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Subvolume A2
Impurities and Defects in Group IV Elements, IV-IV and III-V Compounds

Part α: Group IV Elements

Supplement to Vol. III/ 22b (Print Version)
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4.1.3 Paramagnetic centers

4.1.3.1 Introduction

Electron paramagnetic resonance (EPR) spectra are conveniently analysed using a spin Hamiltonian. In the concept of the spin Hamiltonian, the energies of the levels comprising the ground state are expressed in terms of a polynomial in the effective electron spin operator S and, when magnetic nuclei are present, nuclear spin operators I. A small number of constants in the spin Hamiltonian H can accurately describe the observed transitions. A general form suitable to analyse and identify the spectra observed in diamond is $H = \Sigma H_i$.
In the spin Hamiltonian required to analyse the spectroscopic data, the following terms may appear:

Zeeman effect

$$H_1 = \mu_B \boldsymbol{B}\cdot\mathbf{g}\cdot\boldsymbol{S}$$

H_1 describes the electronic Zeeman effect. All paramagnetic centers have this interaction. Due to the small value of the spin-orbit coupling constant in diamond and the strong crystal field in the solid which effectively quenches orbital contributions to the magnetic moment, the g values for nearly all centers are close to the free-electron value $g = 2.0023$. Identification of spectra on the basis of the **g**-tensor only, the common situation for centers in silicon, is not possible in diamond. Other spin-Hamiltonian constants or characteristics of the spectra have to be used additionally.

Zero-field splitting

$$H_2 = \boldsymbol{S}\cdot\mathbf{D}\cdot\boldsymbol{S}$$

H_2 represents the zero-(magnetic)-field splitting. The interaction is only present for electron spin $S \geq 1$. The identification of centers produced by irradiation, notably several of the R and W spectra, mainly rests on the symmetry and components of the **D**-tensor.

Higher-order Zeeman effect

$$H_3 = g_2\mu_B(B_xS_x^3 + B_yS_y^3 + B_zS_z^3)$$

H_3 represents the rather rare higher-order Zeeman effect which can be present in case $S \geq 3/2$, and has the given form for centers of cubic symmetry. The interaction in diamond has been reported for one center only, i.e. the acceptor-related spectrum NL1. For $S \geq 2$, spin Hamiltonian terms of fourth order in S_x, S_y and S_z may have to be included, even in the case of cubic symmetry. Such situations have been considered, e.g., for spectrum $V^0(^5A_2)$.

Normal-strain effect

$$H_4 = b(\varepsilon_{xx}S_x^2 + \varepsilon_{yy}S_y^2 + \varepsilon_{zz}S_z^2)$$

H_4 expresses the effect of normal strains of the diamond crystal on the spectrum in terms of the deformation potential constant b and normal components of the strain tensor ε_{xx}, ε_{yy} and ε_{zz}. This term was only reported for the analysis of acceptor-related spectrum NL1.

Shear-strain effect

$$H_5 = (d\sqrt{3}/3)[\varepsilon_{xy}(S_xS_y + S_yS_x) + \varepsilon_{yz}(S_yS_z + S_zS_y) + \varepsilon_{zx}(S_zS_x + S_xS_z)]$$

H_5 expresses, similar to the previous term, the effect of distortion of the crystal on the energy levels. The deformation potential constant is d, the components of the shear strain are ε_{xy}, ε_{yz} and ε_{zx}. This term was only reported for spectrum NL1.

Nuclear Zeeman effect

$$H_6 = - g_n \mu_N \boldsymbol{B} \cdot \boldsymbol{I}$$

H_6 gives the Zeeman interaction energy for a nucleus with spin I. The nuclear Zeeman splitting is not observable in first order in EPR. It can be measured by electron-nuclear double resonance (ENDOR) and then leads to unambiguous identification of an impurity through the nuclear magnetic moment ($g_n \mu_N I$). In the form of self-ENDOR this has been applied to establish the presence of nitrogen in centers N1, N2, N3, OK1, P1, P2, W7, W15 and W24. More recently, ligand ENDOR studies in ^{13}C enriched man-made diamond have revealed structural information on defect geometries for the N2, P1, S1 and W8 centers. Matrix ENDOR on hydrogen was reported for CVD grown polycrystalline diamond.

Hyperfine interaction

$$H_7 = \boldsymbol{S} \cdot \mathbf{A} \cdot \boldsymbol{I}$$

H_7 describes the hyperfine interaction between the electron(s) in the paramagnetic defect and a nucleus with spin I. The term has to be summed over all nuclei with non-zero spin for which an interaction is resolved. For spectra in natural diamond always the isotope ^{13}C, with nuclear spin $I = ½$, has to be considered. Due to the low abundance 1.1% of this isotope, the structural details in spectra related to this nuclear interaction have a relatively low intensity. Nitrogen, with $I = 1$ of the 99.63% abundant isotope ^{14}N, is the most common impurity in diamond. The hyperfine splitting into three sets of components reveals the presence of one or several nitrogen atoms. Actual observations of hyperfine interactions have been made for carbon, nitrogen and a few other magnetic impurity isotopes (hydrogen, boron, phosphorus, cobalt, nickel, copper). The hyperfine interaction can give characteristic structure to the EPR spectra, valuable for identification and further understanding of the atomic and electronic structure of the centers.

Nuclear quadrupole interaction

$$H_8 = \boldsymbol{I} \cdot \mathbf{Q} \cdot \boldsymbol{I}$$

H_8 represents the nuclear quadrupole effect. Only effective when $I \geq 1$, for example for ^{14}N, but not for ^{13}C. Being a purely nuclear interaction it is difficult to observe in EPR (Ref. 65L1). ENDOR allows a more accurate determination of the quadrupole tensor, as reported for spectra N1, N3, OK1, P1, P2, W7, W15 and W24.

For further information on EPR, e.g. on symmetry aspects, see the section on Paramagnetic Centers in Silicon (4.2.6). Spectrum labels selected by the authors and already in use in the literature were copied, such as NE1 to NE8, NIRIM-1 to NIRIM-8, Mu, Mu*, S1*, β and $V^0(^5A_2)$. To distinguish the spectra of two different centers with the label H2, they were specified as H2(ht) (ht for heat treatment) and H2(H) (H for hydrogen). Spectra which so far were not labeled, have been given a designation reflecting the city of their first publication, i.e. the convention adopted for silicon has been followed. The introduced labels are AM1 (Amsterdam), BI1 (Birmingham), CL1 (Clayton), GRE1 (Grenoble), KI1 (Kiev) and MA1 (Makeyevka). These labels are to be considered as provisional; they are to be replaced by labels with more physical significance as soon as the required information becomes available in reliable form.

4.1.3.2 EPR spectra

Spectrum A1

Symmetry: monoclinic-I

Spin: $S = 1$

g-tensor: $g_1 = 2.0021$, ||[0 , − 0.7071, + 0.7071]
$g_2 = 2.0016$, ||[+ 0.4540, + 0.6300, + 0.6300]
$g_3 = 2.0026$, ||[− 0.8910, + 0.3210, + 0.3210]

D-tensor: $D_1 = -$ 74 MHz, ||[0 , − 0.7071, + 0.7071]
$D_2 = +$ 154 MHz, ||[+ 0.1426, + 0.6999, + 0.6999]
$D_3 = -$ 80 MHz, ||[− 0.9898, + 0.1009, + 0.1009]

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 2 sites
$A_1 = 29.1$ MHz, ||[0 , + 0.7071, + 0.7071]
$A_2 = 38.1$ MHz, ||[+ 0.7986, − 0.4254, + 0.4254]
$A_3 = 29.1$ MHz, ||[− 0.6018, − 0.5647, + 0.5647]

A-tensor: nucleus ^{13}C, 2 sites
$A_1 = 20.4$ MHz, ||[0 , + 0.7071, + 0.7071]
$A_2 = 26.4$ MHz, ||[+ 0.7071, − 0.5000, + 0.5000]
$A_3 = 19.8$ MHz, ||[− 0.7071, − 0.5000, + 0.5000]

A-tensor: nucleus ^{13}C, 2 sites
$A_1 = 15.6$ MHz, ||[0 , + 0.7071, + 0.7071]
$A_2 = 21.6$ MHz, ||[+ 0.6561, − 0.5337, + 0.5337]
$A_3 = 14.4$ MHz, ||[− 0.7547, − 0.4639, + 0.4639]

A-tensor: nucleus ^{13}C, 4 – 6 sites
$(A_1 + A_2 + A_3)/3 = 11.4$ MHz

Diamond: natural type IIa, after 1...2 MeV electron irradiation at low or at room temperature, after neutron irradiation at room temperature, anneals out around 500 ^{0}C

Model: four-vacancy complex along <110>, single interstitial impurity complex

References: 71K, 73K, 73L1, 77C, 78L2, 79C, 79L2, 80F, 81F, 82F2, 82F3, 83F1, 83F2, 85L1, 88L2, 94N3, 99B1

Spectrum A2

Symmetry: monoclinic-I at low temperature (100 K)
orthorhombic-I at high temperature (300 K)

Spin: $S = 1$

g-tensor: $g_1 = 2.0031$, ||[1, 0, 0]
$g_2 = 2.0015$, ||[0, 1, 1]
$g_3 = 2.0031$, ||[0, − 1, 1]

D-tensor: 100K: $D_1 = -$ 158 MHz, ||[+ 0.9981, − 0.0432, − 0.0432],
$D_2 = +$ 328 MHz, ||[+ 0.0610, + 0.7058, + 0.7058]
$D_3 = -$ 170 MHz, ||[0 , − 0.7071, + 0.7071]
300 K: $D_1 = -$ 170 MHz, ||[1 0, 0]
$D_2 = +$ 352 MHz, ||[0, 1, 1]
$D_3 = -$ 182 MHz, ||[0, − 1, 1]

Diamond: natural type I and II, after electron or fast neutron irradiation at low or at room temperature, anneals out around 500 K
Remark: **D**-tensor increases with temperature in the range 77 K to room temperature
Model: three-vacancy chain in {110} plane, di-interstitial impurity complex, impurity + interstitial complex
References: 73K, 73L1, 77C, 78L2, 79C, 79L2, 80F, 81F, 82F2, 82F3, 83F1, 83F2, 84L3, 88L2, 94N3, 94P2

Spectrum A3

Symmetry: triclinic
Spin: $S = 1$
g-tensor: $g_1 = 2.0027$, ||[+ 0.884, – 0.177, – 0.433]
$g_2 = 2.0020$, ⊥[+ 0.884, – 0.177, – 0.433]
$g_3 = 2.0020$, ⊥[+ 0.884, – 0.177, – 0.433]
D-tensor: $D_1 = +416$ MHz, ||[+ 0.8520, + 0.4245, + 0.3065]
$D_2 = -156$ MHz, ||[+ 0.0006, + 0.5846, – 0.8113]
$D_3 = -260$ MHz, ||[– 0.5236, + 0.6914, + 0.4978]
Diamond: natural type I and II, after electron or fast neutron irradiation at low or at room temperature, anneals out at 470 K
Model: di-interstitial + impurity complex
References: 73K, 78L2, 80F, 81F, 82F2, 82F3, 83F1, 83F2, 84L3, 88L2, 94N3

Spectrum A4

Symmetry: anisotropic, <111> symmetry
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0023$
D-tensor: small, <111> symmetry
Diamond: natural type IIa, after nitrogen ion implantation at 650 ^{0}C
References: 74B2, 78L2, 83F2

Spectrum A5

Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3) = 2.0023$
D-tensor: $D_1 = -103.7$ MHz, ||[0 , – 0.7071, + 0.7071]
$D_2 = +300.0$ MHz, ||[+ 0.6157, + 0.5572, + 0.5572]
$D_3 = -196.3$ MHz, ||[– 0.7880, + 0.4353, + 0.4353]
Remark: parameters similar to those of R4/W6
Diamond: natural type IIa, after carbon or nitrogen implantation at 600 ^{0}C
Model: multivacancy cluster, strained hexavacancy ring, divacancy
References: 78L1, 83F2, 95L

Spectrum A6

Symmetry:	orthorhombic-I
Spin:	$S = 1$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.0023$
D-tensor:	$D_1 = -$ 96 MHz, ‖[1, 0. 0]
	$D_2 = +$ 192 MHz, ‖[0, 1. 1]
	$D_3 = -$ 96 MHz, ‖[0, – 1. 1]
Diamond:	natural type IIa, after carbon or nitrogen implantation at 1000 ^{0}C
Model:	multivacancy cluster
References:	78L1, 83F2

Spectrum A7

Symmetry:	isotropic
Spin:	$S = 1/2$ or 1
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.00$
D/A-tensor:	pair of isotropic lines, symmetrically displaced from central line by ± 6 mT
Diamond:	type IIa, or synthetic, highly boron doped, after electron irradiation, anneals out at 220 K
Remark:	resonance may be due to cavity contamination
References:	71L, 77B, 77C, 82F2, 83F2

Spectrum A8

Symmetry:	isotropic
Spin:	$S = 1/2$ or 1
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.00$
D/A-tensor:	pair of isotropic lines, symmetrically displaced from central line by ± 3.3 mT
Diamond:	type IIa, or synthetic, highly boron doped, after electron irradiation, anneals in at 150 K, anneals out at 220 K
Remark:	resonance may be due to cavity contamination
References:	77B, 77C, 82F2, 83F2

Spectrum A9

Symmetry:	axial, ‖[1, 1, 2]
Spin:	$S = 1/2$
g-tensor:	$g_{\|\|} \approx 0.5$ ($T = 300$ K)
	$g_{\perp} \approx 3$ ($T = 300$ K)
Diamond:	synthetic, boron doped, p-type semiconducting
Remark:	g values strongly temperature dependent
Model:	acceptor-bound hole
References:	72B1, 94J

Spectrum A10

Symmetry:	axial, ‖[1, 1, 2]
Spin:	$S = 1/2$
g-tensor:	$g_{\|\|} \approx 0.5$ ($T = 300$ K)
	$g_{\perp} \approx 2.5$ ($T = 300$ K)
Diamond:	synthetic, boron doped, p-type semiconducting
Remark:	g values strongly temperature dependent
Model:	free hole
References:	72B1, 94J

Spectrum A11

Symmetry:	isotropic
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.0023$
Linewidth:	$\Delta B_{pp} = 0.5...1$ mT
Diamond:	natural type IIa, B-, C-, N- or Sb-ion implanted
Model:	amorphous carbon, implantation damage
References:	74B1, 74B2, 75M, 78L1, 79T, 94G, 96D

Spectrum AB1

Symmetry:	trigonal
Spin:	$S = 1/2$
g-tensor:	$g_{\|\|} = 2.0024$, ‖[1, 1, 1]
	$g_{\perp} = 2.0920$, ⊥[1, 1, 1]
Diamond:	synthetic, grown in nickel solvent/catalyst, anneal at 1600°C
References:	99N1, 00N1, 02B, 02P

Spectrum AB2

Symmetry:	trigonal
Spin:	$S = 1/2$
g-tensor:	$g_{\|\|} = 2.0072$, ‖[1, 1, 1]
	$g_{\perp} = 2.0672$, ⊥[1, 1, 1]
Diamond:	synthetic, grown in nickel solvent/catalyst, anneal at 1600°C
References:	99N1, 00N1, 02B, 02P

Spectrum AB3

Symmetry:	orthorhombic-I
Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.1105$, ‖[1, 0, 0]
	$g_2 = 2.0663$, ‖[0, 1, 1]
	$g_3 = 2.0181$, ‖[0, −1, 1]
Diamond:	synthetic, grown in nickel solvent/catalyst, anneal at 1600°C
References:	99N1, 01P2, 02B, 02P

Spectrum AB4

Symmetry:	orthorhombic-I
Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.0220$, $\|\|[1, 0, 0]$
	$g_2 = 2.0094$, $\|\|[0, 1, 1]$
	$g_3 = 2.0084$, $\|\|[0, -1, 1]$
Diamond:	synthetic, grown in nickel solvent/catalyst, anneal at 1600°C
References:	99N1, 01P2, 02B, 02P

Spectrum AB5

Symmetry:	trigonal
Spin:	$S = 1$
g-tensor:	$g_{\|\|} = 2.037$, $\|\|[1, 1, 1]$
	$g_\perp = 2.022$, $\perp[1, 1, 1]$
D-tensor:	$D = 31.72$ GHz
Diamond:	synthetic, grown in nickel solvent/catalyst
Model:	negative nickel-nitrogen pair
References:	00N1, 01P1, 01P2, 02B, 02P

Spectrum AB6

Symmetry:	triclinic
Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.0185$, $\|\|[-0.79756, 0.42097, 0.43207]$
	$g_2 = 2.0244$, $\|\|[-0.00987, 0.70704, -0.70711]$
	$g_3 = 2.0742$, $\|\|[0.60316, 0.56822, 0.55975]$
Diamond:	synthetic, grown in nickel solvent/catalyst
References:	02B, 02P

Spectrum AB7

Symmetry:	orthorhombic-I
Spin:	$S = 1/2$
g-tensor:	$g_1 = 1.9910$, $\|\|[1, 0, 0]$
	$g_2 = 2.0078$, $\|\|[0, 1, 1]$
	$g_3 = 2.0046$, $\|\|[0, -1, 1]$
Diamond:	synthetic, grown in nickel solvent/catalyst
References:	02B, 02P

Spectrum Boron

Symmetry:	cubic
Spin:	$S = 1/2$ for Γ_7, 3/2 for Γ_8
g-values:	$g_{1/2} = 0.21$, $g_{3/2} = -0.95$
Diamond:	isotopically controlled CVD, type IIb, p-type semiconductor
Model:	hole bound to substitutional boron acceptor
References:	99K1, 99K2, 99K4, 00K1, 01K

Spectrum E1

Symmetry:	axial (tetragonal or trigonal)
Spin:	$S = 1/2$
g-tensor:	$g_{\|\|} = 4.117$
	$g_{\perp} = 4.43$
A-tensor:	nucleus ^{59}Co, spin $I = 7/2$, abundance 100%, 1 site
	$A_{\|\|} = 245$ MHz
	$A_{\perp} = 260$ MHz
Diamond:	synthetic
Model:	Co^{2+} impurity on slightly distorted octohedral interstitial site
Reference:	75B, 94B

Spectrum G1

g-tensor:	$(g_1 + g_2 + g_3)/3 \approx 3$
Diamond:	synthetic, boron doped
Model:	transition metal impurity, nickel or iron
References:	62H, 67S1

Spectrum KUL1

Spin:	$S = 1$
g-tensor:	$g_{\|\|} = 2.00415$, $g_{\perp} = 2.0037$
D-tensor:	$D = 35.8$ mT, $E < 0.1$ mT
A-tensor:	nucleus ^{61}Ni, spin $I = 3/2$, abundance 1.1%
	$A_{\perp} = 8.7$ mT
Diamond:	CVD
Model:	neutral vacancy–nickel–vacancy center [00I]
References:	00I, 00S2, 01I

Spectrum KUL2

Spin:	$S = 1$
g-tensor:	$g = 2.0026$
D-tensor:	$D = 96.5$ mT, $E < 0.1$ mT
A-tensor:	nucleus ^{1}H, spin $I = 1/2$, abundance 100%
	$A = 0.06$ mT
Diamond:	CVD, HPHT powder
Model:	center with one hydrogen atom
References:	01I

Spectrum KUL3

Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.00505$, $g_2 = 2.00426$, $g_3 = 2.00255$
A-tensor:	nucleus ^{1}H, spin $I = 1/2$, abundance 100%
	$A_1 = 0.1$ mT, $A_2 = <0.02$ mT, $A_3 = 0.26$ mT
Diamond:	CVD
Model:	center with one hydrogen atom
References:	01I

Spectrum KUL4

Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.00459$, $g_2 = 2.00316$, $g_3 = 2.00259$
A-tensor:	nucleus ^1H, spin $I = 1/2$, abundance 100%
	$A_1 = 0.105$ mT, $A_2 = 0.087$ mT, $A_3 = 0.112$ mT
Diamond:	CVD
Model:	center with one hydrogen atom
References:	01I

