

Landolt-Börnstein

**Numerical Data and Functional Relationships
in Science and Technology**

**Zahlenwerte und Funktionen
aus Naturwissenschaften und Technik**

New Series / Neue Serie

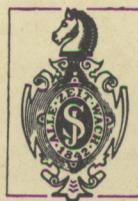
Group III

Volume 17

Semiconductors

Subvolume b

**Physics of II-VI and I-VII Compounds,
Semimagnetic Semiconductors**



Springer-Verlag Berlin · Heidelberg · New York

LANDOLT-BÖRNSTEIN

Zahlenwerte und Funktionen
aus Naturwissenschaften und Technik

Neue Serie

Gesamtherausgabe: K.-H. Hellwege

Gruppe III: Kristall- und Festkörperphysik

Band 17

Halbleiter

Herausgeber: O. Madelung · M. Schulz · H. Weiss †

Teilband b

Physik der II–VI und I–VII-Verbindungen,
semimagnetische Halbleiter

I. Broser · R. Broser · H. Finkenrath · R.R. Gałazka · H.E. Gumlich
A. Hoffmann · J. Kossut · E. Mollwo · H. Nelkowski · G. Nimtz
W. von der Osten · M. Rosenzweig · H.J. Schulz · D. Theis · D. Tschierse

Herausgegeben von O. Madelung



Springer-Verlag Berlin · Heidelberg · New York 1982

CIP-Kurztitelaufnahme der Deutschen Bibliothek

Zahlenwerte und Funktionen aus Naturwissenschaften und Technik/Landolt-Börnstein. – Berlin; Heidelberg; New York:
Springer Paralelt.: Numerical data and functional relationships in science and technology

NE: Landolt, Hans [Begr.]; PT Landolt-Börnstein, ... N.S./Gesamthrg.: K.-H. Hellwege. Gruppe 3, Kristall- und Festkörperphysik. Bd. 17. Halbleiter/Hrsg.: O. Madelung ... Teilbd. b. Physik der II-VI- und I-VII-Verbindungen, semimagnetische Halbleiter/I. Broser ... Hrsg. von O. Madelung. – 1982.

ISBN 3-540-11308-8 (Berlin, Heidelberg, New York)

ISBN 0-387-11308-8 (New York, Heidelberg, Berlin)

NE: Hellwege, Karl-Heinz [Hrsg.]; Madelung, Otfried [Hrsg.]; Broser, Immanuel [Mitverf.]

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Printed in Germany

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Typesetting, printing and bookbinding: Universitätsdruckerei H. Stürtz AG Würzburg

2163/3020 – 543210

Contributors

- I. Broser**, Institut für Festkörperphysik der Technischen Universität, D1000 Berlin
R. Broser, Fritz-Haber-Institut der Max Planck-Gesellschaft, D1000 Berlin
H. Finkenrath, Institut für angewandte Physik der Technischen Hochschule, 6100 Darmstadt, FRG
R.R. Gałazka, Instytut Fizyki Polskiej Akademii Nauk, 02-668 Warszawa, Poland
H.E. Gumlich, Institut für Festkörperphysik III der Technischen Universität, D1000 Berlin
A. Hoffmann, Institut für Festkörperphysik der Technischen Universität, D1000 Berlin
J. Kossut, Instytut Fizyki Polskiej Akademii Nauk, 02-668 Warszawa, Poland
E. Mollwo, 8520 Erlangen, FRG
H. Nelkowski, Institut für Festkörperphysik I der Technischen Universität, D1000 Berlin
G. Nimtz, II. Physikalisches Institut der Universität, 5000 Köln, FRG
W. von der Osten, Fachbereich 6 der Gesamthochschule, 4790 Paderborn, FRG
M. Rosenzweig, Institut für Festkörperphysik der Technischen Universität, D1000 Berlin
H.J. Schulz, Fritz-Haber-Institut der Max Planck-Gesellschaft, D1000 Berlin
D. Theis, Siemens AG, Forschungslabor, 8000 München, FRG
D. Tschierse, Institut für Festkörperphysik III der Technischen Universität, D1000 Berlin

Vorwort

Im Anschluß an die Behandlung der tetraedrisch gebundenen Elemente der IV. Gruppe und der III-V-Verbindungen in Teilband III/17a bringt der vorliegende Band III/17b die physikalischen Eigenschaften der II-VI- und I-VII-Verbindungen. Behandelt werden ferner die semimagnetischen Halbleiter, d.h. Legierungen aus normalen halbleitenden Verbindungen und magnetischen Halbleitern. Weitere Teilbände über Halbleitertechnologie und die physikalischen Eigenschaften anderer Halbleiterfamilien werden folgen.

