, 5 are caused by replacement of the ion $^{12}C^{4+}$, located at one of the vertices of the tetrahedron, by one of the ions S^{4+}, Se^{4+}, and Si^{4+}, respectively. In order to confirm this hypothesis, we undertook careful investigations of the EPR spectra of diamonds of a certain variety*. In one of the diamonds, along with the hyperfine splitting (^{1}), we succeeded in observing superhyperfine splitting caused by the nuclei of the ions $^{13}C^{4+}$, $^{29}Si^{4+}$, and $^{77}Se^{4+}$. The nuclear spins of all these ions are equal to 1/2, as a result of which the superhyperfine spectrum consists of two lines arranged symmetrically with respect to each line of spectrum 1 for each nucleus, respectively. The experimentally observed superhyperfine spectrum is characterized by the constants $a_{Si} = 12.6$ Oe, $a_C = 9.15$ Oe, $a_{Se} = 3.5$ Oe.

According to the data of work (³), the natural abundances of the isotopes are: ^{13}C, 1.1%; ^{29}Si, 4.68%; ^{33}S, 0.75%; and ^{77}Se, 7.58%. It is useful to compare these figures, in terms of the intensities of the hyperfine and superhyperfine splitting lines, with those obtained experimentally. From the intensity and width of the lines of spectrum 1 of the EPR of the ion N^{4+}, it may be assumed that the concentration of nitrogen in diamond is hundredths of a percent relative to carbon. The lines of superhyper-

* According to the classification of Yu. L. Orlov (²), these diamonds belong to variety II.

fine-structure lines belonging to ^{13}C and ^{29}Si are approximately 50 times less intense than the lines of spectrum 1, while the lines belonging to ^{77}Se are approximately 25 times less intense than the lines of spectrum 1. Consequently, in the sample studied the content of ^{13}C and ^{29}Si was 2% of the content of ^{14}N, and the content of ^{77}Se was 4% of the content of ^{14}N, i.e., twice as large as that of ^{13}C and ^{29}Si, which is in complete agreement with the data of Ref. (³). It should be emphasized that the superhyperfine splitting caused by ^{33}S nuclei was not observed experimentally, although the spin of the ^{33}S nucleus is $I = 3/2$. Apparently, the percentage content of ^{33}S in the diamond studied is negligibly small. (All the other sulfur isotopes have spin equal to 0 and therefore do not give superhyperfine splitting.) It is also interesting to note the fact that the intensity of the superhyperfine-splitting lines (spectra 2, 3, 5 (¹)) is 4 times smaller than that of the super-superhyperfine-splitting lines. The superhyperfine spectrum apparently arises when one of the corresponding ions (^{13}C, ^{29}Si, ^{77}Se) occupies a carbon site at the vertex of a tetrahedron, whereas the corresponding super-superhyperfine spectrum appears only when tetrahedra of S, Se, Si are formed as a whole, containing an N^{4+} ion at the center; precisely for this reason, in our view, the intensity of the superhyperfine spectra 2, 3, 5 is 4 times smaller than the intensity of the corresponding super-superhyperfine spectra (Fig. 1 (¹)).

An interesting relationship was found between the constants of the superhyperfine and super-superhyperfine splittings: these constants depend linearly on R/Z, where R is the ionic radius in ångströms and Z is the nuclear charge. This dependence for both constants is presented in Fig. 1, from which it is seen that, as R/Z increases, the superhyperfine-splitting constant decreases, while the super-superhyperfine-splitting constant increases.

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