Spectrum KUL5

Spin:	$S = 1/2$
g-tensor:	$g = 2.00291$
A-tensor:	nucleus ^{14}N, spin $I = 1$, abundance 99.63%
	$A = 0.074$ mT
Diamond:	CVD
Model:	center with one nitrogen atom
References:	01I

Spectrum KUL6

Spin:	$S = 1/2$
g-tensor:	$g_{\parallel} = 2.00307$, $g_{\perp} = 2.00292$
Diamond:	CVD
Remark:	provisional data
References:	01I

Spectrum KUL7

Spin:	$S = 1$
g-tensor:	$g = 2.002$
A-tensor:	nucleus ^{55}Mn, spin $I = 5/2$, abundance 100%
	$A = 118$ MHz
Diamond:	HPHT powder
Model:	center with one manganese atom
References:	01I, 02B

Spectrum KY1

Symmetry:	cubic
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.003$
Linewidth:	$\Delta B = 0.02...0.8$ mT, sample and temperature dependent
Diamond:	natural type IIb, p-type semiconducting
Model:	acceptor impurity
Reference:	67B

Spectrum L1

Symmetry:	isotropic
Spin:	$S = 1/2$
g-tensor:	$g = 2.000$
A-tensor:	nucleus ^{29}Si, spin $I = 1/2$, abundance 4.7%
	$A_1 = 196$ MHz
	$A_2 = 232$ MHz
	$A_3 = 251$ MHz
Diamond:	natural type Ia
Remark:	original label Si-center
Model:	native (silicon+impurity) center (tentative)
Reference:	77M, 94B

Spectrum ME1

Symmetry:	cubic, small tetragonal distortion
Spin:	$S = 3/2$
g-tensor	$g = 2.02$
A-tensor:	nucleus ^{14}N, spin $I = 1$, abundance 99.63%
	$A = 1.336$ MHz
Diamond:	natural, blue Argyle
Model:	nickel-nitrogen center
References:	98N1, 02B

Spectrum N1 (Fig. 1)

Symmetry:	monoclinic-I
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.0024$
A-tensor:	nucleus N_1, isotope ^{14}N, spin $I = 1$, abundance 99.63%, 1 site
	$A_1 = +\ 89.218$ MHz, $\|\|[-0.7071, +0.7071, 0.0000]$
	$A_2 = +126.355$ MHz, $\|\|[+0.5803, +0.5803, +0.5714]$
	$A_3 = +\ 89.198$ MHz, $\|\|[-0.4041, -0.4041, +0.8207]$
Q-tensor:	$Q_1 = +1.213$ MHz, $\|\|[-0.7071, +0.7071, 0.0000]$
	$Q_2 = -2.388$ MHz, $\|\|[+0.5777, +0.5777, +0.5766]$
	$Q_3 = +1.175$ MHz, $\|\|[-0.4077, -0.4077, +0.8170]$
A-tensor:	nucleus N_2, isotope ^{14}N, 1 site
	$A_1 = -8.327$ MHz, $\|\|[-0.7071, +0.7071, 0.0000]$
	$A_2 = -7.875$ MHz, $\|\|[-0.6653, -0.6653, +0.3387]$
	$A_3 = -8.288$ MHz, $\|\|[+0.2395, +0.2395, +0.9409]$
Q-tensor	$Q_1 = +0.0437$ MHz, $\|\|[-0.7071, +0.7071, 0.0000]$
	$Q_2 = -0.2077$ MHz, $\|\|[-0.6732, -0.6732, +0.3060]$
	$Q_3 = +0.1639$ MHz, $\|\|[+0.2164, +0.2164, +0.9520]$
A-tensor:	nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 3 sites
	$A_{\|\|} = 33.6$ MHz
	$A_\perp = 25.8$ MHz

A-tensor: nucleus ^{13}C, 3 sites
$A_{\|}$ = 22.5 MHz
$A_{\perp}$ = 20.7 MHz
A-tensor: nucleus ^{13}C, 2 sites
$A_{\|}$ = 18.9 MHz
$A_{\perp}$ = 15.6 MHz
Remark: ^{14}N ENDOR data in Refs. 92C1, 92C2 and 94B
Diamond: natural brown type Ia
Model: two non-equivalent nitrogen atoms, e.g.ionized nitrogen pair $N_1N_2^+$, complex of vacancy and nitrogen pair $(N_1N_2V)^-$, non-planar N_1CCN_2 complex, complex $N_1CN_2^+$; motional averaging in the temperature range 150...850 ^0C with activation energy 0.4 eV; thermally stable to above 900 ^0C
References: 69S1, 70L, 72S1, 73L2, 75S1, 78L2, 78S1, 79C, 82L1, 83F2, 85L2, 87W, 89N1, 91N2, 92B, 92C1, 92C2, 94B, 95B1, 99B1

Spectrum N2

Symmetry: isotropic
Spin: $S = 1/2$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0030$
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%
A = 0.6 MHz, isotropic
Q-tensor: $Q < 0.3$ MHz
Remark: ^{14}N and ^{13}C ENDOR data in Refs. 89N3, 89N4 and 94B
Diamond: natural brown type Ia, plastically deformed; diamond film
Model: dislocation-related center with nitrogen as a constituent
References: 75S1, 78L2, 83F2, 89N3, 89N4, 91B, 92B, 94B, 95B1, 99B1

Spectrum N3 (Fig. 2)

Symmetry: below 200 ^0C: monoclinic-I, at 550 ^0C: axial || <1, 1, 1>
Spin: $S = 1/2$

	at room temperature	at 550 ^0C
g-tensor:	g_1 = 2.0025, ‖[1, – 1, 0]	$g_{\|}$ = 2.00224, ‖ <1, 1, 1>
	g_2 = 2.0022, ⊥[1, – 1, 0]	$g_{\perp}$ = 2.00236, ⊥<1, 1, 1>
	g_3 = 2.0020, ⊥[1, – 1, 0]	
A-tensor:	nucleus ^{14}N, spin $I = 1/2$, abundance 99.63%	
	A_1 = 4.28 MHz, ‖[+ 0.6355, + 0.6355, + 0.4384]	$A_{\|}$ = 4.4 MHz, ‖ <1, 1, 1>
	A_2 = 3.12 MHz, ‖[– 0.7071, + 0.7071, 0]	$A_{\perp}$ = 3.8 MHz, ⊥<1, 1, 1>
	A_3 = 3.12 MHz, ‖[– 0.3100, – 0.3100, + 0.8988]	
Q-tensor:	Q_1 = – 5.52 MHz, ‖[+ 0.5862, + 0.5862, + 0.5592]	$Q_{\|}$ = – 5.3 MHz, ‖ <1, 1, 1>
	Q_2 = + 2.76 MHz, ‖[– 0.7071, + 0.7071, 0]	
	Q_3 = + 2.76 MHz, ‖[– 0.3954, – 0.3954, + 0.8290]	

Remark: ^{14}N ENDOR data in Refs. 88W1, 92W1 and 94B
Diamond: natural type Ib
Model: (nitrogen+ divacancy) complex, complex of substitutional nitrogen and oxygen impurity
References: 72S1, 76Z, 78L2, 83F2, 86W1, 86W2, 88M, 88W1, 89N2, 92B, 92W1, 94B, 95B1, 98R, 99B1, 00R

Spectrum N4 (Fig. 3)

Symmetry:	monoclinic-I
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.002$
A-tensor:	nucleus ^{14}N, spin $I = 1/2$, abundance 99.63%, 2 sites
	$A_{\parallel} = 91.3$ MHz, $\parallel$[1, 1, 1]
	$A_{\perp} = 65.6$ MHz, $\perp$[1, 1, 1]
Diamond:	natural, brown, plastically deformed
Remark:	anisotropic distribution of orientations
Model:	two equivalent substitutional nitrogen atoms in planar N_1CCN_2 structure, near dislocation
References:	75S1, 77W, 78L2, 78W, 79W, 83F2, 91K, 91N2, 95B1

Spectrum N5

Symmetry:	axial
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.0027$
A-tensor:	nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 1...2 sites
	$A_{\parallel} = 667$ MHz
	$A_{\perp} = 336$ MHz
Remark:	possibly identical to TI1 and $g = 2.0027$ centers
Diamond:	natural type I, crushed, deposited film
Model:	surface center
References:	61W, 67B, 67S2, 74S2, 78S2, 79S, 91B, 94N6

Spectrum N6

Symmetry:	monoclinic-I
Spin:	$S = 5/2$
g-tensor:	measured at frequency 9.5 GHz
	$g_1 = 4.4924$, $\parallel$[+ 0.7071, + 0.7071, 0]
	$g_2 = 4.6684$, $\parallel$[+ 0.2126, – 0.2126, + 0.9537]
	$g_3 = 4.0192$, $\parallel$[+ 0.6744, – 0.6744, – 0.3007]
D-tensor:	$E/D = 0.27$
g-tensor:	measured at frequency 35.5 GHz
	$g_1 = 4.0129$, $\parallel$[+ 0.7071, + 0.7071, 0]
	$g_2 = 4.0274$, $\parallel$[+ 0.2126, – 0.2126, + 0.9537]
	$g_3 = 3.8607$, $\parallel$[+ 0.6744, – 0.6744, – 0.3007]
A-tensor:	nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%
	$A_{\mathrm{I}} = 84$ MHz, 2 sites
	$A_{\mathrm{II}} = 42$ MHz, 3 sites
	$A_{\mathrm{III}} = 27$ MHz, 4 sites
Diamond:	natural, after 3.5 MeV electron irradiation at room temperature
Remark:	original label A-system
Model:	possibly transition metal impurity (iron)
References:	78N, 94N3

Spectrum N7

Spin: $S = 5/2$

g-tensor: measured at frequency 9.5 GHz

$(g_1 + g_2 + g_3)/3 = 4.3$

D-tensor: $E/D = 0.33$

Diamond: natural, after 3.5 MeV electron irradiation at room temperature

Remark: original label B-system

Model: possibly transition metal impurity (iron)

References: 78N, 94N3

Spectrum NE1 (Fig. 4)

Symmetry: monoclinic-I

Spin: $S = 1/2$

g-tensor: $g_1 = 2.1282$, ||[0 , − 0.7071, + 0.7071]

$g_2 = 2.007$, ||[+ 0.2419, + 0.6861, + 0.6861]

$g_3 = 2.0908$, ||[+ 0.9703, − 0.1711, − 0.1711]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites

$A_1 = 2.09$ mT, ⊥[0, − 1, 1], 5^0 away from [1, 1, 1]

$A_2 = 1.43$ mT, ⊥[0, − 1, 1]

$A_3 = 1.45$ mT, ||[0, − 1, 1]

Diamond: synthetic, grown from nickel-iron solvent, after 4 hours anneal at temperature $T = 2150$ K under pressure $p = 5.5$ GPa

Model: nickel impurity in divacancy with one nitrogen atom at each end: N_SVNiVN_S chain in (011) plane

References: 93N2, 94M, 95B1, 95Y, 96Y, 97N, 98N2, 99B1, 99M3, 99N2, 00C1, 00N2, 02B, 02P

Spectrum NE2 (Fig. 5)

Symmetry: triclinic

Spin: $S = 1/2$

g-tensor: $g_1 = 2.1301$, 20^0 away from [0, 1, − 1], 5^0 away from {0, 1, 1}

$g_2 = 2.0100$, 14^0 away from [0, 1, 1]

$g_3 = 2.0931$

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site

$A_1 = 2.10$ mT, ⊥[0, 1, − 1], 3^0 away from [1, 1, 1]

$A_2 = 1.42$ mT, ⊥[0, 1, − 1]

$A_3 = 1.41$ mT, ||[0, 1, − 1]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site

$A_1 = 1.875$ mT, ⊥[0, 1, − 1], 1^0 away from [1, 1, 1]

$A_2 = 1.185$ mT, ⊥[0, 1, − 1]

$A_3 = 1.25$ mT, ||[0, 1, − 1]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site

$A_1 = 0.175$ mT, ||[1, 1, 1]

$A_2 = 0.35$ mT, ||[2, − 1, − 1]

$A_3 = 0.246$ mT, ||[0, 1, − 1]

Diamond: synthetic, grown from nickel-iron solvent, after 4 hours anneal at temperature $T = 2150$ K under pressure $p = 5.5$ GPa, natural blue Argyle
Model: nickel impurity in divacancy with one nitrogen atom at each end: N_sVNiVN_s chain in (011) plane, additional nitrogen atom out of plane
References: 93N2, 94M, 95B1, 95Y, 96N, 96Y, 97N, 98N1, 98N2, 99B1, 99M3. 99N2, 00C1, 02B, 02P

Spectrum NE3 (Fig. 6)
Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g_1 = 2.0729$, $\|[0, -0.7071, +0.7071]$
$g_2 = 2.0008$, $\|[+0.1219, +0.7018, +0.7018]$
$g_3 = 2.0476$, $\|[+0.9925, -0.0862, -0.0862]$
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site
$A_1 = 1.6$ mT, $\perp[0, 1, -1]$, 4^0 away from $[1, 1, 1]$
$A_2 = 1.24$ mT, $\perp[0, 1, -1]$
$A_3 = 1.15$ mT, $\|[0, 1, -1]$
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
$A_1 = 0.665$ mT, $\|[-1, 1, -1]$
$A_2 = 0.5$ mT, $\perp[-1, 1, -1]$
$A_3 = 0.5$ mT, $\perp[-1, 1, -1]$
Diamond: synthetic, grown from nickel-iron solvent, after 4 hours anneal at temperature $T = 2150$ K under pressure $p = 5.5$ GPa
Model: nickel impurity in divacancy with substitutional nitrogen atom at one end in (011) plane, two substitutional nitrogen atoms out of plane at other end
References: 93N2, 95B1, 95Y, 96Y, 97N, 98N2, 99B1, 99M3, 99N2, 00C1, 02B. 02P

Spectrum NE4
Symmetry: trigonal
Spin: $S = 1/2$
g-tensor: $g_{\|} = 2.0227$, $\|[1, 1, 1]$
$g_{\perp} = 2.0988$, $\perp[1, 1, 1]$
Diamond: synthetic, grown from nickel-iron solvent, as grown
Model: nickel impurity in divacancy
References: 94N5, 97N, 98P, 99B1, 99N1, 99N2, 00C1, 00N2, 02B

Spectrum NE4*
Symmetry: trigonal
Spin: $S = 1/2$
g-tensor $g_{\|} = 2.004$, $\|[1, 1, 1]$
$g_{\perp} = 2.093$, $\perp[1, 1, 1]$
Remark: observed in ODMR
Diamond: synthetic, nickel catalyst
Model: similar to NE4
References: 98P, 99N1

Spectrum NE5

Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g_1 = 2.0903$, ||[0 , − 0.7071, + 0.7071]
$g_2 = 2.0044$, ||[+ 0.1392, + 0.7002, + 0.7002]
$g_3 = 2.039$, ||[+ 0.9903, − 0.0984, − 0.0984]
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
$A_1 = 1.225$ mT, ||[1, 1, 1]
$A_2 = 0.95$ mT, ⊥[1, 1, 1]
$A_3 = 0.95$ mT, ⊥[1, 1, 1]
Diamond: synthetic, grown from nickel-iron solvent, after 5 hours anneal at temperature $T = 2100$ K under pressure $p = 5.5$ GPa
Model: nickel impurity in four-vacancy chain with one substitutional nitrogen atom at each end: N_SVVNiVVN_S in (011) plane, alternatively N_SCVNiVCN_S chain in (011) plane
References: 94N5, 95Y, 97N, 99B1, 99M3, 99N2, 00N2, 02B, 02P

Spectrum NE6

Symmetry: orthorhombic-I
Spin: $S = 1/2$
g-tensor: $g_1 = 1.995$, ||[1, 1, 0]
$g_2 = 2.0207$, ||[1, − 1, 0]
$g_3 = 2.0109$, ||[0, 0, 1]
Diamond: synthetic, grown from nickel-iron solvent, after 5 hours anneal at temperature $T = 2100$ K under pressure $p = 5.5$ GPa
Model: nickel-nitrogen complex
References: 94N5, 95Y, 97N, 99B1, 02B

Spectrum NE7

Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g > 2.0027$
A-tensor: $A = 0.6...0.9$ mT
Diamond: synthetic, grown from nickel-iron solvent, after 5 hours anneal at temperature $T = 2100$ K under pressure $p = 5.5$ GPa
Model: nickel-nitrogen complex
References: 94N5, 95Y, 97N, 99B1, 99N2, 02B

Spectrum NE8

Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g_1 = 2.0439$, ||[0, 1, 1]
$g_2 = 2.1722$, ⊥[0, 1, 1]
$g_3 = 2.0846$, ⊥[0, 1, 1]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 4 sites
$A_1 = 31.9$ MHz
$A_2 = 21.8$ MHz
$A_3 = 21.0$ MHz
Diamond: natural and synthetic grown from nickel-iron solvent
Model: positive N_2C-VNiV-CN_2 complex
References: 99B1, 99N2, 02B

Spectrum NE9

Symmetry: trigonal
Spin: $S = 1/2$
g-tensor: $g_1 = 2.0921$, $\|[1, 1, 1]$
$g_2 = 2.1705$, $\perp[1, 1, 1]$
Diamond: synthetic grown from nickel-iron solvent
Model: neutral C_3-VNiV-N_3 complex
References: 02B

Spectrum NIRIM-1

Symmetry: cubic or trigonal
Spin: $S = 1/2$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0112$
Diamond: synthetic, grown from Ni solvent with nitrogen getters
Model: interstitial Ni^+, electronic configuration $3d^9$, isotropic (cubic) in the temperature range 25...77 K, anisotropic (trigonal) at 4 K
References: 90I1, 94N2, 95G2, 98C, 99D, 99G, 00C1, 00G, 02B, 02P

Spectrum NIRIM-2

Symmetry: trigonal
Spin: $S = 1/2$
g-tensor: $g_{\|} = 2.3285$
$g_{\perp} \approx 0$
Diamond: synthetic, grown from Ni solvent with nitrogen getters
Model: complex of interstitial Ni^+ and vacancy or local charge compensation, nickel-boron complex
References: 90I1, 94N2, 95G2, 98C, 98P, 99D, 99M1, 00C1, 02B, 02P

Spectrum NIRIM-3

Symmetry: tetragonal
Spin: $S = 1/2$
g-tensor: $g_{\|} = 2.0009$
$g_{\perp} = 2.0024$
A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 4 sites
$A_{\|} = 32.8$ MHz, $\|[1, 1, 1]$
$A_{\perp} = 21.0$ MHz, $\perp[1, 1, 1]$

Diamond: synthetic, grown from Ni or B solvent, boron doped, after electron irradiation or H implantation
Model: positively charged vacancy (tentative)
Reference: 94I

Spectrum NIRIM-4 (Fig. 7)
Symmetry: orthorhombic-I
Spin: $S = 3/2$
g-tensor: $g_1 = 2.00332$, ||[1, 0, 0]
$g_2 = 2.00256$, ||[0, 1, 1]
$g_3 = 2.00419$, ||[0,– 1, 1]
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site
$A_1 = 11.2$ MHz, ||[1, 0, 0]
$A_2 = 108.6$ MHz, ||[0, 1, 1]
$A_3 = 10.3$ MHz, ||[0,– 1, 1]
A-tensor: nucleus ^{11}B, spin $I = 3/2$, abundance 80.2%, 1 site
$A_1 = 32.8$ MHz, ||[1, 0, 0]
$A_2 = 24.9$ MHz, ||[0, 1, 1]
$A_3 = 42.6$ MHz, ||[0, – 1, 1]
Remark: hyperfine interaction with ^{10}B, spin $I = 3$, abundance 19.8%, also observed
Diamond: synthetic, grown from Ni-2%Ti or Co solvent, boron doped, after electron irradiation
Model: <100>-split positively charged boron-nitrogen interstitialcy
References: 94I, 97I2

Spectrum NIRIM-5
Symmetry: trigonal
g-tensor: $g_{\|} = 4.0$, ||[1, 1, 1]
$g_{\perp} \approx 0$, ⊥[1, 1, 1]
Diamond: synthetic, grown from Ni solvent, boron doped, as grown
Reference: 94I

Spectrum NIRIM-6
g-tensor: $g = 2.0077$, ||[1, 0, 0]
Diamond: synthetic, grown from Ni(2%Ti) solvent
Reference: 94I