Der Umfang eines Manuskriptes wächst beim Schreiben. Diese Erfahrung haben alle Autoren gemacht, und so sind ihre Beiträge um das Doppelte bis Zehnfache (!) umfangreicher geworden als bei einer ersten Planung abgeschätzt worden war. Dies hat zur Folge, daß mehr Teilbände erscheinen werden als in der Übersicht in Band 17a angegeben wurde. Der Überblick über den Gesamtinhalt auf der Deckelinnenseite des vorliegenden Teilbandes gibt die neue (und hoffentlich endgültige) Aufteilung des Stoffes auf die Teilbände 17a...17i.

Einige Worte zum Gebrauch dieses Bandes mögen nützlich sein. Für die Organisation des Datenmaterials in den Abschnitten über die einzelnen Substanzen sind verschiedene Wege möglich, wie bei jeder linearen Darstellung eines vielfach-verknüpften Problems. Das hier eingehaltene Schema ist ein Kompromiß zwischen einer nach theoretischen Gesichtspunkten geordneten Einteilung (elektronische Eigenschaften, Gittereigenschaften usw.) und einer nach experimentellen Gebieten geordneten Gliederung (Transporteigenschaften, optische Eigenschaften usw.). Dies mag zur Folge haben, daß der Leser Daten in einem anderen Abschnitt findet als er zunächst erwartet. Ein Gliederungsschema auf der Innenseite des Buchdeckels soll zum schnelleren Auffinden helfen.

Bei der Auswahl der Daten war die Richtschnur, sich nicht nur auf die Halbleitereigenschaften eines Materials zu beschränken, sondern alle die Daten zu bringen, die ein Halbleiterphysiker sucht. Struktureigenschaften oder Information über Phasenübergänge u.dgl. wurden nicht ausgelassen, obwohl sie in anderen Landolt-Börnstein-Bänden ausführlicher dargestellt werden. Sie wurden in einem Rahmen gebracht, wie er von einem Benutzer dieser Bände erwartet werden mag. Für eine Resonanz der Leser zu dieser Frage, ebenso wie für Hinweise und ergänzendes Material wäre ich dankbar.

Ich möchte allen denjenigen meinen Dank ausdrücken, die geholfen haben die Herausgabe dieses Bandes zu einem glücklichen Ende zu führen, den Autoren, die alle Änderungen in ihren Manuskripten hingenommen haben, die für eine einheitliche Darstellung der Daten notwendig waren, den Mitarbeitern der Landolt-Börnstein-Redaktion, insbesondere Herrn Dr. W. Polzin und Frau D. Dolle, deren präzise und engagierte Mitarbeit mir ganz wesentlich geholfen hat und nicht zuletzt dem Springer-Verlag für ein weiteres Beispiel hervorragender Buchherstellung.

Dieser Band wurde wie alle anderen Bände des Landolt-Börnstein ohne finanzielle Hilfe von anderer Seite veröffentlicht.

Marburg, im August 1982

Der Herausgeber

Preface

In continuation of the treatment of the tetrahedrally bonded elements of the IVth group and the III-V compounds in subvolume 17a this subvolume presents the physical properties of the II-VI and I-VII compounds. The volume also contains a chapter on semi-magnetic semiconductors, i.e. on the solid solutions between ordinary semiconducting compounds and magnetic semiconductors. Further subvolumes on semiconductor technology and on the physical properties of other semiconductor families will follow.

The scope of a manuscript grows during the writing. This experience has been made by all authors: their contributions became twice to ten times (!) as large as estimated in an earlier stage of preparation. Consequently, more subvolumes will be published than announced in the list of contents of subvolume 17a. A new – and hopefully final – subdivision of the material on subvolumes 17a...17i is presented on the inside of the front cover of this volume.

A few words about the use of this book may be helpful. The data in the sections for the various substances can be organized in different ways – as can each linear presentation of a multi-connected problem. The organization used here is a compromise between a theoretical one (electronic properties, lattice properties etc.) and a phenomenological one (transport properties, optical properties etc.). Thus the reader may find an item in a section in which he does not expect it at first. The organization scheme printed on the inside of the front cover should help to find the way more easily.

The policy for the selection of the data was not to compile only the semiconductor properties of materials but to present all data a semiconductor physicist is looking for. Thus structural data and information about phase transitions etc. – which can be found more completely in other Landolt-Börnstein volumes – have not been omitted but are presented to such extent as may be expected by a user. A resonance by the users to these questions as well as remarks, hints and additions would be helpful to the editor.

I would like to express my gratitude to all who helped to bring the edition of this volume to a successful end – to the authors, who accepted all changes in their manuscripts necessary to reach a uniform presentation of the material, to the editorial staff of the Landolt-Börnstein office, especially Dr. W. Polzin and Frau D. Dolle whose precise and engaged cooperation was extremely helpful to me, and last but not least to Springer-Verlag for another demonstration of their excellent standard of book production.

As all previous volumes of Landolt-Börnstein, this new one is published without any financial support from other sources.

Marburg, August 1982

The Editor

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A. Introduction

1. List of symbols

In the following list all symbols frequently used in this volume are specified. The references in the last column refer to the introductory part A in subvolume 17a (cited as 17a/followed by the number of the respective section) or to that section of part B of this subvolume where the quantity is defined or introduced the first time (cited as 17b/ followed by the number of the respective section). The units listed in the second-last column are the most frequently used units. In the tables of part B data are generally given in units of the original paper. To facilitate a conversion from CGS units to SI units or vice versa conversion tables are presented in section 3 below.

Symbol	Property	Unit	Introduced in section
a	thermal diffusivity	$\text{cm}^2 \text{s}^{-1}$	17b/3.6
a, b, c	lattice parameters	$\text{\AA}$	
A, B, C	anisotropy parameter of warped energy surfaces	—	17a/2.1.1, eq.(A.6)
b	mobility ratio μ_n/μ_p	—	
$B(B_S, B_T)$	bulk modulus (adiabatic, isothermal)	dyn cm^{-2}	17a/2.1.2, eq.(A.17)
B	Nernst coefficient	$\text{cm}^2 \text{K}^{-1} \text{s}^{-1}$	17a/2.2.1
B	magnetic induction	T, G	
$B_{n(p)}$	capture coefficient for electrons (holes) ($= \sigma_{n(p)} v_{th}$)	$\text{cm}^3 \text{s}^{-1}$	
c_{lm}	elastic moduli (stiffnesses)	dyn cm^{-2}	17a/2.1.2, eq.(A.19)
$c_{lm}^{(E)}$	elastic moduli at constant electric displacement (electric field)	dyn cm^{-2}	
c_{ikl}	third order elastic moduli	dyn cm^{-2}	17a/2.1.2
C	capacity	F	
C_i	deformation potentials	eV	17b/3.7, 3.10
C_p, C_v	heat capacities	$\text{J mol}^{-1} \text{K}^{-1}$	
d	density	g cm^{-3}	
d	thickness (of samples)	cm	
d_{opt}	optical density	—	
d_{ik}	piezoelectric strain coefficients	cm V^{-1}	17a/2.2.1
$D_u(u')$	deformation potentials for [100] and [111] stress, respectively	eV	17a/2.4.1, eq.(A.86/7)
$D_{n(p)}$	diffusion coefficient for electrons (holes)	$\text{cm}^2 \text{s}^{-1}$	
Dq	crystal field splitting parameter	cm^{-1}	17b/3.7
e	elementary charge	C	
$e_{(T)}^*$	(transverse) effective ion charge	e	17a/2.1.2, 17b/3.1
e	polarization vector	—	17a/2.1.2
e_{ik}	strain tensor (6×6) (in literature frequently labeled S_{ij})	—	17a/2.1.2
e_{ik}	piezoelectric stress coefficients	C cm^{-2}	17a/2.2.1, eq.(A.33)
e_k	strain vector (6-component)	—	17a/2.1.2
E	electric field strength	V cm^{-1}	
E	energy	eV	
$E_{0,1,2...}$	energies of critical points in optical spectra	eV	17a/2.1.1
$E(\Gamma_6)...$	energy of band edge of type $\Gamma_6...$	eV	17a/2.4.1
$E_{[hkl]}$	Young's modulus (measured in [hkl] direction)	dyn cm^{-2}	17a/2.4.2, eq.(A.100)
$E_{a(d)}$	energy of acceptor (donor) state measured from the respective band edge	eV	17a/2.3.1
E_A	activation energy (of conductivity or other temperature or pressure dependent properties)	eV	
E_b	binding energy (mostly of exciton)	eV	17a/2.1.1
E_{bx}	binding energy of an exciton to an impurity, localization energy of bound exciton	eV	
E_b^{e-h}	binding energy of electron-hole liquid (relative to free exciton binding energy)	eV	17b/3.6