Spectrum NIRIM-7
g-tensor: $g = 1.9926$, ||[1, 0, 0]
Diamond: synthetic, grown from Ni(2%Ti) solvent
Reference: 94I

Spectrum NIRIM-8
Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g \approx 2.0024$

A-tensor: nucleus ^{31}P, spin $I = 1/2$, abundance 100%, 1 site: A small
nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site: $A \approx 90$ MHz
Diamond: synthetic, grown from phosphorus catalyst
Model: complex of substitutional phosphorus and nitrogen impurities on next-nearest neighbor positions in (011) plane: P_SCN_S
Remark: related spectra MA1 (Refs. 91S1, 91S2) and BI1 (Ref. 94Z3)
Reference: 97I1

Spectrum NL1

Symmetry: cubic
Spin: $S = 3/2$
g value: $g = (-)1.10 \pm 0.05$
g_2 value: $g_2 = (+)0.01 \pm 0.02$
d,b values: $d/b = 1.55 \pm 0.05$
Diamond: natural type IIb, p-type semiconducting
Remark: observed at low temperatures ($T \leq 2$ K), under external uniaxial stress ($p \geq 0.25$ GPa)
Model: hole bound to acceptor boron
References: 81A1, 81A3, 83A, 85A

Spectrum NOC1, NOC2, NOC3

Symmetry: low
Spin: $S = 1/2 + 1/2$
g-tensor: $g = 2.0024$
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
$A_{\|} = 114$ MHz, $\|[1, 1, 1]$
$A_{\perp} = 82$ MHz, $\perp[1, 1, 1]$
Diamond: synthetic, grown in nickel-iron solvent, high nitrogen concentration
Model: coupled pair of substitutional nitrogen atoms, three different pairs with site separations between 0.357 and 0.564 nm
References: 99N3, 99N4, 99N6

Spectrum NOC4

Symmetry: low
Spin: $S = 1/2$
g-tensor: $g_1 = 4.0085$
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
$A_{\|} = 114$ MHz, $\|[1, 1, 1]$
$A_{\perp} = 82$ MHz, $\perp[1, 1, 1]$
Diamond: synthetic, grown in nickel-iron solvent, high nitrogen concentration
Model: pairs of substitutional nitrogen atoms with separation greater than 0.7 nm
References: 99N4

Spectrum NOL1

Symmetry:	trigonal
Spin:	$S = 1$
g-tensor:	$g_{\|\|} = 2.0235$, $\|\|[1, 1, 1]$
	$g_{\perp} = 2.002$, $\perp[1, 1, 1]$
D-tensor:	$D = 171$ GHz
Diamond:	synthetic, grown in nickel(-iron) solvent
Model:	positive pair Ni_iB_s
References:	02B

Spectrum O1

Symmetry:	monoclinic-I (Ref. 88L2)	orthorhombic-I (Ref. 90E)
Spin:	$S = 1$	
g-tensor:	$g_1 = 2.0022$, $\|\|[0, -1, 1]$	$g_1 = 2.0028$, $\|\|[0, -1, 1]$
	$g_2 = 2.0020$, $\|\|[1, 0, 0]$	$g_2 = 2.0027$, $\|\|[1, 0, 0]$
	$g_3 = 2.0014$, $\|\|[0, 1, 1]$	$g_3 = 2.0016$, $\|\|[0, 1, 1]$
D-tensor:	$D_1 = -108.3$ MHz, $\|\|[0, -0.707, +0.707]$	$D_1 = \pm 107.7$ MHz, $\|\|[0, -1, 1]$
	$D_2 = -96.9$ MHz, $\|\|[1.000, +0.005, +0.005]$	$D_2 = \pm 97.8$ MHz, $\|\|[1, 0, 0]$
	$D_3 = +205.2$ MHz, $\|\|[-0.007, +0.707, +0.707]$	$D_3 = \leq 206.1$ MHz, $\|\|[0, 1, 1]$
Remark:	parameters of **g** and **D**-tensors depend on temperature of annealing	
Diamond:	natural type I and IIa, after neutron or electron irradiation and annealing above $\approx 750\ ^0$C, anneals out at $\approx 1100\ ^0$C	
Model:	4-vacancy chain, (three-vacancy+substitutional oxyen) chain, (four-vacancy+interstitial oxygen) chain	
References:	54G, 55G, 62L, 66C2, 72W, 73L1, 77C, 77L1, 77L2, 78L2, 79C, 79V, 83F2, 84L1, 84L2, 85L1, 86L, 87W, 88L2, 89N1, 90E, 94N4	

Spectrum O2

Symmetry:	isotropic
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.0028$
Remark:	linewidth from 1...10mT, depending on neutron dose, temperature of measurement and annealing
Diamond:	natural, after neutron irradiation
References:	54G, 55G, 62L, 67B, 91B, 94N3

Spectrum O3

Symmetry:	orthorhombic-II
Spin:	$S = 1$
g-tensor:	$g_1 = 2.0021$, $\|\|[1, 0, 0]$
	$g_2 = 2.0026$, $\|\|[0, 1, 0]$
	$g_3 = 2.0022$, $\|\|[0, 0, 1]$
D-tensor:	$D_1 = 458.2$ MHz
	$D_2 = 350.3$ MHz
	$D_3 = -808.6$ MHz

Diamond: synthetic, type IIa, 2 MeV electron irradiation at 100 K
Model: three or two <100>-split interstitials
References: 99T1, 00H2, 01G1, 01G3

Spectrum O4

Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g_1 = 1.8438$, ||[0, 1, 1]
$g_2 = 1.7045$, ⊥[0, 1, 1]
$g_3 = 2.3463$, ⊥[0, 1, 1]
A-tensor: nucleus ^{59}Co, spin $I = 7/2$, abundance 100%, 1 site
$A_1 = 180$ MHz, ||[0, 1, 1]
$A_2 = 163$ MHz, ⊥[0, 1, 1]
$A_3 = 248$ MHz, ⊥[0, 1, 1]
Diamond: synthetic, grown in cobalt-containing metal solvent catalyst
Model: negative C_3-VCoV-C_2N complex
References: 99J, 00C1, 00J, 00T1, 02B

Spectrum OK1 (Fig. 8)

Symmetry: monoclinic-I
Spin: $S = 1/2$
g-tensor: $g_1 = 2.0031$, ||[0 , − 0.7071, + 0.7071]
$g_2 = 2.0019$, ||[+ 0.7096, + 0.4983, + 0.4983]
$g_3 = 2.0025$, ||[− 0.7046, + 0.5017, + 0.5017]
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%
$A_1 = 15.48$ MHz, ||[0 , − 0.7071, + 0.7071]
$A_2 = 21.66$ MHz, ||[+ 0.4226, − 0.6409, − 0.6409]
$A_3 = 15.19$ MHz, ||[+ 0.9063, + 0.2988, + 0.2988]
Q-tensor: nucleus ^{14}N
$Q_1 = +1.31$ MHz, ||[0 , − 0.7071, + 0.7071]
$Q_2 = -2.67$ MHz, ||[+ 0.5892, − 0.5713, − 0.5713]
$Q_3 = +1.36$ MHz, ||[+ 0.8080, + 0.4166, + 0.4166]
A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 2 sites
$A_{xx} = 23.7$ MHz, ||[1, 0, 0]
A-tensor: nucleus ^{13}C, 2 sites
$A_{||} = 13.5$ MHz
$A_{\perp} = 9.9$ MHz
A-tensor: nucleus ^{13}C, 3 sites
$(A_1 + A_2 + A_3)/3 = 6.6$ MHz
A-tensor: nucleus ^{13}C, 6 sites
$(A_1 + A_2 + A_3)/3 = 3.9$ MHz
Remark: ^{14}N ENDOR in Refs. 88B and 89N2
Diamond: natural type Ib
Model: (nitrogen+vacancy) complex, (nitrogen+vacancy+oxygen) complex, N_sCO_s complex
References: 70K, 72S1, 73L2, 77L4, 77M, 78L2, 78S1, 83F2, 86W1, 86W2, 88B, 88M, 88W1, 89N2, 92B, 92W3, 94B, 95B1

Spectrum P1 (Figs. 9-12)

Symmetry: trigonal

Spin: $S = 1/2$

g-tensor: $g_{\|} = +\,2.0024 \pm 0.0001$, $\|[1, 1, 1]$

$g_{\perp} - g_{\|} = +\,0.0001 \pm 0.00003$

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site

$T = 4.2$ K: $A_{\|} = 114.032$ MHz, $\|[1, 1, 1]$ $T = 300$ K: $A_{\|} = 113.982$ MHz, $\|[1, 1, 1]$

$A_{\perp} = 81.318$ MHz, $\perp[1, 1, 1]$ $A_{\perp} = 81.345$ MHz, $\perp[1, 1, 1]$

Q-tensor: nucleus ^{14}N, 1 site

$Q_{\|} = -\,2.649$ MHz, $\|[1, 1, 1]$

$Q_{\perp} = +\,1.325$ MHz, $\perp[1, 1, 1]$

A-tensor: nucleus ^{15}N, spin $I = 1/2$, abundance >90%, 1 site

$A_{\|} = -\,159.730$ MHz, $\|[1, 1, 1]$

$A_{\perp} = -\,113.838$ MHz, $\perp[1, 1, 1]$

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 1 site in shell a (Fig. 10)

$A_{\|} = 338.171$ MHz, $\|[1, 1, 1]$

$A_{\perp} = 139.531$ MHz, $\perp[1, 1, 1]$

A-tensor: nucleus ^{13}C, 3 sites in shell d (Fig. 10)

$A_1 = 30.921$ MHz, $\|[+\,0.7071, -\,0.7071, \quad 0.0000]$

$A_2 = 40.292$ MHz, $\|[+\,0.6039, +\,0.6039, +\,0.5201]$

$A_3 = 31.662$ MHz, $\|[-\,0.3678, -\,0.3678, +\,0.8541]$

A-tensor: nucleus ^{13}C, 3 sites in shell c (Fig. 10)

$A_1 = -\,26.488$ MHz, $\|[+\,0.7071, -\,0.7071, \quad 0.0000]$

$A_2 = -\,22.771$ MHz, $\|[+\,0.5599, +\,0.5599, +\,0.6107]$

$A_3 = -\,25.319$ MHz, $\|[-\,0.4318, -\,0.4318, +\,0.7919]$

A-tensor: nucleus ^{13}C, 3 sites in shell b (Fig. 10)

$A_1 = 10.638$ MHz, $\|[+\,0.7071, -\,0.7071, \quad 0.0000]$

$A_2 = 14.153$ MHz, $\|[+\,0.6073, +\,0.6073, +\,0.5122]$

$A_3 = 10.618$ MHz, $\|[-\,0.3622, -\,0.3622, +\,0.8589]$

A-tensor: nucleus ^{13}C, 6 sites in shell e or g (Fig. 10)

$A_1 = 11.757$ MHz, $\|[+\,0.7935, +\,0.5193, +\,0.3173]$

$A_2 = 8.579$ MHz, $\|[-\,0.1262, +\,0.6492, -\,0.7501]$

$A_3 = 8.122$ MHz, $\|[-\,0.5991, +\,0.5587, +\,0.5736]$

A-tensor: nucleus ^{13}C, 3 sites

$(A_1 + A_2 + A_3)/3 = 4.15$ MHz

A-tensor: nucleus ^{13}C, 6 (or 9) sites

$(A_1 + A_2 + A_3)/3 = 2.75$ MHz

Diamond: synthetic and natural type Ib, type Ia (Refs. 81B and 82F1), type IIa (Refs. 94Z1 and 94Z2)

Remarks: sign of g values positive (Ref. 74S1), g-tensor anisotropic (Fig. 12, Ref. 94Z1), spin relaxation times in Refs. 60S, 76Z, 78B and 97W1, ^{14}N ENDOR in Refs. 66C1, 89N2, 92C3 and 94C, ^{15}N ENDOR in Refs. 92C3 and 94C, ^{13}C ENDOR in Refs. 92C3 and 94C (Fig. 11), ODMR on 2.56 eV optical system in Ref. 95N, ^{12}C isotopically enriched diamond in Refs. 94Z1 and 94Z2, ^{15}N isotopically enriched in Ref. 75K

Model: neutral substitutional nitrogen, <1, 1, 1> static distortion (Fig. 9), crystallographic point group 3m, energy for dynamic Jahn-Teller averaging 0.7 eV (Refs. 67L, 67S3, 80A, 81A2 and 88H2)

References: 59S1, 60S, 62H, 62L, 64S, 65D1, 65D4, 65F, 65L1, 65L2, 65S1, 65S2, 66B, 66C1, 66C2, 66S, 67L, 67S1, 67S2, 67S3, 68P, 68S1, 69S2, 70L, 71C, 71S3, 71S4, 72B2, 72S2, 73L2, 74S1, 75K, 75S1, 75S2, 75S3, 76Z, 77L4, 77S, 78B, 78L1, 78L2, 78S1, 78S2, 79A, 79C, 79H2, 80A, 80B, 81A1, 81A2, 81B, 82F1, 82L1, 82W2, 83F1, 83F2, 85L2, 86W1, 86W2, 87W, 88H1, 88H2, 88L2, 88M, 88W1, 89N2, 90F2, 90I3, 90I4, 90O3, 90S, 90W, 91B, 91H, 91K, 91N1, 92B, 92C3, 92S, 92W3, 93C, 93H5, 93K, 93M3, 93N3, 94B, 94C, 94J, 94L2, 94N1, 94Z1, 94Z2, 95B1, 95N, 96G1, 96G2, 96H, 96K1, 96R1, 96T7, 96V, 96W3, 97G2, 97K, 97T1, 97W1, 98N2, 98R, 98S, 99B1, 99D, 99I, 99N5, 99N6, 99N7, 99O, 99R, 99Y, 00R, 00S3, 00T2, 00V, 01I, 01N, 01W1, 02P

Spectrum P2

Symmetry: trigonal

Spin: $S = 1/2$

g-tensor: $g_{\|} = 2.0023$, $\|[1, 1, 1]$
$g_{\perp} = 2.0032$, $\perp[1, 1, 1]$

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 3 sites
$A_{\|} = 11.2$ MHz, $\|[+0.3746, -0.6556, -0.6556]$ (Ref. 93W1)
$A_{\perp} = 7.4$ MHz, $\perp[+0.3746, -0.6556, -0.6556]$
$A_1 = 9.1$ MHz, $\|[0, -0.707, +0.707]$ (Ref. 78S1)
$A_2 = 10.4$ MHz, $\|[+0.363, +0.659, +0.659]$
$A_3 = 8.8$ MHz, $\|[-0.932, +0.256, +0.256]$

Q-tensor: nucleus ^{14}N, 3 sites
$Q_{\|} = -3.2$ MHz, $\|[1, 1, 1]$
$Q_{\perp} = +1.6$ MHz, $\perp[1, 1, 1]$

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 1 site
$A_{\|} = 404$ MHz, $\|[1, 1, 1]$
$A_{\perp} = 174$ MHz, $\perp[1, 1, 1]$

A value: nucleus ^{13}C, 3 sites
$A_{xx} = 27.6$ MHz, $\|[1, 0, 0]$

A value: nucleus ^{13}C, 3 sites
$A_{xx} = 19.2$ MHz, $\|[1, 0, 0]$

Diamond: natural type I

Remarks: known as the "14 line" spectrum, ^{14}N ENDOR in Refs. 73L3, 84W and 93W1, model confirmed by ODMR (Ref. 80B)

Model: three equivalent substitutional nitrogen atoms nearest neighbor to common vacancy

References: 59S1, 59S2, 64S, 66C2, 71S2, 73L3, 76Z, 77L4, 78L2, 78S1, 79C, 79H1, 80B, 82W2, 83F2, 84W, 88H2, 88L1, 92B, 93H5, 93W1, 94B, 94D, 94P1, 94W2, 95B1, 95W3, 96W3, 97W1, 98R, 99B1, 99D, 00S3, 00T2

Spectrum PA1

Symmetry: trigonal

Spin: $S = 1/2$

g-tensor: $g_{\|} = 2.25$, $\|[1, 1, 1]$
$g_{\perp} = 0$, $\perp[1, 1, 1]$

Remark: observed in ODMR, similar to NIRIM-2, but associated ZPL at 1.06 eV
Diamond: synthetic, grown in nickel solvent catalyst
Model: nickel related
References: 98P, 02B

Spectrum R1, R1a–R1f (Fig. 13)

Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $g_1 = 2.0018$, ||[+ 0.7071, – 0.7071, 0] (Ref. 96T1)
$g_2 = 2.0019$, ||[+ 0.7071, + 0.7071, 0]
$g_3 = 2.0025$, ||[0 , 0 , + 1.0000]
$g_1 = 2.0019$, ||[+ 0.7071, – 0.7071, 0] (Ref. 94W1)
$g_2 = 2.0020$, ||[+ 0.6984, + 0.6984, – 0.1564]
$g_3 = 2.0027$, ||[+ 0.1106, + 0.1101, + 0.9877]
D-tensor: $D_1 = + 1408.6$ MHz, ||[+ 0.7071, – 0.7071, 0]
$D_2 = - 2805.4$ MHz, ||[+ 0.6747, + 0.6747, – 0.2990]
$D_3 = + 1396.8$ MHz, ||[+ 0.2115, + 0.2115, + 0.9542]
$D_{R1a} = 0.9918 D_{R1}$, $D_{R1b} = 0.9890 D_{R1}$, $D_{R1c} = 0.9879 D_{R1}$, $D_{R1d} = 0.9793 D_{R1}$, $D_{R1e} = 0.9746 D_{R1}$, $D_{R1f} = 0.9724 D_{R1}$
A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 2 sites
$A_{||} = 122.9$ MHz, ||[1,– 1, 0]
$A_{\perp} = 12.0$ MHz, ⊥[1,– 1, 0]
A-tensor: nucleus ^{13}C, 4 sites
$A_1 = 44.4$ MHz, ||[0, – 1, 1] (Ref. 83L2)
$A_2 = 39.9$ MHz, ||[4, 9, 9]
$A_3 = 43.8$ MHz, ||[– 9, 2, 2]
$A_{||} = 48$ MHz, ||[+ 0.5000, – 0.5000, + 0.7071] (Ref. 96T1)
$A_{\perp} = 36$ MHz, ⊥[+ 0.5000, – 0.5000, + 0.7071]
A-tensor: nucleus ^{13}C, 4 sites
$A_1 = 30.6$ MHz, ||[0, – 1, 1] (Ref. 83L2)
$A_2 = 24.3$ MHz, ||[4, 9, 9]
$A_3 = 27.3$ MHz, ||[– 9, 2, 2]
$A_{||} = 27$ MHz (Ref. 96T1)
$A_{\perp} = 27$ MHz
Diamond: synthetic and natural type I and II, after 2 MeV electron or fast neutron irradiation, anneals out at 300...400 ^0C
Remark: original label b-system, ^{13}C isotopically enriched diamond in Refs. 93T2, 95T3, 96T1
Model: complex of impurity and interstitial carbon, strained neutral lattice vacancy, <001>-split di-carbon interstitial
References: 62F, 63F, 65D3, 66C2, 72W, 73L1, 77C, 77L1, 78L2, 79C, 79V, 81F, 82F2, 82F3, 83F1, 83F2, 83L2, 85L1, 87W, 88H1, 88L2, 89N1, 92B, 93T1, 93T2, 94L3, 94L4, 94N3, 94W1, 95T3, 96L1, 96T1, 96T3, 96T5, 96T7, 97B1, 97B2, 97T2, 97T5, 98B, 99B1, 99B2, 99M2, 99T1, 99T3, 00H2, 01G1, 01G3, 01T, 01W1

Spectrum R2

Symmetry: tetragonal
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor: $D_{\|} = +\ 2760$ MHz, $\|$[1, 0, 0]
$D_{\perp} = -\ 1380$ MHz, $\perp$[1, 0, 0]
Diamond: synthetic and natural type I and II, after electron or neutron irradiation at low and at room temperature, anneals out at 400...500 ^{0}C
Remarks: excited state about 37 meV above diamagnetic ground state, original label c-system
Model: complex of impurity and interstitial carbon, <100>-distorted neutral lattice vacancy
References: 62F, 63F, 63H, 65D3, 66C2, 72W, 73K, 73L1, 75W, 77C, 77L1, 78L2, 79C, 79L2, 79V, 81F, 82F2, 82F3, 83F1, 83F2, 85L1, 87W, 88L2, 89N1, 93M1, 93M2, 93T2, 94L3, 94N3, 96L1, 96T1, 97T2, 99B1, 99D, 99M2, 99T1, 99T2, 00H1, 00H2, 01G1, 01G2, 01G3, 01T, 01W1