Introduction: 1. List of symbols

Symbol	Property	Unit	Introduced in section
E_b^{biex}	biexciton binding energy (relative to free exciton binding energy)	eV	17b/3.6
$E_{c(v)}$	band edge of conduction (valence) band	eV	17a/2.1.1, eq.(A.1)
E_{el}	electron energy	eV	
$E_{ex, ion}$	bound exciton ionization energy	eV	17b/4.5
E_F	Fermi energy	eV	
E_g	energy gap	eV	17a/2.1.1
$E_{g, th}$	energy gap at 0 K (thermal energy gap)	eV	17a/2.2.1
$E_{g, dir(ind)}$	direct (indirect) energy gap	eV	17a/2.1.1
E_{gx}	excitonic energy gap ($E_g - E_b$)	eV	17a/2.1.1
E_{gx}^{thr}	exciton absorption threshold energy	eV	17b/4.5
$E_n(k)$	band structure function	eV	17a/2.1.1
E_p	characteristic energy in Kane's theory ($= (2m_0/\hbar^2) P^2$)	eV	17a/2.4.1, eq.(A.79)
E_{pl}	plasmon energy	eV	17b/3.1
E_t, E_{trap}	energy of trap level	eV	
E_{vac}	vacuum energy level	eV	
E_{zp}	zero phonon transition energy (bound exciton)	eV	17b/4.5
f	frequency	Hz	
f_i	ionicity, electronegativity	—	
f_{ex}	oscillator strength of free exciton	—	17b/3.7
F	parameter of Kane's theory	—	17b/5
g^*, g_{eff}	effective g-factor	—	17a/2.1.1, eq.(A.15)
g_c, g_n	g-factor of conduction electrons	—	
g_v, g_p	g-factor of holes (valence band)	—	
g_{so}	g-factor in spin-orbit split valence band	—	
g_{ik}	piezoelectric strain coefficients	$\text{cm}^2 \text{C}^{-1}$	17a/2.2.1, eq.(A.35)
$G_{[hkl]}$	torsional (shear) modulus in [hkl] direction	dyn cm^{-2}	
ΔG_f^0	standard free energy of formation	kcal mol^{-1}	
h_{ik}	piezoelectric stress coefficients	V cm^{-1}	17a/2.2.1, eq.(A.35)
$H(H_{B, K})$	hardness (Brinell, Knoop)	kg mm^{-2}	
H	magnetic field strength	$\text{A cm}^{-1}, \text{Oe}$	
ΔH_{at}^0	standard heat of atomization	kcal mol^{-1}	
ΔH_f^0	standard heat of formation	kcal mol^{-1}	
ΔH_m	heat of fusion	kcal mol^{-1}	
ΔH_v	heat of vaporization	kcal mol^{-1}	
ΔH_c	heat of conversion	kcal mol^{-1}	
ΔH_s	heat of sublimation	kcal mol^{-1}	
ΔH_{tr}	(phase) transformation heat	kcal mol^{-1}	
i	current density	A cm^{-2}	
I	current	A	
I_{ph}	photocurrent	A	
I	intensity	$\text{cm}^{-2} \text{s}^{-1}$	
$I_{r, t}$	intensity (reflected, transmitted)	$\text{cm}^{-2} \text{s}^{-1}$	17a/2.2.2, eq.(A.41)
I_R	Raman intensity	$\text{cm}^{-2} \text{s}^{-1}$	
j	index designating the branches of the phonon dispersion curves	—	17a/2.1.2
k	extinction coefficient (absorption index)	—	17a/2.2.2, eq.(A.41)
k	Boltzmann constant	J K^{-1}	
k	wave vector of electrons	cm^{-1}	17a/2.1.1
k_0	location of band edge in k -space	cm^{-1}	17a/2.1.1
$k_{c(v)}$	location of conduction (valence) band edge	cm^{-1}	17a/2.1.1
k_{lm}	electromechanical coupling factor	—	17b/3.5
k_t	thickness coupling factor	—	17b/3.5
K	absorption coefficient	cm^{-1}	17a/2.2.2, eq.(A.38)
K	anisotropy constant of ellipsoidal energy surfaces	—	17a/2.4.2, eq.(A.95)
K	exciton wave vector	cm^{-1}	17a/2.1.1, eq.(A.14)

Symbol	Property	Unit	Introduced in section
L	symmetry point in the Brillouin zone	—	17a/2.4, Fig. A.4
L, M, N	valence band anisotropy parameters	—	17a/2.4.1, eq. (A.71)
$\Delta l/l$	linear thermal elongation	—	—
m_0	electron mass	g	—
m^*	effective mass	m_0	17a/2.1.1
m^{**}	polaronic mass	m_0	17a/2.1.1, eq. (A.10)
$m_{n(p)}$	effective mass of electrons (holes)	m_0	17a/2.1.1, eq. (A.1)
$m_{ex, h(l)}$	effective mass of heavy (light) excitons (sometimes M is also used)	m_0	—
$m_{p, h(l)}$	effective mass of heavy (light) holes	m_0	—
$m_{ }(m_{\perp})$	longitudinal (transverse) effective mass	m_0	17a/2.4.1, eq. (A.75)
$m(\Gamma_6) \dots$	effective mass at band edge of type $\Gamma_6 \dots$	m_0	17a/2.4.1
m_{ds}	density of states mass	m_0	17a/2.1.1, eq. (A.9)
m_{so}	effective mass in the spin-orbit split valence band	m_0	—
$m_{\omega c}$	effective "cyclotron resonance mass"	m_0	17a/2.2.2, eq. (A.57)
m_{ik}	elastoresistance coefficients	—	17a/2.2.1, eq. (A.32)
n	refractive index (real refractive index)	—	17a/2.2.2, eq. (A.37)
$n_0 (= n_{\omega})$	refractive index for ordinary ray	—	—
$n_e (= n_e)$	refractive index for extraordinary ray	—	—
$n_{a, b, c}$	refractive index in a, b, c direction	—	—
Δn	birefringence ($= n_{ } - n_{\perp}$)	—	—
n	electron concentration (also carrier concentration in general)	cm^{-3}	—
n_i	intrinsic carrier concentration	cm^{-3}	17a/2.1.3, eq. (A.20)
$n_{a(d)}$	acceptor (donor) concentration	cm^{-3}	—
n_{ion}	concentration of ionized impurities	cm^{-3}	—
$n_{l(h)}$	concentration of light (heavy) electrons	cm^{-3}	—
p	pressure	bar	—
p	hole concentration	cm^{-3}	—
p_i	pyroelectric constants	$\text{A s cm}^{-2} \text{K}^{-1}$	17b/3.5
$p_{l(h)}$	concentration of light (heavy) holes	cm^{-3}	—
p_{ijkl}	elasto-optic tensor components	—	17a/2.2.2
p_{ij}	elasto-optic constants of cubic crystals	—	17a/2.4.2
P	Ettinghausen coefficient	$\text{K cm}^3 \text{J}^{-1}$	17a/2.2.1
P	Kane's matrix elements (see E_p)	eV cm	—
P_i	dielectric polarization vector	C cm^{-2}	—
q	valence band parameter	—	17a/2.4.1, eq. (A.73)
q	wave vector of phonons	cm^{-1}	—
q_{ijkl}	piezo-optic tensor components	—	17a/2.2.2
q_{ij}	piezo-optic constants in cubic crystals	—	—
r	radius (ionic, covalent, of exciton ...)	cm	—
$r_{ij}^{X(e)}$	linear electro-optic constant at constant stress (strain)	cm V^{-1}	17b/3.5
R	resistance	Ω	—
R	reflectance	—	17a/2.2.2, eq. (A.42)
R	volume recombination coefficient	$\text{cm}^{-3} \text{s}^{-1}$	—
R_H	Hall coefficient	$\text{cm}^3 \text{C}^{-1}$	17a/2.2.1
S	spin quantum number	—	—
$S_{(A)}$	Seebeck coefficient, thermoelectric power (of material A)	VK^{-1}	17a/2.2.1, eq. (A.42)
S_R	Righi-Leduc coefficient	$\text{cm}^2 \text{V}^{-1} \text{s}^{-1}$	17a/2.2.1
s_{ml}	elastic compliances	$\text{cm}^2 \text{dyn}^{-1}$	17a/2.1.2, eq. (A.19)
S^0	standard entropy (at 298.15 K)	$\text{cal mol}^{-1} \text{K}^{-1}$	—
ΔS_f^0	standard entropy (change) of formation	$\text{cal mol}^{-1} \text{K}^{-1}$	—
ΔS_{at}^0	standard entropy (change) of atomization	$\text{cal mol}^{-1} \text{K}^{-1}$	—
ΔS_m^0	entropy (change) of fusion	$\text{cal mol}^{-1} \text{K}^{-1}$	—
t	time	s	—