Spectrum R3

Symmetry: triclinic
Spin: $S = 1$
g-tensor: $g_1 = 2.0019$, $\|$[+ 0.758, + 0.650, − 0.051]
$g_2 = 2.0024$, $\perp$[+ 0.758, + 0.650, − 0.051]
$g_3 = 2.0024$, $\perp$[+ 0.758, + 0.650, − 0.051]
D-tensor: $D_1 = +\ 276.6$ MHz, $\|$[+ 0.928, + 0.311, + 0.207]
$D_2 = -\ 123.6$ MHz, $\|$[− 0.243, + 0.082, + 0.967]
$D_3 = -\ 153.0$ MHz, $\|$[+ 0.284, − 0.947, + 0.152]
Diamond: natural type I and II, after fast neutron or electron irradiation at low or at room temperature, anneals out at 500...600 ^{0}C
Remark: original label d-system
Model: complex of impurity and interstitial carbon
References: 62F, 63F, 65D3, 66C2, 73L1, 75L2, 77C, 77L1, 78L2, 78L3, 79C, 79L2, 79V, 81F, 82F2, 83F2, 85L1, 87W, 88L2, 89N1, 94L5, 94N3, 99T1

Spectrum R4/W6

Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $g_1 = 2.0024$, $\|$[0, − 1, 1]
$g_2 = 1.9996$, $\|$[1, 1, 1]
$g_3 = 2.0022$, $\|$[− 2, 1, 1]
D-tensor: $D_1 = +\ 108$ MHz, $\|$[0, − 1, 1]
$D_2 = -\ 312$ MHz, $\|$[1, 1, 1]
$D_3 = +\ 204$ MHz, $\|$[− 2, 1, 1]
Diamond: natural type Ia or IIa, synthetic type IIa/b, after 2 MeV electron irradiation at low and at room temperature, enhanced by anneal above 500 ^{0}C, anneals out at 800...900 ^{0}C
Remarks: original label e-system, spectra R4 and W6 are related to same center, spectrum similar (identical?) to A5, g and D values temperature dependent, ^{13}C enriched diamond in Refs. 96T6 and 97T4

Model: complex of impurity and interstitial carbon, neutral divacancy

References: 64C, 73L1, 75L2, 77C, 77L1, 78L1, 78L2, 78L3, 79C, 79V, 81F, 82F2, 83F2, 84L1, 85L1, 86L, 88L2, 89N1, 94N4, 95L, 96T6, 97T4, 99B1, 99B2, 99D, 99T4, 02B

Spectrum R5

Symmetry: orthorhombic-I

Spin: $S = 1$

g-tensor: $g_1 = 2.0024$, ||[1, 0, 0]
$g_2 = 2.0019$, ||[0, 1, 1]
$g_3 = 2.0028$, ||[0, − 1, 1]

D-tensor: $T \leq 77$ K: $D_1 = -190$ MHz, ||[1, 0, 0] (Ref. 73L1)
$D_2 = +420$ MHz, ||[0, 1, 1]
$D_3 = -230$ MHz, ||[0,− 1, 1]

D-tensor: $T \approx 293$ K:

D_1	− 265 MHz (Ref. 73L1)	− 244 MHz, ||[1, 0, 0] (Ref. 90E)
D_2	+ 570 MHz	+ 524 MHz, ||[0, 1, 1]
D_3	− 305 MHz	− 280 MHz, ||[0, − 1, 1]

Diamond: natural type IIa, after 2 MeV electron irradiation, anneals in at 600 ^{0}C, anneals out at 1200 ^{0}C, type Ia,b after neutron irradiation, after Ni or C ion bombardment

Remark: D values dependent on temperature of measurement and anneal

Model: three-vacancy chain, complex of divacancy and substitutional oxygen: $(O_s)V_2$, complex of trivacancy and interstitial oxygen: $(O_i)V_3$

References: 73L1, 77C, 77L1, 78L2, 79C, 79V, 83F2, 85L1, 86L, 88L2, 89N1, 90E, 94N4

Spectrum R6

Symmetry: orthorhombic-I

Spin: $S = 1$

g-tensor: $g_1 = 2.0021$, ||[1, 0, 0]
$g_2 = 2.0014$, ||[0, 1, 1]
$g_3 = 2.0021$, ||[0, − 1, 1]

D-tensor: $D_1 = -$ 57.5 MHz, ||[1, 0, 0]
$D_2 = +$ 119.7 MHz, ||[0, 1, 1]
$D_3 = -$ 62.2 MHz, ||[0, − 1, 1]

Diamond: natural type IIa, after 2 MeV electron irradiation, anneals in at 800 ^{0}C, anneals out at 1400 ^{0}C, type Ia,b after neutron irradiation

Model: five-vacancy chain, multi-oxygen-vacancy complex

References: 73L1, 77C, 77L1, 78L2, 79C, 79V, 83F2, 85L1, 86L, 87W, 88L2, 89N1, 94N4

Spectrum R7

Symmetry: orthorhombic-I

Spin: $S = 1$

g-tensor: $g_1 = 2.0025$, ||[1, 0, 0]
$g_2 = 2.0019$, ||[0, 1, 1]
$g_3 = 2.0028$, ||[0, − 1, 1]

D-tensor: $D_1 = -160.2$ MHz, ||[1, 0, 0]
$D_2 = +389.3$ MHz, ||[0, 1, 1]
$D_3 = -229.1$ MHz, ||[0, −1, 1]
Diamond: natural type IIa, after 2 MeV electron irradiation, anneals in at 950 °C, anneals out at 1450 °C
Remark: earlier spin value $S = 3/2$ incorrect
Model: multi-oxygen-vacancy complex $[(O_s)_2V, (O_i)_2V_3]$
References: 73L1, 77C, 78L2, 79C, 79V, 83F2, 85L1, 86L, 88L2, 94N4

Spectrum R8

Symmetry: orthorhombic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor: $D_1 = -168$ MHz, ||[1, 0, 0]
$D_2 = +336$ MHz, ||[0, 1, 1]
$D_3 = -168$ MHz, ||[0, −1, 1]
(for $S = 3/2$: $D_{\|[011]} = +168$ MHz, $D_{\perp[011]} = -84$ MHz)
Diamond: natural type IIa, after 2 MeV electron irradiation, anneals in at 900 °C, anneals out at 1400 °C
Model: three-vacancy chain, multi-oxygen-vacancy complex: $(O_i)_3V_3$
References: 73L1, 77C, 78L2, 79C, 79V, 83F2, 85L1, 86L, 88L2, 94N4

Spectrum R9

Symmetry: orthorhombic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor: $D_1 = -454$ MHz, ||[1, 0, 0]
$D_2 = +908$ MHz, ||[0, 1, 1]
$D_3 = -454$ MHz, ||[0, −1, 1]
(for $S = 3/2$: $D_{\|[011]} + 454$ MHz, $D_{\perp[011]} = -227$ MHz)
Diamond: natural type IIa, after 2 MeV electron irradiation, anneals in at 900 °C, anneals out at 1250 °C
Model: oxygen-vacancy complex: O_sV, O_iV_2
References: 73L1, 77C, 78L2, 79C, 79V, 83F2, 86L, 88L2, 94N4

Spectrum R10

Symmetry: orthorhombic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor: $D_1 = -35$ MHz, ||[1, 0, 0]
$D_2 = +70$ MHz, ||[0, 1, 1]
$D_3 = -35$ MHz, ||[0, −1, 1]
(for $S = 3/2$: $D_{\|[011]} = +35$ MHz, $D_{\perp[011]} = -17.5$ MHz)
Diamond: natural type IIa, after 2 MeV electron irradiation, anneals in at 900 °C, anneals out at 1200 °C
Model: oxygen-multi-vacancy complex: O_sV_5, O_iV_6
References: 73L1, 77C, 78L2, 79C, 79V, 83F2, 85L1, 86L, 88L2, 94N4

Spectrum R11

Symmetry:	orthorhombic-I
Spin:	$S = 1$ (or: $S = 3/2$)
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor:	$D_1 = -27$ MHz, $\parallel$[1, 0, 0]
	$D_2 = +54$ MHz, $\parallel$[0, 1, 1]
	$D_3 = -27$ MHz, $\parallel$[0, −1, 1]
	(for $S = 3/2$: $D_{\parallel[011]} = +27$ MHz, $D_{\perp[011]} = -13.5$ MHz)
Diamond:	natural type IIa, after 2 MeV electron irradiation, anneals in at 900 ^{0}C, anneals out at 1200 ^{0}C
Model:	oxygen-multi-vacancy complex: O_sV_6. O_iV_7
References:	73L1, 77C, 78L2, 79C, 79V, 83F2. 85L1, 86L, 88L2, 94N4, 97B2

Spectrum R12

Symmetry:	trigonal
Spin:	$S = 1$ (or: $S = 3/2$)
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor:	$D_\parallel = +104$ MHz, $\parallel$[1, 1, 1]
	$D_\perp = -52$ MHz, $\perp$[1, 1, 1]
	(for $S = 3/2$: $D_{\parallel[111]} = +52$ MHz, $D_{\perp[111]} = -26$ MHz)
Diamond:	natural type IIa, after 2 MeV electron irradiation, anneals in at 1100 ^{0}C, still present after anneal at 1650 ^{0}C
References:	73L1, 77C, 78L2, 79C, 83F2, 85L1. 88L2, 94N4

Spectrum R13

Symmetry:	triclinic
Spin:	$S = 1$
g-tensor:	$g_1 = 2.0021$, $\parallel$[+ 0.696, + 0.696, + 0.174]
	$g_2 = 2.0029$, $\perp$[+ 0.696, + 0.696, + 0.174]
	$g_3 = 2.0029$, $\perp$[+ 0.696, + 0.696, + 0.174]
D-tensor:	$D_1 = +1365$ MHz, $\parallel$[+ 0.917, + 0.301, + 0.261]
	$D_2 = -515$ MHz, $\parallel$[+ 0.039, + 0.584, − 0.811]
	$D_3 = -850$ MHz, $\parallel$[− 0.396, + 0.754, + 0.524]
Diamond:	natural type IIa, after 2 MeV electron irradiation at room temperature, anneals out at 400 ^{0}C
Model:	complex of substitutional impurity and split interstitial carbon
References:	83L2, 85L1, 88L2, 94N3, 96L1

Spectrum R14

Symmetry:	triclinic
Spin:	$S = 1$
g-tensor:	$g_1 = 2.0018$, $\parallel$[+ 0.264, + 0.961, − 0.087]
	$g_2 = 2.0022$, $\parallel$[− 0.857, + 0.192, − 0.478]
	$g_3 = 2.0025$, $\parallel$[− 0.443, + 0.201, + 0.874]

D-tensor: $D_1 = +165.9$ MHz, ||[+ 0.916, + 0.379, + 0.132]
$D_2 = -78.2$ MHz, ||[+ 0.140, + 0.007, – 0.990]
$D_3 = -87.7$ MHz, ||[– 0.376, + 0.925, – 0.046]
Diamond: natural type Ia and IIa, after neutron and electron irradiation at room temperature, anneals out at 600 ^{0}C
Model: complex of impurity and interstitial carbon
References: 84L2, 85L1, 88L2, 94L5, 94N3, 99T1

Spectrum R15

Symmetry: triclinic
Spin: $S = 1$
g-tensor: $g_1 = 2.0018$, ||[+ 0.521, + 0.389, + 0.760]
$g_2 = 2.0023$, ⊥[+ 0.521, + 0.389, + 0.760]
$g_3 = 2.0023$, ⊥[+ 0.521, + 0.389, + 0.760]
D-tensor: $D_1 = +137.3$ MHz, ||[+ 0.719, + 0.633, + 0.288]
$D_2 = -64.2$ MHz, ||[+ 0.695, – 0.644, – 0.319]
$D_3 = -73.1$ MHz, ||[– 0.016, + 0.429, – 0.903]
Diamond: natural type Ia and IIa, after neutron and electron irradiation at room temperature, anneals out at 500 ^{0}C
Model: complex of impurity and interstitial carbon
References: 84L2, 85L1, 88L2, 94L5, 94N3

Spectrum R16

Symmetry: low
Spin: $S = 1/2$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.003$, $g_{min} \approx 2.0026$, $g_{max} \approx 2.0033$
Diamond: natural type IIa, after 2 MeV electron irradiation at room temperature, anneals in at 700 ^{0}C, anneals out at 900 ^{0}C
Remark: values of parameters still tentative
References: 84L2, 86L, 88L2, 94N4

Spectrum R17

Symmetry: triclinic
Spin: $S = 1$
g-tensor: $g_1 = 2.0020$, ||[+ 0.437, + 0.686, – 0.582]
$g_2 = 2.0026$, ⊥[+ 0.437, + 0.686, – 0.582]
$g_3 = 2.0026$, ⊥[+ 0.437, + 0.686, – 0.582]
D-tensor: $D_1 = +245.8$ MHz, ||[+ 0.932, + 0.311, + 0.185]
$D_2 = -95.0$ MHz, ||[+ 0.259, – 0.930, + 0.259]
$D_3 = -150.8$ MHz, ||[+ 0.253, – 0.193, – 0.948]
Diamond: natural type IIa, after 2 MeV electron irradiation at room temperature, anneals in at 700 ^{0}C, still present after anneal at 1650 ^{0}C
References: 84L2, 85L1, 88L2, 94N4

Spectrum R18

Spin: $S = 1/2$

g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0029$

Diamond: natural type IIa, after 2 MeV electron irradiation at room temperature, anneals in at 900 ^{0}C, still present after anneal at 1650 ^{0}C

References: 86L, 88L2, 91B, 94N4

Spectrum RM1

Symmetry: monoclinic-I

Spin: $S = 1/2$

g-tensor: $g_1 = 2.1719$, ||[+0.615, +0.615, +0.494]
$g_2 = 2.052$, ||[+0.707, –0.707, 0.000]
$g_3 = 2.042$, ||[–0.349, –0.349, +0.869]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 4 sites
$A_1 = 31.8$ MHz, ||[+0.707, –0.707, 0.000]
$A_2 = 26.4$ MHz, ||[0.000, 0.000, +1.000]
$A_3 = 23.1$ MHz, ||[+0.707, +0.707, 0.000]

Diamond: synthetic, nickel catalyst

Model: nickel–vacancy–4-nitrogen center

References: 99M3

Spectrum RO1

Symmetry: tetragonal

Spin: $S = 1/2$

g-tensor: $g_{||} = 2.0151$, ||[0, 0, 1]
$g_\perp = 2.2113$, ⊥[0, 0, 1]

Diamond: natural, Ural

Model: nickel related

References: 94M, 02B

Spectrum S1 (S2)

Symmetry: cubic

Spin: $S = 3/2$

g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0023$, at room temperature
$(g_1 + g_2 + g_3)/3 = 2.0027$, in temperature range 4...77 K

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 10%, 4 sites
$T = 4$ K: $A_{||} = 141.8$ MHz, ||[1, 1, 1]
$A_\perp = 81.7$ MHz, ⊥[1, 1, 1]
$T = 77$ K: $A_{||} = 141.5$ MHz, ||[1, 1, 1]
$A_\perp = 81.9$ MHz, ⊥[1, 1, 1]

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 10%, 12 sites
$T = 4$ K: $A_1 = 13.42$ MHz, ||[+ 0.6086, + 0.6086, – 0.5090]
$A_2 = 9.40$ MHz, ||[+ 0.3599, + 0.3599, + 0.8607]
$A_3 = 9.23$ MHz, ||[– 0.7071, + 0.7071, 0]
$T = 77$ K: $A_{||} = 13.5$ MHz, ||[1, 1, 1]
$A_\perp = 9.5$ MHz, ⊥[1, 1, 1]

Diamond: natural, after electron or neutron irradiation at low and at room temperature, synthetic grown from Ni,Ti solvent, anneals out at 800 ^{0}C

Remarks: original label A-center for both S1 and S2, earlier interpretation that S1 and S2 spectra belong to different centers abandoned, ^{13}C enriched synthetic diamond and ENDOR in Ref. 92I

Model: negative isolated lattice vacancy in $^4A_2$ ground state, crystallographic point group $\bar{4}$ 3m

References: 63B, 65D2, 65D3, 66C2, 70L, 71L, 73L2, 75L1, 77C, 78L2, 83F2, 86L, 87W, 88L2, 89N1, 92B, 92I, 93T2, 93W2, 94B, 94N3, 95B1, 95W1, 96T7, 97T2, 99T5, 00G

Spectrum S1* (Fig. 14)

Symmetry: cubic

Spin: $S = 3/2$

g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0023$

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 4 sites

$A_{\|} = 91.3$ MHz, $\|[1, 1, 1]$

$A_{\perp} = 35.8$ MHz, $\perp[1, 1, 1]$

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 12 sites

$A_{\|} = 9.1$ MHz, $\|[1, 1, 1]$

$A_{\perp} = 6.9$ MHz, $\perp[1, 1, 1]$

Diamond: natural, after electron irradiation and anneal

Model: negative isolated lattice vacancy in $^4T_1$ excited state

Reference: 93W2, 00G

Spectrum S2

Remark: see spectrum S1 (S2)

Spectrum S3

Symmetry: isotropic

Spin: $S = 1/2$

g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00238$

Diamond: natural, after electron irradiation

Remark: original label C-center

References: 63B, 65D3, 66C2, 71L, 77C, 78L2, 83F2, 94N3

Spectrum S4

Symmetry: isotropic

Spin: $S = 1/2$

g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00234$

Diamond: natural, after electron irradiation

Remarks: two lines separated by ≈ 0.1 mT

original label B-center

References: 63B, 66C2, 71L, 77C, 78L2, 83F2, 94N3

Spectrum TI1

Symmetry:	isotropic
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.0027$
Diamond:	pulverised
Model:	surface damage
Remark:	probably identical to N5
References:	61W, 67B, 67S2, 74S2, 78S2, 79S, 91B, 94N6

Spectrum W1

Symmetry:	orthorhombic-I
Spin:	$S = 1$
g-tensor:	$g_1 = 2.0029$, ‖[1, 0, 0]
	$g_2 = 2.0026$, ‖[0, 1, 1]
	$g_3 = 2.0029$, ‖[0, – 1, 1]
D-tensor:	$D_1 = -217$ MHz, ‖[1, 0, 0]
	$D_2 = +374$ MHz, ‖[0, 1, 1]
	$D_3 = -157$ MHz, ‖[0,– 1, 1]
Diamond:	natural type Ib
Remark:	possibly produced by geological irradiation and heating, centers possibly equal to A2, R5, R7 or R8 observed after electron or neutron irradiation and anneal
Model:	native three-vacancy center
References:	71S1, 73L1, 77C, 78L2, 79C, 79L1, 83F2

Spectrum W2

Symmetry:	orthorhombic-I
Spin:	$S = 1$
g-tensor:	$g_1 = 2.0030$, ‖[1, 0, 0]
	$g_2 = 2.0027$, ‖[0, 1, 1]
	$g_3 = 2.0030$, ‖[0, – 1, 1]
D-tensor:	$D_1 = -206$ MHz, ‖[1, 0, 0]
	$D_2 = +411$ MHz, ‖[0, 1, 1]
	$D_3 = -206$ MHz, ‖[0,– 1, 1]
Diamond:	natural type Ib
Remark:	possibly produced by geological irradiation and heating, centers possibly equal to A2, R5, R7 or R8 observed after electron or neutron irradiation and anneal
Model:	native three-vacancy center
References:	71S1, 73L1, 77C, 78L2, 79C, 79L1, 83F2