Introduction: 1. List of symbols

Symbol	Property	Unit	Introduced in section
T	temperature	K, °C	
T	transmission coefficient	—	
T_b	boiling temperature	K	
T_m	melting temperature	K	
T_{tr}	transition temperature	K	
T_q	quenching temperature	K	
T_p	temperature of glow peak	K	
T_C	Curie temperature	K	17b/5
T_G	transition temperature paramagnet – spin glass	K	17b/5
T_N	Néel temperature	K	17b/5
u	atomic position parameter (defined in figures for the respective lattice)	—	
U	voltage	V	
U_{th}	thermoelectric voltage	V	
v_{th}	thermal velocity	cm s ⁻¹	
$v_{LA(TA)} (v_{L(T)})$	velocity of longitudinal (transverse) acoustic (sound) waves	cm s ⁻¹	17a/2.1.2
v_{dr}	drift velocity	cm s ⁻¹	
V	Verdet coefficient	deg T ⁻¹ cm ⁻¹	17a/2.2.2
$V_{(m)}$	(molar) volume	cm ³ (mol ⁻¹)	
X	symmetry point in the Brillouin zone	—	17a/2.4.1, Fig. A4
X_i	deformation potentials	eV	17b/3.5
X_k	stress vector (6-component)	dyn cm ⁻²	17a/2.1.2
X_{ik}	stress tensor (6 × 6) (in literature often labeled T_{ij})	dyn cm ⁻²	17a/2.1.2
$X_{[hkl]}$	stress in [hkl] direction	dyn cm ⁻²	
α	polarizability	cm ³	
$\alpha(\alpha_F)$	(Fröhlich) polaron coupling constant	—	17a/2.1.1, eq. (A.11)
$\alpha(\alpha_{\perp}, \alpha_{\parallel})$	linear thermal expansion coefficient (perpendicular and parallel to the crystallographic axis)	K ⁻¹	17a/2.1.2, eq. (A.17)
$\alpha_{a, b, c}$	linear thermal expansion coefficient in a, b, c direction	K ⁻¹	
α_i	direction cosines	—	
α, β	exchange constants	eV	17b/5
$\beta(\beta_2)$	two-photon absorption coefficient	cm W ⁻¹	17a/2.2.2
β	volume thermal expansion coefficient ($= 3\alpha$)	K ⁻¹	17a/2.1.2, eq. (A.17)
$\beta_{2\omega}$	absorption coefficient associated with second harmonic generation	cm W ⁻¹	17b/3.10
β_n	absorption coefficient for two-photon excited non-equilibrium free carriers	cm W ⁻¹	17b/3.10
β_{Σ}	total non-linear absorption coefficient ($= \beta_2 + \beta_{2\omega} + \beta_n$)	cm W ⁻¹	17b/3.10
β_3	three photon absorption coefficient	cm ³ W ⁻²	17b/3.10
γ_i	Luttinger coefficients	—	17a/2.4.1, eq. (A.73)
γ	Grüneisen constant	—	17a/2.1.2, eq. (A.18)
γ_{jq}	mode Grüneisen parameter	—	17a/2.1.1, eq. (A.18)
Γ	center of Brillouin zone	—	17a/2.4.1, Fig. A4
Γ	sound absorption coefficient	db cm ⁻¹	
δ	Anderson-Grüneisen constant	—	17b/3.1
Δ	[100]-axis in k -space	—	17a/2.4.1, Fig. A4
$\Delta_{(0)}, \Delta_{so}$	spin-orbit splitting energy at Γ	eV	
$\Delta_{1(2)}$	spin-orbit splitting energy at L(X)	eV	
Δ_{cf}, Δ_{cr}	crystal field splitting energy	eV	17b/3.10
Δ_1	short range electron-hole interaction	eV	17b/3.7
$\Delta_{dip}, \Delta_{ex}$	exciton exchange interaction energies	eV	17b/4.1
Δ_{L-T}^L	longitudinal-transverse exciton splitting energy	eV	17b/4.1
Δ_{ex}^{magn}	splitting of free exciton line in magnetic field	eV	17b/5
Δ_L, Δ_T	exchange energy of longitudinal (transverse) exciton	eV	17b/4.1
ϵ_0	permittivity of free space	F cm ⁻¹	
ϵ	dielectric constant	—	