Spectrum W3

Symmetry:	orthorhombic-I
Spin:	$S = 1$

g-tensor: $g_1 = 2.0029$, ||[1, 0, 0]
$g_2 = 2.0026$, ||[0, 1, 1]
$g_3 = 2.0029$, ||[0, – 1, 1]
D-tensor: $D_1 = -230$ MHz, ||[1, 0, 0]
$D_2 = +460$ MHz, ||[0, 1, 1]
$D_3 = -230$ MHz, ||[0, – 1, 1]
Diamond: natural type Ib
Remark: possibly produced by geological irradiation and heating, centers possibly equal to A2, R5, R7 or R8 observed after electron or neutron irradiation and anneal
Model: native three-vacancy center
References: 71S1, 73L1, 77C, 78L2, 79C, 79L1, 83F2

Spectrum W4
Symmetry: orthorhombic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor: $D_1 = -74$ MHz, ||[1, 0, 0]
$D_2 = +147$ MHz, ||[0, 1, 1]
$D_3 = -74$ MHz, ||[0, – 1, 1]
Diamond: natural type IIb, semiconducting, after 2 MeV electron irradiation at room temperature
References: 77C, 78L2, 79C, 83F2, 94N3

Spectrum W5
Symmetry: orthorhombic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.00$
D-tensor: $D_1 = -53$ MHz, ||[1, 0, 0]
$D_2 = +105$ MHz, ||[0, 1, 1]
$D_3 = -53$ MHz, ||[0, – 1, 1]
Diamond: natural type IIb, semiconducting, after 2 MeV electron irradiation at room temperature
References: 77C, 78L2, 79C, 83F2, 94N3

Spectrum W6
Remark: identical to spectrum R4

Spectrum W7 (Fig. 15)
Symmetry: triclinic
Spin: $S = 1/2$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0028$ (Ref. 73L2), 2.0023 (Refs. 91N1, 91N2)
A-tensor: nucleus N_1, isotope ^{14}N, spin $I = 1$, abundance 99.63%, 1 site
$T < 77$ K: $A_{||} = 121.39$ MHz, ||[1, 1, 1]
$A_{\perp} = 86.00$ MHz, ⊥[1, 1, 1]
Q-tensor: $T < 77$ K: $Q_{||} = -2.55$ MHz, ||[1, 1, 1]
$Q_{\perp} = +1.27$ MHz, ⊥[1, 1, 1]

A-tensor: nucleus N_2, isotope ^{14}N, 1 site,
$T < 77$ K: $A_1 = 13.58$ MHz, ||[– 0.4936, + 0.7418, + 0.4540]
$A_2 = 16.01$ MHz, ||[+ 0.8663, + 0.4053, + 0.2920]
$A_3 = 14.00$ MHz, ||[– 0.0347, – 0.5431, + 0.8390]

Q-tensor: $T < 77$ K: $Q_1 = + 0.13$ MHz, ||[– 0.6427, + 0.5931, + 0.4850]
$Q_2 = – 0.13$ MHz, ||[+ 0.7622,+ 0.5897,+ 0.2761]
$Q_3 = 0.00$ MHz, ||[+ 0.1233, – 0.5301, + 0.8390]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
$T = 450$ ^{0}C: $A_1 = 57.7$ MHz, ||[1, 0, 0]
$A_2 = 50.2$ MHz, ||[0, 1, 1]
$A_3 = 64.2$ MHz, ||[0, – 1, 1]

Diamond: natural brown type I, plastically deformed

Remarks: anisotropic distribution of orientations, ^{14}N ENDOR in Refs. 89N4, 91N1 and 94B

Model: two non-equivalent substitutional nitrogen atoms in non-coplanar configuration $N_1CCN_2^+$, close to dislocation, motional averaging for temperatures above 200 K with activation energy 0.24 eV

References: 70L, 73L2, 75S1, 78L2, 78W, 79C, 82L1, 83F2, 85L2, 89N4, 91N1, 91N2, 92B, 94B, 95B1, 99B1

Spectrum W8

Symmetry: cubic

Spin: $S = 3/2$

g value: $g = 2.0319$

A value: nucleus ^{61}Ni, spin $I = 3/2$, abundance 86%, 1 site
$A = 18.5$ MHz

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 4 nearest-neighbor sites
$A_{||} = 38.07$ MHz, ||[1, 1, 1]
$A_{\perp} = 9.67$ MHz, $\perp$[1, 1, 1]

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 12 next-nearest neighbor sites
$A_1 = 10.86$ MHz, ||[+ 0.6124, + 0.6124, + 0.5000]
$A_2 = 7.73$ MHz, ||[– 0.3535, – 0.3535, + 0.8660]
$A_3 = 7.65$ MHz, ||[– 0.7071, + 0.7071, 0.0000]

Diamond: synthetic (powder) grown from Ni,Ti or Ni,Zr solvent, natural type Ia,b powder (77L2)

Remarks: hyperfine-tensor A(^{61}Ni) measured in synthetic enriched Ni doped diamond (Ref. 71S3), hyperfine interaction with ^{13}C measured by FT– ESR (ESEEM) in Ref. 90I2, ODMR on 2.56 eV luminescence in Refs. 94P3, 95H and 95N

Model: negative substitutional nickel impurity, electron configuration $3d^7$

References: 66L, 68P, 70B, 71S3, 72B2, 75B, 75S3, 77L2, 78B, 78L2, 79C, 82C, 83F2, 90F2, 90I1, 90I2, 90I3, 90I4, 90S, 92B, 94B, 94H2, 94N2, 94P3, 95G2, 95H, 95N, 97O, 98C, 98N2, 99B1, 99D, 00C1, 01P1, 01P2, 02B, 02P

Spectrum W9

Symmetry: orthorhombic

Spin: $S = 1$

g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.002$
D-tensor:	$D_{\|\|} = +132$ MHz, $\|\|[0, -1, 1]$
	$D_{\perp} = -66$ MHz, $\perp[0, -1, 1]$
Diamond:	natural brown type IIa
Model:	native center, still present after anneal at 1000 ^{0}C
References:	78L2, 79L1, 83F2, 83L1, 87L1, 87L2

Spectrum W10

Symmetry:	trigonal
Spin:	$S = 2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.001$
D-tensor:	$D_{\|\|} = +102.8$ MHz, $\|\|[1, 1, 1]$
	$D_{\perp} = -51.4$ MHz, $\perp[1, 1, 1]$
Diamond:	natural brown type IIa
Remarks:	spin value earlier reported as $S = 1$, **D**-tensor temperature dependent (Ref. 87L2)
Model:	interstitial neutral chromium (tentative)
References:	78L2, 79L1, 83F1, 83F2, 83L1, 87L1, 87L2, 95L, 01B, 02B

Spectrum W11

Symmetry:	triclinic
Spin:	$S = 3/2$ (or: $S = 1$, Ref. 93T1)
g-tensor:	$g_1 = 2.0024$
	$g_2 = 2.0022$
	$g_3 = 2.0021$
D-tensor:	$D_1 = -241.3$ MHz, $\|\|[+0.025, +0.751, +0.659]$
	$D_2 = -199.6$ MHz, $\|\|[+0.719, -0.474, +0.508]$
	$D_3 = +440.9$ MHz, $\|\|[+0.700, +0.463, -0.544]$
Diamond:	natural or synthetic type Ib, after neutron or electron irradiation, anneals out at 250...300 ^{0}C
Remarks:	EPR from excited state about 1.5 meV above ground state, **g**-tensor slightly angular dependent: anisotropy of principal values not reliably determined, parameters of **D**-tensor compounded from Refs. 94L1 and 94W1
Model:	negative vacancy, perturbed by nearby impurity (nitrogen)
References:	78L2, 83F2, 87W, 89W, 91W, 93T1, 94L1, 94N3, 94W1, 95B1

Spectrum W12

Symmetry:	triclinic
Spin:	$S = 3/2$
g-tensor:	$g_1 = 2.0047$, $\|\|[-0.797, -0.110, +0.594]$
	$g_2 = 1.9967$, $\|\|[+0.597, -0.370, +0.712]$
	$g_3 = 1.9990$, $\|\|[+0.139, +0.916, +0.376]$
D-tensor:	$D_1 = -144.6$ MHz, $\|\|[-0.412, +0.836, +0.364]$
	$D_2 = -337.4$ MHz, $\|\|[+0.676, -0.009, +0.737]$
	$D_3 = +481.9$ MHz, $\|\|[+0.623, +0.550, -0.557]$
Diamond:	natural or synthetic type Ib, after neutron or electron irradiation, anneals out at 375...400 ^{0}C

Remarks: anisotropy of **g**-tensor not reliably determined, parameters of **g** and **D**-tensors compounded from Refs. 94L1 and 94W1
Model: negative vacancy, perturbed by nearby impurity (nitrogen)
References: 78L2, 83F2, 87W, 89W, 91W, 93T1, 94L1, 94N3, 94W1, 95B1

Spectrum W13
Symmetry: monoclinic-I
Spin: $S = 3/2$
g-tensor: $g_1 = 1.9982$, ||[0.000, + 0.707, + 0.707]
$g_2 = 1.9975$, ||[+ 0.766,– 0.455, + 0.455]
$g_3 = 2.0037$, ||[+ 0.643,+ 0.542, – 0.542]
D-tensor: $D_1 = -193.0$ MHz, ||[0.000, + 0.707, + 0.707]
$D_2 = -307.7$ MHz, ||[+ 0.669, – 0.526, + 0.526]
$D_3 = +500.7$ MHz, ||[+ 0.743, + 0.473, – 0.473]
Diamond: natural or synthetic type Ib, after neutron or electron irradiation, anneals out at 375...400 ^{0}C
Remarks: anisotropy of **g**-tensor not reliably determined, parameters of **g** and **D**-tensors compounded from Refs. 94L1 and 94W1
Model: negative vacancy, perturbed by nearby impurity (nitrogen)
References: 78L2, 83F2, 87W, 89W, 91W, 93T1, 94L1, 94N3, 94W1, 95B1

Spectrum W14
Symmetry: monoclinic-I
Spin: $S = 3/2$ (or: $S = 1$, Ref. 93T1)
g-tensor: $g_1 = 1.9978$, ||[0.000, + 0.707, + 0.707]
$g_2 = 1.9955$, ||[+ 0.829, – 0.395, + 0.395]
$g_3 = 2.0035$, ||[+ 0.559, + 0.586, – 0.586]
D-tensor: $D_1 = -344.7$ MHz, ||[0.000, + 0.707, + 0.707]
$D_2 = -196.3$ MHz, ||[+ 0.799, – 0.426, + 0.426]
$D_3 = +540.9$ MHz, ||[+ 0.602, + 0.565, – 0.565]
Diamond: natural or synthetic type Ib, after neutron or electron irradiation, anneals out at 400...425 ^{0}C
Remarks: anisotropy of **g**-tensor not reliably determined, parameters of **g** and **D**-tensors compounded from Refs. 94L1 and 94W1
Model: negative vacancy, perturbed by nearby impurity (nitrogen)
References: 78L2, 83F2, 87W, 89W, 91W, 93T1, 94L1, 94N3, 94W1, 95B1

Spectrum W15 (Figs. 16-18)
Symmetry: trigonal
Spin: $S = 1$
g-tensor: $g_{\|} = 2.0028$, ||[1, 1, 1]
$g_{\perp} = 2.0028$, $\perp$[1, 1, 1]
D-tensor: $D_{\|} = +1916$ MHz, ||[1, 1, 1]
$D_{\perp} = -958$ MHz, $\perp$[1, 1, 1]

A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site
$A_{\|} = 2.30$ MHz, $\|[1, 1, 1]$
$A_{\perp} = 2.10$ MHz, $\perp[1, 1, 1]$

Q-tensor: nucleus ^{14}N, 1 site
$Q_{\|} = -3.36$ MHz, $\|[1, 1, 1]$
$Q_{\perp} = +1.68$ MHz, $\perp[1, 1, 1]$

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 3 sites
$A_{\|} = 205$ MHz, $\|[+0.627, -0.551, -0.551]$
$A_{\perp} = 123$ MHz, $\perp[+0.627, -0.551, -0.551]$

A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 3 sites
$(A_1 + A_2 + A_3)/3 = 15.1$ MHz

Diamond: natural type Ib, after electron or neutron irradiation, anneals in at 700 ^{0}C, still present after anneal at 1300 ^{0}C

Remarks: spin-Hamiltonian parameters also determined by Raman heterodyne detected EPR (Fig. 17) (Refs. 90F1, 90H, 92H1, 92M2, 93H1, 96W1, 96W2) or ENDOR (Fig. 18) (Refs. 90M, 93H2), by spectral hole burning (Refs. 84H, 87R, 92R1) and ODMR (Fig. 16) (Refs. 88O1, 90O2) using optical transition at wavelength 637 nm ($E = 1.945$ eV) (Ref. 76D) from ^3A spin-triplet ground state to ^3E excited state. Spin dynamics in Refs. 89O, 90O1, 91R, 92H3, 92O. Sign of $D_{\|}$ positive (Ref. 90M)

Model: negative nitrogen-vacancy pair

References: 75L1, 76D, 77L3, 78L2, 80W, 83F2, 84H, 87R, 87W, 88H1, 88L1, 88O1, 89N1, 89O, 90F1, 90H, 90M, 90O1, 90O2, 90O3, 91G, 91O, 91R, 92B, 92H1, 92H3, 92M2, 92M1, 92O, 92R1, 92R2, 93H1, 93H2, 93H3, 93H4, 94B, 94D, 94N4, 95B1, 96B, 96L2, 96L3, 96W1, 96W2, 97G1, 97L, 00N2, 01C2, 02B

Spectrum W16

Symmetry: monoclinic-I

Spin: $S = 1$ (or: $S = 3/2$)

g-tensor: $g_1 = 2.0029$, $\|[+0.614, +0.558, -0.558]$
$g_2 = 2.0026$, $\|[\ 0.000, +0.707, +0.707]$
$g_3 = 2.0022$, $\|[+0.789, -0.434, +0.434]$

D-tensor: $D_1 = +1652$ MHz, $\|[+0.614, +0.558, -0.558]$
$D_2 = -\ 803$ MHz, $\|[\ 0.000, +0.707, +0.707]$
$D_3 = -\ 849$ MHz, $\|[+0.789, -0.434, +0.434]$
(for $S = 3/2$: $D_1 = +826$ MHz, $D_2 = -402$ MHz, $D_3 = -425$ MHz)

Diamond: natural type Ib, after electron or neutron irradiation, anneals in at 800 ^{0}C, still present after anneal at 1400 ^{0}C

References: 78L2, 83F2, 87W, 94N4

Spectrum W17

Symmetry: triclinic

Spin: $S = 1$ (or: $S = 3/2$)

g-tensor: $g_1 = 2.0033$, ||[+ 0.620, + 0.555, – 0.555]
$g_2 = 2.0025$, ||[+ 0.289, – 0.819, – 0.496]
$g_3 = 2.0018$, ||[+ 0.730, – 0.147, + 0.668]
D-tensor: $D_1 = +1568$ MHz, ||[+ 0.620, + 0.555, – 0.555]
$D_2 = -717$ MHz, ||[+ 0.289, – 0.819, – 0.496]
$D_3 = -851$ MHz, ||[+ 0.730, – 0.147, + 0.668]
(for $S = 3/2$: $D_1 = +784$ MHz, $D_2 = -359$ MHz, $D_3 = -426$ MHz)
Remark: principal directions of **g** and **D**-tensors do not reflect triclinic symmetry
Diamond: natural type Ib, after electron or neutron irradiation, anneals in at 900 ^{0}C, still present after anneal at 1400 ^{0}C
References: 78L2, 83F2, 87W, 94N4

Spectrum W18

Symmetry: monoclinic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $g_1 = 2.0033$, ||[+ 0.617, + 0.556, – 0.556]
$g_2 = 2.0027$, ||[0.000, + 0.707, + 0.707]
$g_3 = 2.0023$, ||[+ 0.787, – 0.436, + 0.436]
D-tensor: $D_1 = +1421$ MHz, ||[+ 0.617, + 0.556, – 0.556]
$D_2 = -666$ MHz, ||[0.000, + 0.707, + 0.707]
$D_3 = -753$ MHz, ||[+ 0.787, – 0.436, + 0.436]
(for $S = 3/2$: $D_1 = +711$MHz, $D_2 = -333$ MHz, $D_3 = -377$ MHz)
Diamond: natural type Ib, after electron or neutron irradiation, anneals in at 900 ^{0}C, still present after anneal at 1400 ^{0}C
References: 78L2, 83F2, 87W, 94N4

Spectrum W19

Symmetry: monoclinic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $g_1 = 2.0028$, ||[+ 0.347, + 0.663, – 0.663]
$g_2 = 2.0031$, ||[0.000, + 0.707, + 0.707]
$g_3 = 2.0029$, ||[+ 0.938, – 0.245, + 0.245]
D-tensor: $D_1 = +941$ MHz, ||[+ 0.347, + 0.663, – 0.663]
$D_2 = -333$ MHz, ||[0.000, + 0.707, + 0.707]
$D_3 = -608$ MHz, ||[+ 0.938, – 0.245, + 0.245]
(for $S = 3/2$: $D_1 = +471$ MHz, $D_2 = -167$ MHz, $D_3 = -304$ MHz)
Diamond: natural type Ib diamond, after electron or neutron irradiation, after anneal at 900 ^{0}C
References: 78L2, 83F2, 94N4

Spectrum W20

Symmetry: monoclinic-I
Spin: $S = 1/2$

g-tensor:	$g_1 = 2.074$, ‖[+ 0.259, + 0.683, – 0.683]
	$g_2 = 2.100$, ‖[0.000, + 0.707, + 0.707]
	$g_3 = 2.018$, ‖[+ 0.966, – 0.183, + 0.183]
Diamond:	natural type Ib, after electron irradiation and aneal at 400 ^{0}C
References:	78L2, 83F2, 94N4

Spectrum W21

Symmetry:	orthorhombic-I
Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.0026$, ‖[0, 1, – 1]
	$g_2 = 2.0090$, ‖[1, 0, 0]
	$g_3 = 2.0044$, ‖[0, 1, 1]
A-tensor:	nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 1 site
	$A_{\|\|} = 117$ MHz, ‖[0, 1, – 1]
	$A_{\perp} = 0$ MHz, ⊥[0, 1, – 1]
A-tensor:	nucleus ^{14}N, 2 sites
	$A_{\|\|} = 20.4$ MHz, ‖[– 0.474, – 0.623, + 0.623]
	$A_{\perp} = 12.6$ MHz, ⊥[– 0.474, – 0.623, + 0.623]
Q-tensor:	nucleus ^{14}N, 2 sites
	$Q_{\|\|} = -$ 3.3 MHz, ‖[– 0.474, – 0.623, + 0.623]
	$Q_{\perp} = +$ 1.65 MHz, ⊥[– 0.474, – 0.623, + 0.623]
Diamond:	natural yellow type Ia
Model:	complex of three substitutional nitrogen atoms coplanar in {011} plane
References:	78L2, 78L4, 82L2, 83F2, 94B, 94W2, 95B1, 99B1, 99B3

Spectrum W22

Symmetry:	monoclinic-I
Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.1096$, ‖[0.000, + 0.707, + 0.707]
	$g_2 = 2.0817$, ‖[+ 0.940, – 0.242, + 0.242]
	$g_3 = 2.0216$, ‖[– 0.342, – 0.664, + 0.664]
Diamond:	natural type Ib
Model:	related to oxygen (tentative)
References:	79L1, 83F2

Spectrum W23

Symmetry:	monoclinic-I
Spin:	$S = 1/2$
g-tensor:	$g_1 = 2.1121$, ‖[0.000, + 0.707, + 0.707]
	$g_2 = 2.0833$, ‖[+ 0.940, – 0.242, + 0.242]
	$g_3 = 2.0197$, ‖[– 0.342, – 0.664, + 0.664]
Diamond:	natural type Ib
Model:	related to oxygen (tentative)
References:	79L1, 83F2

Spectrum W24

Symmetry:	trigonal
Spin:	S = 1/2
g-tensor:	$g_{\|\|}$ = 2.0025, ||[1, 1, 1]
	$g_{\perp}$ = 2.0025, ⊥[1, 1, 1]
A-tensor:	nucleus ^{14}N, spin I = 1, abundance 99.63%, 2 sites
	$A_{\|\|}$ = 155.26 MHz, ||[1, 1, 1]
	$A_{\perp}$ = 81.51 MHz, ⊥[1, 1, 1]
Q-tensor:	$Q_{\|\|}$ = − 1.497 MHz, ||[1, 1, 1]
	$Q_{\perp}$ = + 0.748 MHz, ⊥[1, 1, 1]
A-tensor:	nucleus ^{13}C, spin I = 1/2, abundance 1.1%, 6 sites
	$(A_1 + A_2 + A_3)/3$ = 12.3 MHz
Diamond:	natural yellow type Ia
Remarks:	hyperfine interaction with ^{15}N and ^{14}N ENDOR in Ref. 94T1
Model:	complex of two equivalent nitrogen atoms on nearest-neighbor substitutional sites, positively charged
References:	79W, 81W, 83F2, 83W, 88H1, 91N2, 93K, 94B, 94T1, 94T2, 95B1, 95W3, 96B

Spectrum W25

Symmetry:	monoclinic-I
Spin:	S = 1
g-tensor:	$(g_1 + g_2 + g_3)/3$ = 2.0027
D-tensor:	D_{zz} = − 2732 MHz, ||[0, 1, 1]
	D_{xx} = + 1606 MHz, ||[− 1, − 1, 1]
A-tensor:	nucleus ^{14}N, spin I = 1, abundance 99.63%
	$A_{\|\|}$ = 29.4 MHz, ||[− 0.669, − 0.525, + 0.525]
	$A_{\perp}$ = 20.6 MHz, ⊥[− 0.669, − 0.525, + 0.525]
Q-tensor:	$Q_{\|\|}$ = − 3.0 MHz, ||[− 0.559, − 0.586, + 0.586]
	$Q_{\perp}$ = + 1.5 MHz, ⊥[− 0.559, − 0.586, + 0.586]
Diamond:	natural (green) type Ia, after irradiation and anneal to 550...750 ^{0}C
Remark:	resonance observed in excited state (*) populated by illumination ($\lambda \leq$ 500 nm ≈ ZPL of H4 optical center)
Model:	complex of four substitutional nitrogen atoms around divacancy in excited state: {[$(N_s)_3$]VV[$(N_s)(C_s)_2$]}*
References:	80W, 81L, 83F2, 88H1, 94B, 95B1, 95W2, 96B

Spectrum W26

Symmetry:	orthorhombic-I
Spin:	S = 1
g-tensor:	$(g_1 + g_2 + g_3)/3$ = 2.0027
D-tensor:	D_{zz} = − 2630 MHz, ||[0, 1, 1]
	D_{xx} = + 1428 MHz, ||[0, − 1, 1]
A-tensor:	nucleus ^{14}N, spin I = 1, abundance 99.63%, 2 sites
	$A_{\|\|}$ = 21.5 MHz, ||[− 0.423, − 0.641, + 0.641]
	$A_{\perp}$ = 10.2 MHz, ⊥[− 0.423, − 0.641, + 0.641]

Q-tensor: $Q_{\|} = -$ 3.2 MHz, ||[– 0.423, – 0.641, + 0.641]
$Q_{\perp} = +$ 1.6MHz, ⊥[– 0.423, – 0.641, + 0.641]
Diamond: natural (green) type Ia, after irradiation and anneal to 550...750 ^{0}C
Remark: resonance observed in excited state (*) populated by illumination ($\lambda \leq 500$ nm ≈ ZPL of H3 optical center)
Model: complex of two equivalent substitutional nitrogen atoms around vacancy in excited state: $(N_S V N_S)^*$
References: 80W, 81L, 83F2, 88H1, 94B, 95B1, 95W2, 96B

Spectrum W27

Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0025$
D-tensor: $D_{\|} = +$ 1794 MHz, ||[+ 0.208, + 0.692, + 0.692]
$D_{\perp} = -$ 897 MHz, ⊥[+ 0.208, + 0.692, + 0.692]
A-tensor: nucleus ^{14}N, spin $I = 1$, abundance 99.63%
$(A_1 + A_2 + A_3)/3 \approx 34$ MHz
Diamond: natural (green) type Ia
Model: cluster of (two) nitrogen atoms
References: 80W, 83F2, 94B, 95B1

Spectrum W28

Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0020$
D-tensor: $D_1 = -$ 662 MHz, ||[+ 0.707, – 0.707, + 0.000]
$D_2 = -$ 376 MHz, ||[+ 0.074, + 0.074, – 0.995]
$D_3 = +$ 1038 MHz, ||[+ 0.703, + 0.703, + 0.105]
Diamond: natural (green) type Ia
Model: cluster of nitrogen atoms
References: 80W, 81L, 83F2, 87W, 94W3, 94B, 95B1

Spectrum W29

Symmetry: monoclinic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $g_1 = 2.002$, ||[0.000, – 0.707, + 0.707]
$g_2 = 2.005$, ||[+ 0.623, – 0.553, – 0.553]
$g_3 = 1.997$, ||[+ 0.783, + 0.440, + 0.440]
D-tensor: $D_1 = -$ 596 MHz, ||[0.000, – 0.707, + 0.707]
$D_2 = +$ 907 MHz, ||[+ 0.623, – 0.553, – 0.553]
$D_3 = -$ 311 MHz, ||[+ 0.783, + 0.440, + 0.440]
(for $S = 3/2$: $D_1 = -$ 298 MHz, $D_2 = +$ 454 MHz, $D_3 = -$ 156 MHz)
Diamond: natural type I, after neutron or electron irradiation, anneals in above 500 ^{0}C, anneals out above 800 ^{0}C
References: 83F2, 86L, 87W, 88L1, 94N4, 99K3

Spectrum W30

Symmetry:	trigonal
Spin:	$S = 1/2$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.00$
A-tensor:	nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
	$A_{\|\|} = 137$ MHz, $\|\|[1, 1, 1]$
	$A_{\perp} = 62$ MHz, $\perp[1, 1, 1]$
A-tensor:	nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
	$A_{\|\|} = 12$ MHz, $\|\|[1, 1, 1]$
	$A_{\perp} = 6$ MHz, $\perp[1, 1, 1]$
Diamond:	natural type Ia, after irradiation and anneal to 400 ^{0}C, still present after anneal at 800 ^{0}C
Model:	complex of two pairs of equivalent nitrogen atoms along one <1, 1, 1> axis
References:	81L, 83F2, 88L1, 94B, 94W3, 95B1

Spectrum W31

Symmetry:	trigonal
Spin:	$S = 1/2$
g-tensor:	$g_{\|\|} = 2.0020$, $\|\|[1, 1, 1]$
	$g_{\perp} = 2.0025$, $\perp[1, 1, 1]$
A-tensor:	nucleus ^{33}S, spin $I = 3/2$, abundance 0.75%, 1 site
	$A_{\|\|} = 1029$ MHz, $\|\|[1, 1, 1]$
	$A_{\perp} = 1034$ MHz, $\perp[1, 1, 1]$
A-tensor:	nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 4 sites
	$A_{\|\|} = 70.6$ MHz, $\|\|[+0.485, +0.618, +0.618]$
	$A_{\perp} = 45.1$ MHz, $\perp[+0.485, +0.618, +0.618]$
A-tensor:	nucleus ^{13}C, 6 sites
	$A_{\|\|} = 14.9$ MHz, $\|\|[1, 1, 1]$
	$A_{\perp} = 9.8$ MHz, $\perp[1, 1, 1]$
A-tensor:	nucleus ^{13}C, 12 sites
	$(A_1 + A_2 + A_3)/3 = 4.8$ MHz
Diamond:	natural type Ib, after heating to above 300 ^{0}C in dark
Model:	ionized interstitial sulphur impurity: $(S_i)^+$
References:	82W1, 83F2, 85W, 86W1, 86W2, 92B, 92W3, 94B, 02B

Spectrum W32

Symmetry:	trigonal
Spin:	$S = 1$
g-tensor:	$(g_1 + g_2 + g_3)/3 = 2.002$
D-tensor:	$D_{\|\|} = +136.4$ MHz, $\|\|[1, 1, 1]$
	$D_{\perp} = -68.2$ MHz, $\perp[1, 1, 1]$
Diamond:	natural type IIb, p-type semiconducting, still present after anneal at 1000 ^{0}C
Model:	native center
References:	83F2, 83L1, 87L1, 87L2, 01B, 02B

Spectrum W33

Symmetry: monoclinic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.003$
D-tensor: $D_1 = -1175$ MHz, $\|[0.000, -0.707, +0.707]$
$D_2 = +1857$ MHz, $\|[+0.515, -0.606, -0.606]$
$D_3 = -682$ MHz, $\|[+0.857, +0.364, +0.364]$
(for $S = 3/2$: $D_1 = -588$ MHz, $D_2 = +929$ MHz, $D_3 = -341$ MHz)
Diamond: natural and synthetic type Ib, after neutron irradiation, anneals in at 700 ^{0}C, anneals out at 1100 ^{0}C
References: 87W, 88L1, 94N4, 00N2

Spectrum W34

Symmetry: monoclinic-I
Spin: $S = 1$ (or: $S = 3/2$)
g-tensor: $(g_1 + g_2 + g_3) = 2.002$
D-tensor: $D_1 = -240$ MHz, $\|[0.000, -0.707, +0.707]$
$D_2 = +766$ MHz, $\|[+0.751, -0.467, -0.467]$
$D_3 = -526$ MHz, $\|[+0.660, +0.531, +0.531]$
(for $S = 3/2$: $D_1 = -120$ MHz, $D_2 = +383$ MHz, $D_3 = -263$ MHz)
Diamond: natural and synthetic type Ib, after irradiation, anneals in at 800 ^{0}C, anneals out at 1100 ^{0}C
References: 87W, 88L1, 94N4

Spectrum W35

Symmetry: orthorhombic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 1.998$
D-tensor: $T = 293$ K: $D_1 = +202.2$ MHz, $D_2 = -36.0$ MHz, $D_3 = -166.3$ MHz
$T = 130$ K: $D_1 = +207.8$ MHz, $\|[0, -1, 1]$; $D_2 = -34.0$ MHz, $\perp[0, -1, 1]$; $D_3 = -173.8$ MHz, $\perp[0, -1, 1]$
Diamond: natural brown type IIa
Model: native center
References: 87L1, 87L2

Spectrum W36

Symmetry: trigonal
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.002$
D-tensor: $D_{\|} = +103.4$ MHz, $\|[1, 1, 1]$
$D_{\perp} = -51.7$ MHz, $\perp[1, 1, 1]$
A-tensor: nucleus ^{11}B, spin $I = 3/2$, $g_n = -1.79$
$A_{\|} = 8.7$ MHz, $\|[1, 1, 1]$
$A_{\perp} = 6.0$ MHz, $\perp[1, 1, 1]$

Q-tensor: nucleus ^{11}B
$Q_{\|} = -3.6$ MHz
$Q_{\perp} = +1.8$ MHz
Diamond: natural type IIb, p-type semiconducting
Model: native boron-related center, copper-related center
References: 87L1, 87L2, 94B, 01B, 02B

Spectrum W38
Symmetry: isotropic
Spin: $S = 1/2$
g-tensor: $(g_1 + g_2 + g_3)/3 \approx 2.0027$
Diamond: type Ib
Remark: bahaviour similar to interstitial sulphur (W31)
Model: singly ionized oxygen
Reference: 92W3

Spectrum W40
Symmetry: orthorhombic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0026$
D-tensor: $D_{xx} = -1602$ MHz, $\|[1, -1, 0]$
$D_{yy} = -1522$ MHz, $\|[0, 0, -1]$
$D_{zz} = +3124$ MHz, $\|[1, 1, 0]$
Diamond: natural type IaB, after electron irradiation and anneal at 1500 ^{0}C
Model: similarities with W26
Reference: 94W3

Spectrum W41
Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0026$
D-tensor: $D_{xx} = -693$ MHz, $\|[+0.707, -0.707, 0.000]$
$D_{yy} = -771$ MHz, $\|[+0.624, +0.624, -0.469]$
$D_{zz} = +1464$ MHz, $\|[+0.332, +0.332, +0.883]$
Diamond: natural type IaB, after electron irradiation and anneal at 1500 ^{0}C
Reference: 94W3

Spectrum W42
Symmetry: monoclinic-I
Spin: $S = 1$
g-tensor: $(g_1 + g_2 + g_3)/3 = 2.0026$
D-tensor: $D_{xx} = -430$ MHz, $\|[+0.707, -0.707, 0.000]$
$D_{yy} = -378$ MHz, $\|[+0.081, +0.081, -0.993]$
$D_{zz} = +808$ MHz, $\|[+0.702, +0.702, +0.115]$

Diamond: natural type IaB, after electron irradiation and anneal at 1500 ^{0}C
Model: similarities with W28
Reference: 94W3

Spectrum W44

Symmetry: orthorhombic-I
Spin: $S = 5/2$
g-tensor: $g = 2.0025$, almost isotropic
D-tensor: $D_1 = 62$ MHz, ||[1, 1, 0]
$D_2 = -56$ MHz, ||[1, −1, 0]
$D_3 = -6$ MHz, ||[0, 0, 1]
Diamond: natural, type Ia
Model: transition metal in $3d^5$ configuration
References: 02B

Spectrum Mu

Symmetry: isotropic
Spin: $S = 1/2$
g-tensor: $g = -2.0034$
A-tensor: positive muon μ^+, spin $I = 1/2$, 1 site
$A = 3711$MHz
Diamond: natural type Ia, IIa
Model: normal muonium, tetrahedral interstitial site
References: 82H, 88O2

Spectrum Mu*

Symmetry: axial, ||[1, 1, 1]
Spin: $S = 1/2$
g-tensor: $g = -1.9932$
A-tensor: positive muon μ^+, spin $I = 1/2$, 1 site
$A_{||} = +167.5$ MHz, ||[1, 1, 1]
$A_\perp = -392.0$ MHz, ⊥[1, 1, 1]
A-tensor: nucleus ^{13}C, spin $I = 1/2$, abundance 99%, 2 sites
$A_{||} = 218$ MHz, ||[1, 1, 1]
$A_\perp = 80$ MHz, ⊥[1, 1, 1]
Diamond: synthetic, ^{13}C enriched to 99%
Model: anomalous muonium, bond-centered site
References: 82H, 87S, 88O2, 93S

Spectrum β

Diamond: type IaA and synthetic Ib, after neutron irradiation, anneals in at ≈500 ^{0}C, anneals out at ≈ 800 ^{0}C
Remarks: no further details given
Reference: 89N1

Spectrum CL1

Symmetry:	axial, ‖[1, 1, 1]
Spin:	$S = 1/2$
g-tensor:	$g \approx 2.0028$
A-tensor:	(probably) nucleus ^{14}N, spin $I = 1$, abundance 99.63%
	$A_{\parallel} = 124$ MHz, ‖[1, 1, 1]
	$A_{\perp} = 104$ MHz, ⊥[1, 1, 1]
Diamond:	natural, champagne colored, Argyle
Remarks:	only one center orientation observed
Reference:	93H5

Spectrum KI1

g-tensor:	$g_{eff} = 3.0...3.4$
Diamond:	synthetic powder
Model:	ferromagnetic inclusions
Remark:	g-values similar to G1
Reference:	95B2

Spectrum MA1 (Fig. 19)

Symmetry:	axial
Spin:	$S = 1/2$
g-tensor:	$g = 2.0025$
A-tensor:	nucleus ^{31}P, spin $I = 1/2$, abundance 100%
	$A_{\parallel} = 65$ MHz
	$A_{\perp} = 55$ MHz
Diamond:	synthetic crystalline diamond powder, phosphorus doped
Model:	phosphorus impurity, either isolated or in impurity complex
Remarks:	related spectra BI1 (Ref. 94Z3) and NIRIM-8 (Ref. 97I1)
References:	91S1, 91S2, 94Z3, 97I1, 02G1

Spectrum BI1

Symmetry:	isotropic
Spin:	$S = 1/2$
g-tensor:	$g = 2.0023$
A-tensor:	nucleus ^{31}P, spin $I = 1/2$, abundance 100%
	$A = 75$ MHz
Diamond:	CVD grown film, phosphorus implanted during deposition
Model:	substitutional phosphorus impurity
Remarks:	related spectra MA1 (Refs. 91S1, 91S2) and NIRIM-8 (Ref. 97I1)
Reference:	91S1, 91S2, 94Z3, 97I1, 00C2, 01C1

Spectrum AM1

Symmetry:	orthorhombic-I
Spin:	$S = 1$
g-tensor:	$g = 2.00$
D-tensor:	$D_1 = +616$ MHz, $\|\|[0, 1, 1]$
	$D_2 = -110$ MHz, $\|\|[1, 0, 0]$
	$D_3 = -506$ MHz, $\|\|[0, 1, -1]$
Diamond:	natural, brown
Remark:	photo-excited triplet state, observed by ODMR on 2.818 eV zero-phonon emission
Model:	oxygen related (tentative)
References:	92H2, 92W2

Spectrum $V^0(^5A_2)$

Symmetry:	cubic
Spin:	$S = 2$
g-tensor:	$g = 2.0033$
A-tensor:	nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 4 nearest-neighbor sites
	$A_{\|\|} = 91.13$ MHz, $\|\|[1, 1, 1]$
	$A_\perp = 35.03$ MHz, $\perp[1, 1, 1]$
A-tensor:	nucleus ^{13}C, spin $I = 1/2$, abundance 1.1%, 12 next-nearest-neighbor sites
	$A_{\|\|} = 12.01$ MHz, $\|\|[1, 1, 1]$
	$A_\perp = 8.36$ MHz, $\perp[1, 1, 1]$
Diamond:	natural, type IaB
Remarks:	4^{th}-order spin-Hamiltonian parameter $a < 1$ MHz, ^{13}C hyperfine parameters measured by ENDOR
Model:	neutral vacancy, pointgroup symmetry $\bar{4}$ 3m, in photo-excited state $^5A_2$
References:	95T1, 95W1, 96T7, 97T2

Spectrum H2(ht)

Symmetry:	orthorhombic-I
Spin:	$S = 1/2$
g-tensor:	$g = 2.00252$
A-tensor:	nucleus ^{14}N, spin $I = 1$, abundance 99.63%, 2 sites
	$A_{\|\|} = 16.8$ MHz, $\|\|[1, 1, 1]$
	$A_\perp = 3.6$ MHz, $\perp[1, 1, 1]$
Diamond:	synthetic Ib, neutron irradiated, annealed at 1700 ^0C
Remarks:	related to and named after H2 optical center (Ref. 56C), observed after heat treatment, different from H2(H) hydrogen-related spectrum
Model:	negative NVN center
References:	56C, 93M3, 93N3, 94B, 94D, 94N4

Spectrum H1(H) (Figs. 20, 21)

Spin:	$S = 1/2$
g-tensor:	$g = 2.0028$
A-tensor:	nucleus ^{1}H, spin $I = 1/2$, abundance ≈ 100%
	$A_{\parallel} = 27.5$ MHz
	$A_{\perp} = -5.5$ MHz
Diamond:	polycrystalline, grown by chemical vapor deposition (CVD)
Remarks:	hydrogen identified by (forbidden $\Delta m_I = \pm 1$) electron-proton spin-flip transitions, ^{1}H ENDOR observed (Ref. 98T1) on $g = 2.0028$ resonance: matrix ENDOR not related to unique H atom of H1(H) magnetic resonance center; not related to H1 optical spectrum
Model:	hydrogen on dangling carbon bond, axial ‖[1, 1, 1], inside a vacancy, decoration of grain boundary, or in intergranular material
References:	93C, 93J, 93N1, 94H1, 95Z, 96K1, 96Z, 98M, 98T1, 99R, 00K2, 01W2

Spectrum H2(H)

Spin:	$S = 1/2$
g-tensor:	$g = 2.0028$
A-tensor:	nucleus ^{1}H, spin $I = 1/2$, abundance ≈ 100%
	$A_{\parallel} = 17.9$ MHz
	$A_{\perp} = -2.7$ MHz
Diamond:	polycrystalline, grown by chemical vapor deposition (CVD)
Remarks:	not related to H2 optical (heat-treatment) center
Model:	hydrogen on dangling carbon bond, axial ‖[1, 1, 1], in distorted region, on grain boundary or in intergranular material
References:	95Z, 96Z, 98M, 98T1