Symbol	Property	Unit	Introduced in section
$\varepsilon_{1(2)}$	real (imaginary) part of dielectric constant	—	17a/2.2.2, eq.(A.39)
$\varepsilon(0)$	low frequency dielectric constant	—	17a/2.2.2, eq.(A.53)
$\varepsilon(\infty)$	high frequency dielectric constant	—	17a/2.2.2, eq.(A.53)
ε_L	lattice part of dielectric constant	—	17a/2.2.2, eq.(A.48)
ζ	reduced wave vector coordinate	—	—
θ	Faraday angle	deg	17a/2.2.2
Θ_D	paramagnetic Curie temperature	K	—
Θ_D	Debye temperature	K	17a/2.1.2
$\kappa(\kappa_{L,el})$	thermal conductivity (lattice, electronic contribution)	Wcm ⁻¹ K ⁻¹	17a/2.2.1, eq.(A.36)
κ	compressibility (= 1/bulk modulus)	cm ² dyn ⁻¹	—
$\kappa_{S(T)}$	adiabatic (isothermal) compressibility	cm ² dyn ⁻¹	—
$\kappa_{V(l)}$	volume (linear) compressibility	cm ² dyn ⁻¹	—
κ	valence band parameter	—	17a/2.4.1, eq.(A.73)
λ	wavelength	cm	—
$\mu(\mu_{ex})$	reduced mass (of excitons)	m_0	—
$\mu_{n(p)}$	electron (hole) mobility	cm ² V ⁻¹ s ⁻¹	17a/2.2.1, eq.(A.25)
μ_{dr}	drift mobility	cm ² V ⁻¹ s ⁻¹	17a/2.2.1
μ_H	Hall mobility	cm ² V ⁻¹ s ⁻¹	17a/2.2.1, eq.(A.27)
ν	number of equivalent ellipsoidal band edges	—	17a/2.1.1, eq.(A.9)
ν	Poisson's ratio	—	17a/2.4.2, eq.(A.100)
ν	frequency	s ⁻¹	—
$\bar{\nu}$	wavenumber	cm ⁻¹	—
$\bar{\nu}_R$	Raman wavenumber	cm ⁻¹	—
$\bar{\varepsilon}_u$	deformation potential for pure shear	eV	17a/2.1.1, eq.(A.13)
$\bar{\varepsilon}_d$	diagonal component of deformation potential tensor	eV	17a/2.1.1, eq.(A.13)
π_{ik}	piezoresistance coefficients	cm ² dyn ⁻¹	17a/2.2.1, eq.(A.32)
π_{ik}	piezooptic constants (coefficients of the piezooptic tensor in cubic crystals)	cm ² dyn ⁻¹	—
ρ	resistivity	Ω cm	—
$\rho_{ik}^{(2)}$	magnetoresistance tensor (6 × 6)	G ⁻² , T ⁻²	17a/2.2.1, eq.(A.30)
$\rho_{ijkl}, \rho_{ijkl}^{(2)}$	fourth-rank tensor components in a power expansion of the resistivity in a magnetic field	Ω cm G ⁻²	17a/2.2.1, eq.(A.29)