Spectrum GRE1

Symmetry:	isotropic
Spin:	$S = 1/2$
g-tensor:	$g = 1.9990...2.0007$
Diamond:	polycrystalline, grown by chemical vapor deposition (CVD), boron implanted
Model:	holes in impurity band
Reference:	95G1, 97C

4.1.3.3 *g*-values and linewidths of paramagnetic centers in CVD diamond

Paramagnetic centers in polycrystalline diamond grown by chemical vapor deposition (CVD). Resonances are generally interpreted as arising from dangling bonds on carbon atoms, from unsaturated bonds on grain boundaries or in intergranular (diamond-like or non-diamond) material. Further spectra observed in CVD films: GRE1, H1(H), H2(H), and P1 in averaged form (Refs. 91H, 91K, 93C, 94J, 94L2, 96G1, 96G2, 96K1, 96R1, 96V, 97G2, 97T1). The similar spectra TI1/N5 with isotropic g = 2.0027 are due to mechanical damage.

g-value	Linewidth [mT]	Reference
2.0015	2.3	96V
2.0019	0.5	92F
2.002	0.25...0.28	91K
2.002	1.3...1.4	91K
2.0024	0.19...0.33	93F3
2.0025	0.9	95P
2.0026	0.25	96C
2.0026	0.35	96V
2.0026	1.1	96V
2.0026	0.25	97C
2.0027	0.3...0.6	88W2
2.0027	0.36	92Z
2.0027	0.2...0.3	94J
2.0027		96K1
2.0027	0.25...0.4	96K2
2.0027		96R2
2.0027	broad	97W2
2.0028		91B
2.0028	0.4	92F
2.0028	0.3...0.5	93F1
2.0028	0.35...0.5	93F2
2.0028	0.24	93J
2.0028	0.76	93J
2.0028	0.35...0.45	94F
2.0028		94T3
2.0028		95T2
2.0028		95Z
2.0028	0.4	96R1
2.0028	0.18...0.26	96T2
2.0028	0.6...0.75	96T2
2.0028		96T4, 98T2
2.0028		97T1
2.0028		97T3
2.0028	0.22	98T1

g-value	Linewidth [mT]	Reference
2.0029	0.3	94G
2.0029	0.4	94L2
2.0029	0.8	96C
2.0029	0.4	96G1
2.0029	0.4	96G2
2.0029	0.8	97C
2.0029	0.4	97G2
2.0029	narrow	97W2
2.0030	0.3...0.4	95G1
2.003	0.3	96I
2.003	0.3	97S1, 97S2, 97S3, 96S1, 96S2, 00S1
2.0033		91B
2.0033	0.17...0.35	97F
2.0035	0.8	94G
2.0035	0.7...1.4	95R
2.0035		96T4, 98T2
2.0035		97T3
2.0036		97W2
2.0040		95T2

Figures for 4.1.3

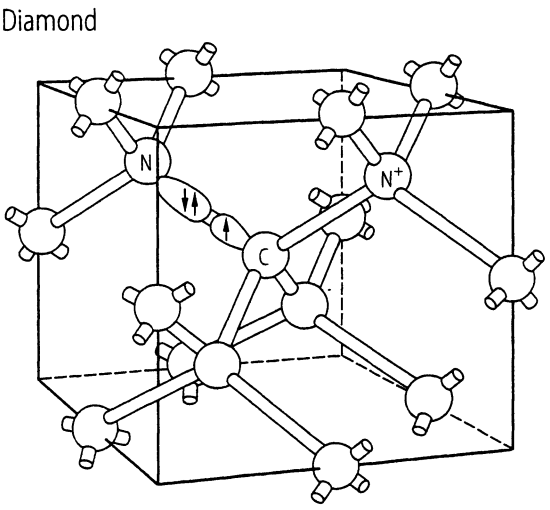

Fig. 1. Diamond. Atomic structure model for the N1 center. After Cox, et al. [92C1].

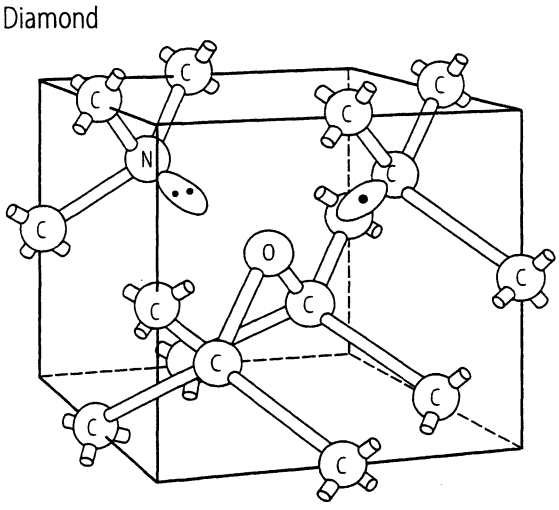

Fig. 2. Diamond. Atomic structure model for the N3 center. After van Wyk, et al. [92W1].

Diamond

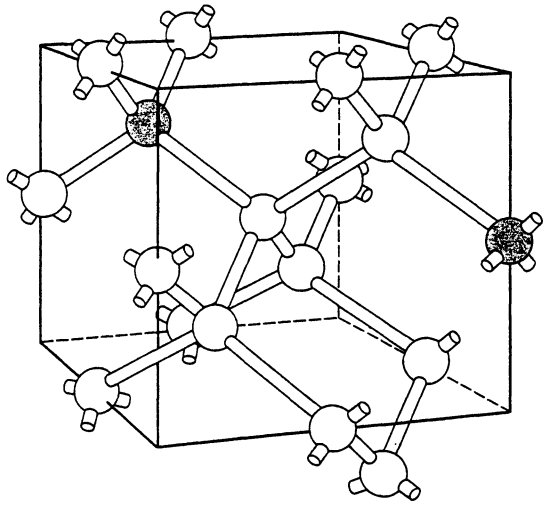

Fig. 3. Diamond. Atomic structure models for the dinitrogen centers N4. After Baker and Newton [95B1].

Diamond

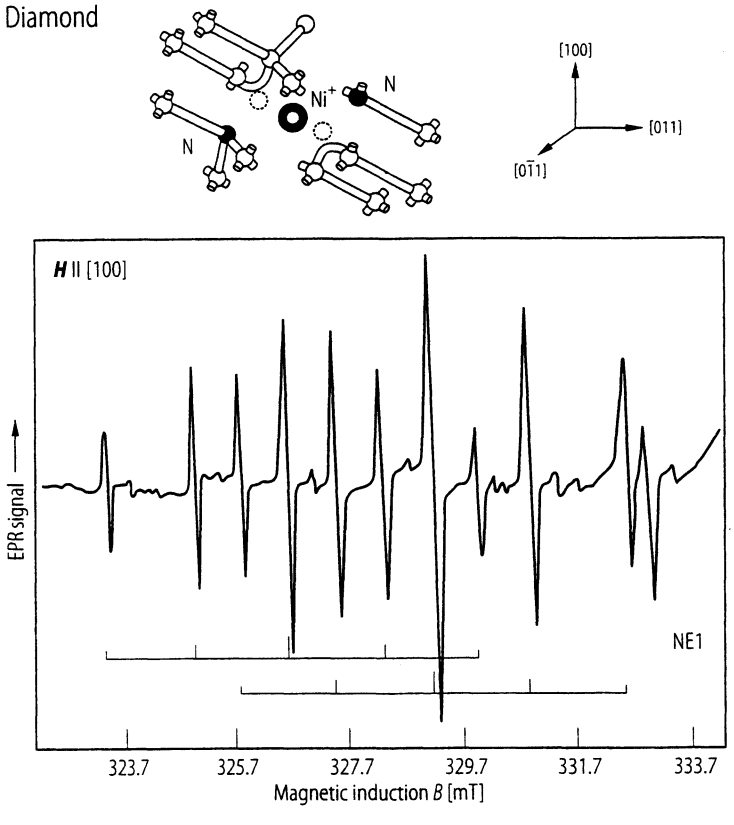

Fig. 4. Diamond. EPR spectrum and atomic structure model for the NE1 center. Hyperfine structure due to nitrogen atom pair indicated by bar diagrams. After Nadolinny, et al. [97N].

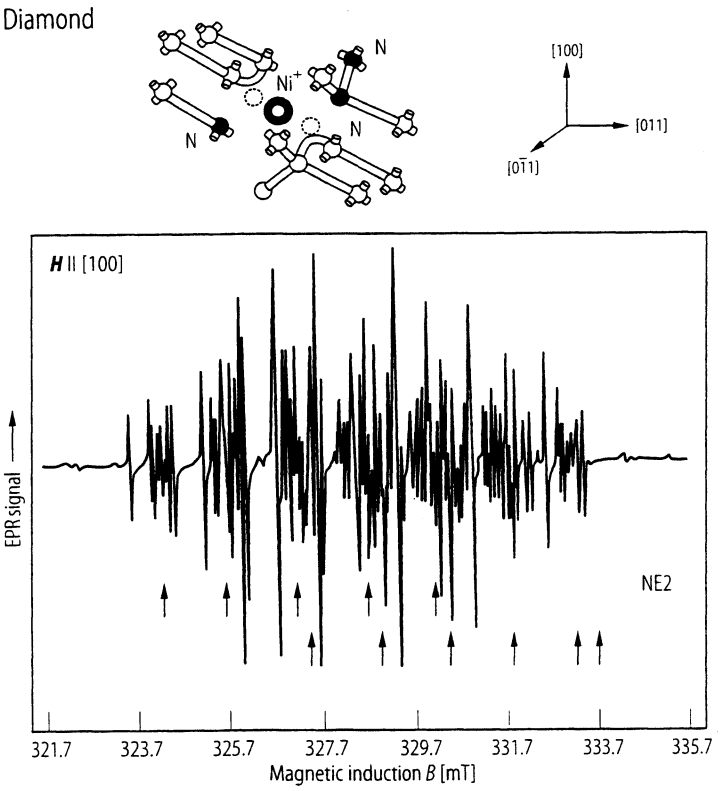

Fig. 5. Diamond. EPR spectrum and atomic structure model for the NE2 center. Hyperfine structure due to nitrogen atoms indicated by arrows. After Nadolinny, et al. [97N].

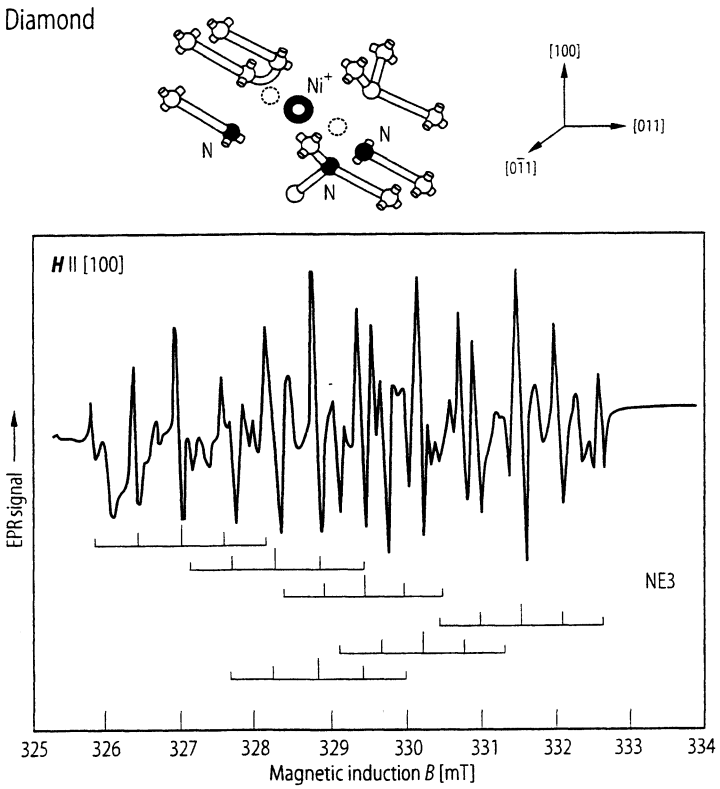

Fig. 6. Diamond. EPR spectrum and atomic structure model for the NE3 center. Hyperfine structure due to nitrogen atoms indicated by bar diagrams. After Nadolinny, et al. [97N].

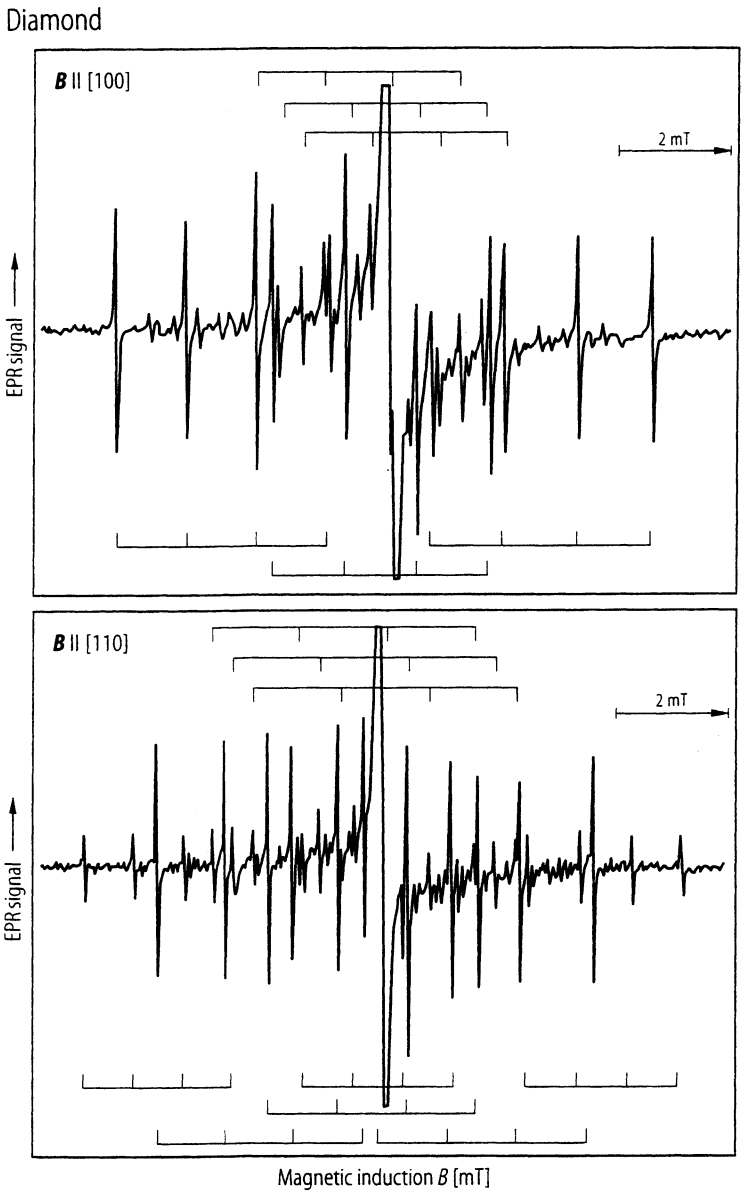

Fig. 7. Diamond. EPR spectrum NIRIM-4 showing quartet hyperfine structure due to ^{11}B (nuclear spin $I = 3/2$) indicated by bar diagrams. After Isoya, et al. [97I2].

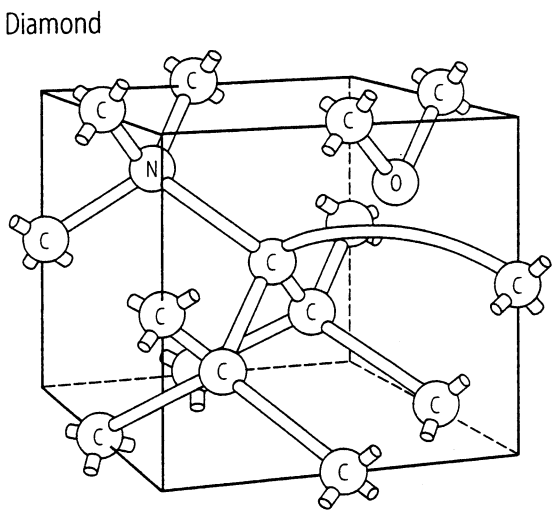

Fig. 8. Diamond. Atomic structure model for the OK1 center. After Newton and Baker [89N2].

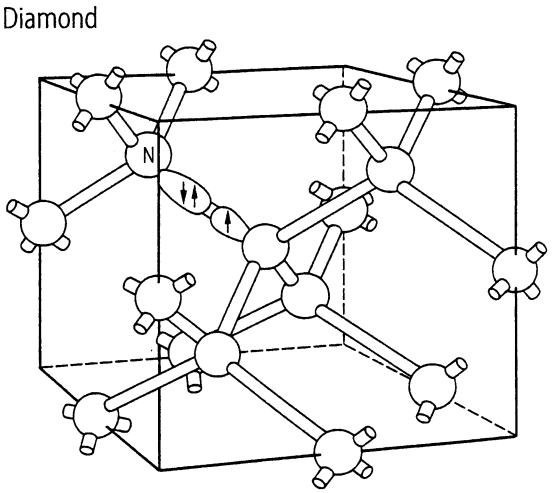

Fig. 9. Diamond. Atomic structure model for the P1 center. After Newton and Baker [89N2].

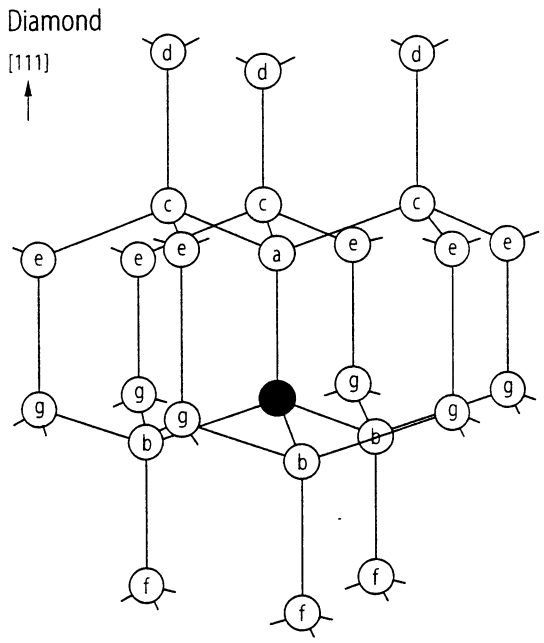

Fig. 10. Diamond. Carbon atom sites around the single substitutional nitrogen atom (filled circle) in the P1 center. The labelling a...g of shells of carbon sites correspond to the ^{13}C hyperfine interactions as given for spectrum P1. After Cox, et al. [94C].

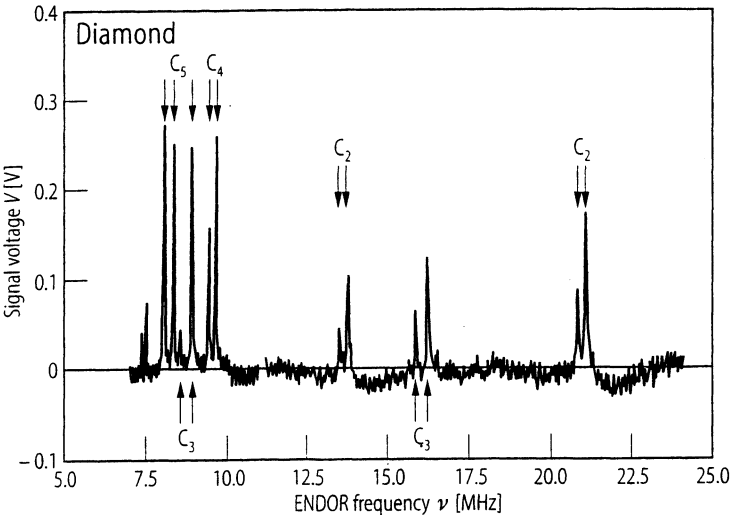

Fig. 11. Diamond. Low-frequency part of the ^{13}C ENDOR spectrum of substitutional nitrogen (EPR spectrum P1). Shells of carbon atom sites are indicated. After Cox, et al. [94C].

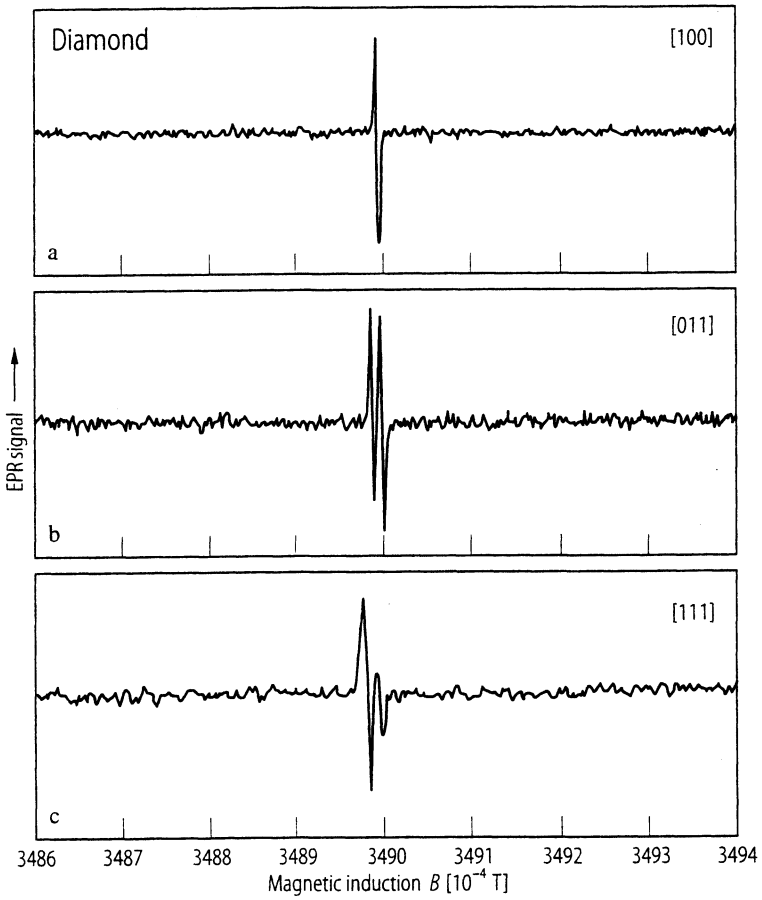

Fig. 12. Diamond. High-resolution EPR spectrum P1. Central part of the spectrum (m_I = 0) showing resolved fine structure revealing trigonal symmetry. After Zhang, et al. [94Z1].

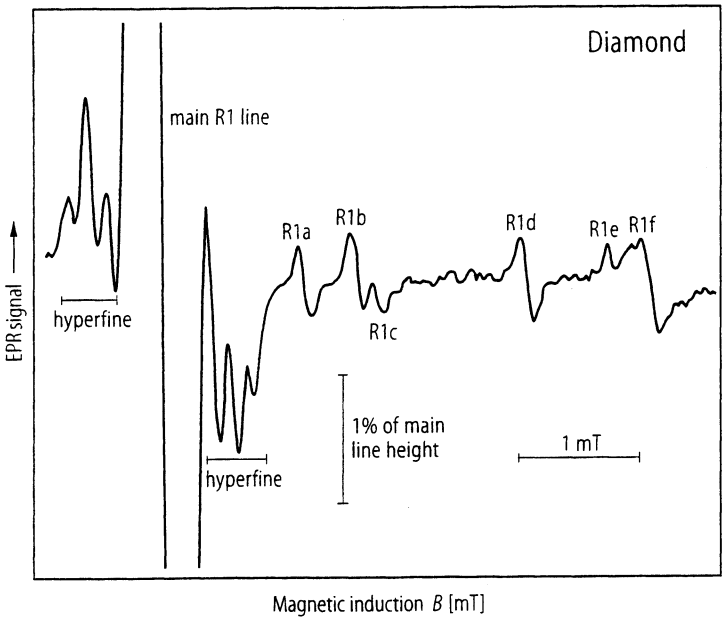

Fig. 13. Diamond. Features in the EPR spectrum R1 revealing existence of species R1a to R1f. After Lea-Wilson and Lomer [96L1].

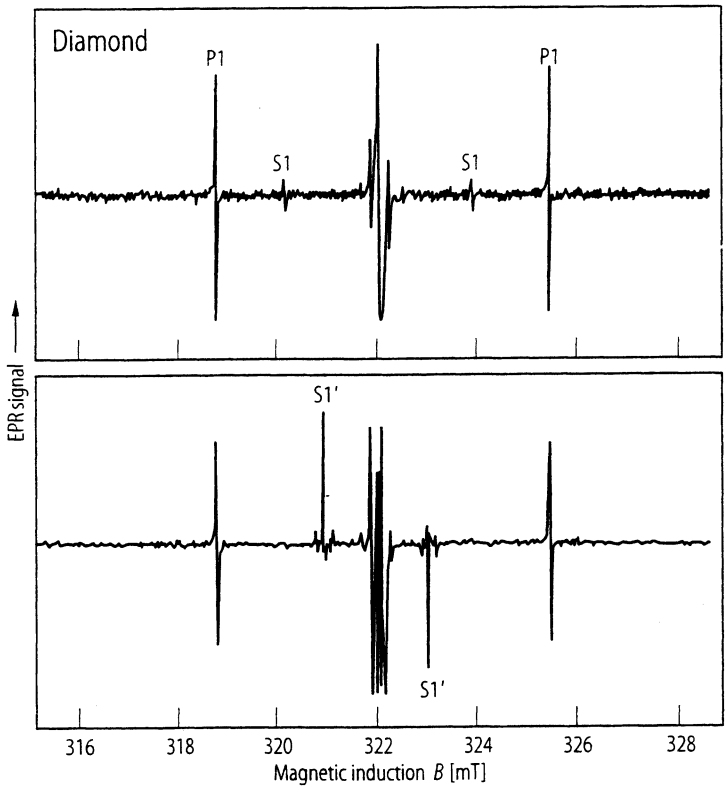

Fig. 14. Diamond. EPR spectrum S1* related to the negatively charged lattice vacancy in excited state, generated by illumination (bottom part of figure). After van Wyk and Woods [93W2].

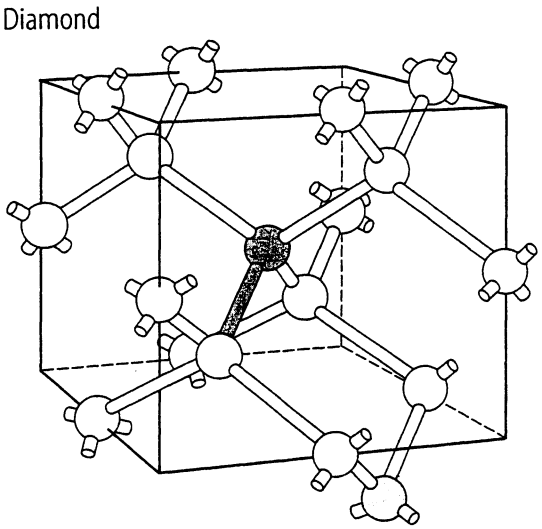

Fig. 15. Diamond. Atomic structure model for the di-nitrogen center W7. After Baker and Newton [95B1].

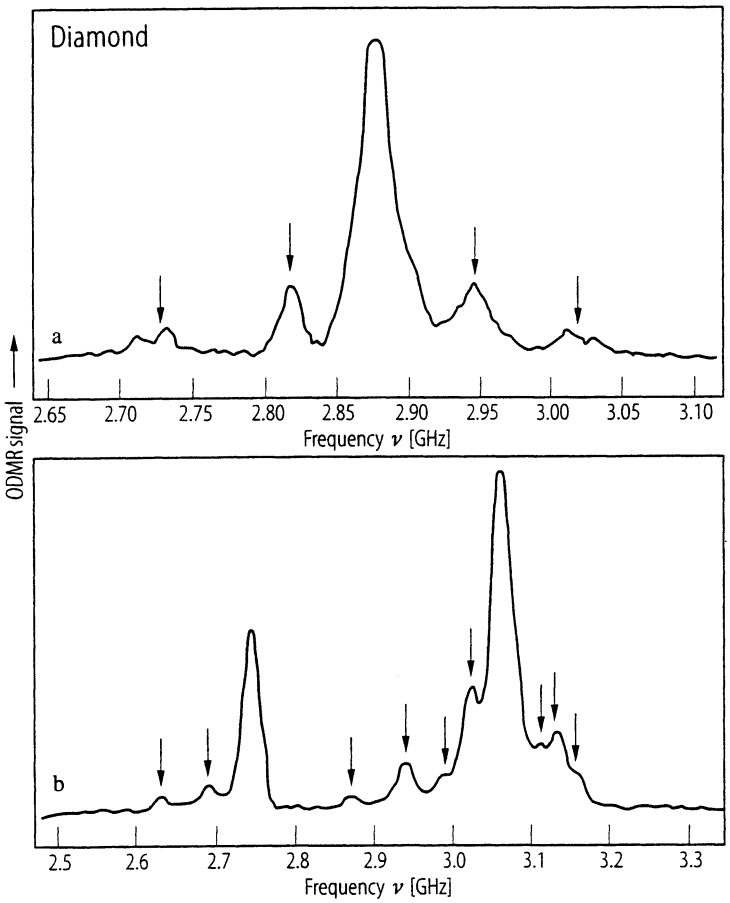

Fig. 16. Diamond. Optically detected magnetic resonance (ODMR) spectrum of the nitrogen-vacancy center (W15) at (**a**) zero magnetic field and (**b**) at B = 10 mT. Arrows indicate side-band structures due to interactions of W15 with the P1 center. After van Oort, et al. [90O3].

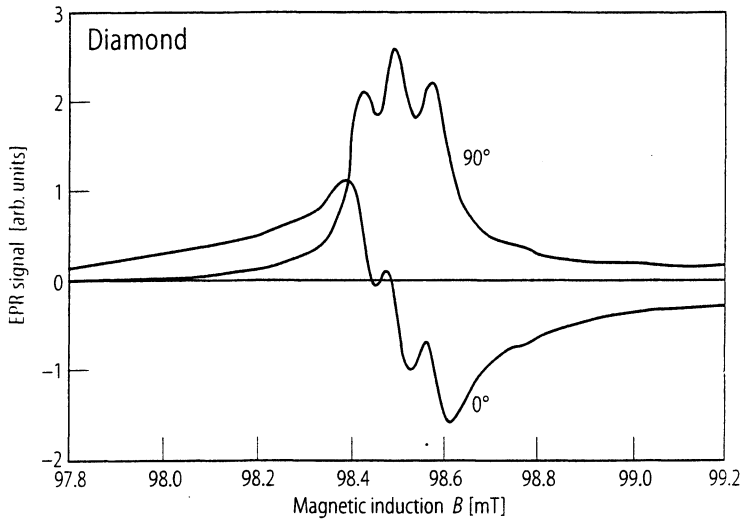

Fig. 17. Diamond. Raman heterodyne detected EPR in the triplet ground state of the nitrogen-vacancy center (W15), in-phase (0°) or out-of-phase (90°). After Holliday, et al. [90H].

For Fig. 18 see next page

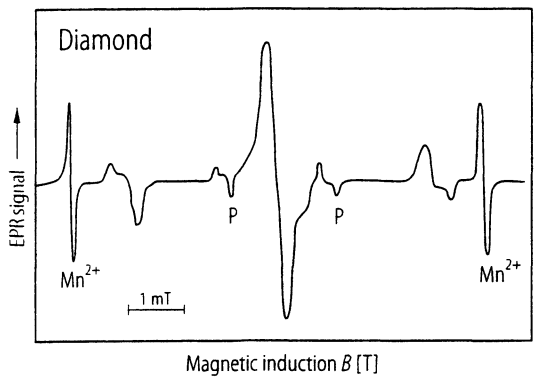

Fig. 19. Diamond. EPR spectrum MA1 showing doublet hyperfine structure due to ^{31}P (nuclear spin I = ½). After Samsonenko, et al. [91S1].

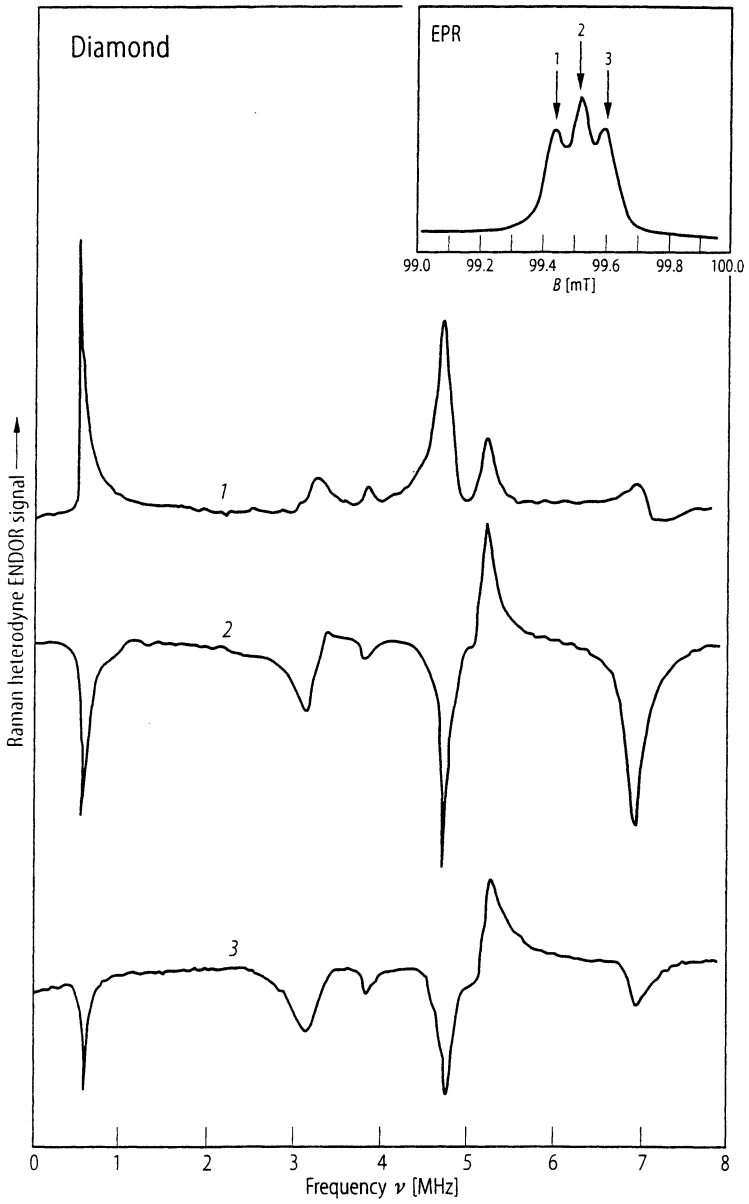

Fig. 18. Diamond. Raman heterodyne detected ENDOR of the nitrogen-vacancy center, EPR spectrum W15. ENDOR is induced on the EPR transitions 1, 2 and 3 as indicated in the inset. After Manson, et al. [92M1].

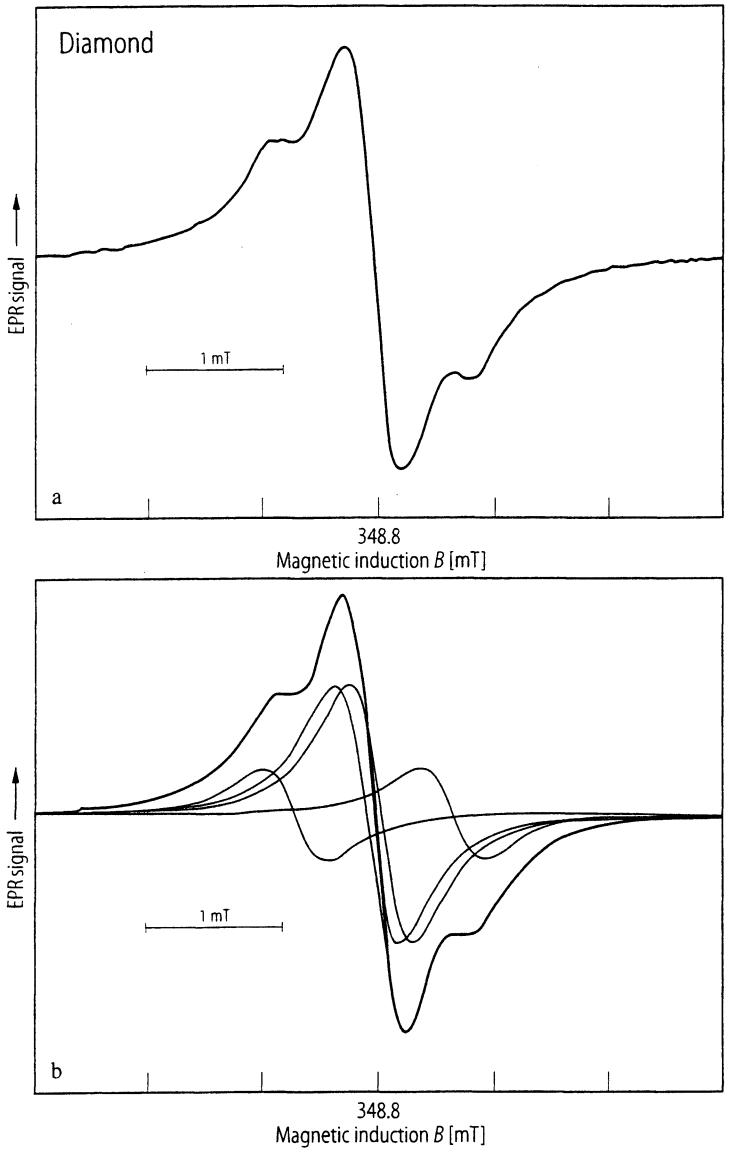

Fig. 20. Diamond. EPR spectrum of H1(H) **(a)** showing its four components as decomposed in **(b)**, **(b)**: center doublet corresponds to the two allowed $\Delta m_I = 0$ transitions, outer components correspond to the two forbidden transitions with $|\Delta m_I| = 1$. After Holder, et al. [94H1].

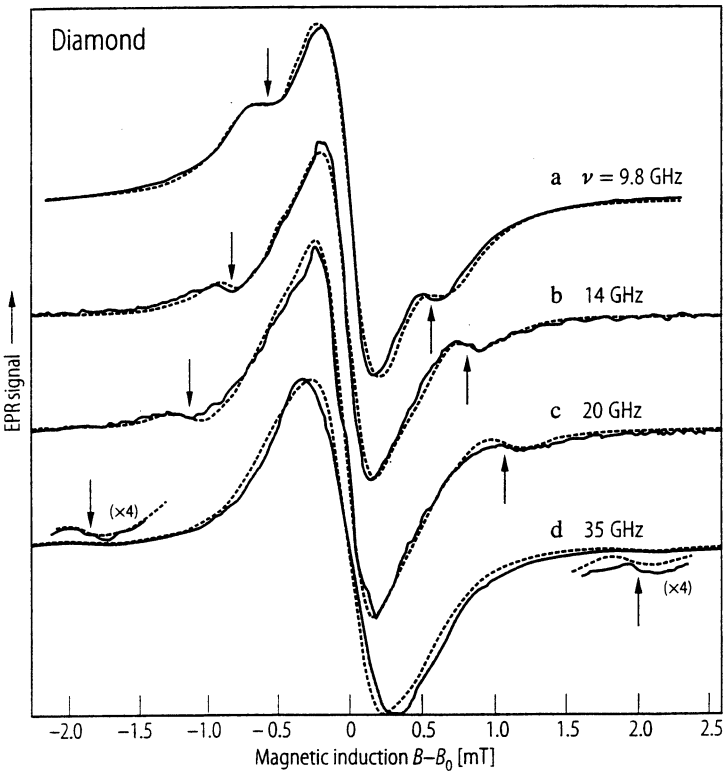

Fig. 21. Diamond. Multifrequency EPR of the H1(H) center. The splitting of the two forbidden transitions $|\Delta m_I| = 1$ (indicated by arrows) increases proportional to the frequency while their intensity decreases. Theoretical fits to the spectrum are shown by dashed lines. After Zhou, et al. [96Z].

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