$\Delta\rho/\rho_0$	magnetoresistance	—	17a/2.2.1, eq.(A.30)
σ	cross section	cm ²	—
$\sigma_{(i)}$	(intrinsic) conductivity	Ω^{-1} cm ⁻¹	17a/2.2.1
$\sigma_{n(p)}$	contribution of electrons (holes) to the conductivity	Ω^{-1} cm ⁻¹	17a/2.2.1, eq.(A.25)
$\sigma_{n(p)}$	capture cross section of electrons (holes) at impurities	cm ²	—
σ_{ph}	photoconductivity	Ω^{-1} cm ⁻¹	—
σ_s	surface conductivity	Ω^{-1}	—
σ_d	dark conductivity	Ω^{-1} cm ⁻¹	—
σ_R	Raman cross section	cm ²	—
τ	relaxation time, decay time, delay time, rise time	s	—
φ	photoelectric threshold	eV	17b/3.6
Φ	work function	eV	17b/3.6
$\Phi_{ph(th)}$	photoelectric (thermoelectric) work function	eV	—
χ	electron affinity	eV	17b/3.6
χ_v	magnetic volume susceptibility	—	—
χ_g, χ	magnetic mass susceptibility	cm ³ g ⁻¹	—
χ_m	magnetic molar susceptibility	cm ³ mol ⁻¹	—
ω	circular frequency	rad s ⁻¹	—
$\omega_j(q)$	phonon dispersion relation	s ⁻¹	17a/2.1.2, eq.(A.16)
$\hbar\omega$	photon energy	eV	—
ω_c	cyclotron resonance frequency	s ⁻¹	17a/2.2.2, eq.(A.56)
ω_p	plasma resonance frequency	s ⁻¹	17a/2.2.2, eq.(A.49)
ω_q	phonon frequency	s ⁻¹	—
$\omega_{TO(LO)}$	frequency of transverse (longitudinal) optical phonon	s ⁻¹	17a/2.1.2
ω_D	Debye frequency	s ⁻¹	17a/2.1.2

2. List of abbreviations

a, $A(A^0, A^+)$	acceptor (neutral, positively charged)
a	amorphous
AAS	atom absorption spectroscopy
ac	acoustic
ac	alternating current
AKCR	Azbel-Kaner cyclotron resonance
APW	augmented plane wave (method)
$A^0X(D^0X)$	neutral acceptor (donor) bound exciton
bcc	body centered cubic
BE	bound exciton
BIN, BIS, TRIG	binary, bisectrix, trigonal axis
c	crystalline
calc	calculated
CB	conduction band
COL	complex orange luminescence
cov	covalent
CPM	circular polarization modulation
cub	cubic
CVD	chemical vapor deposition
cw	constant wave
D, d	donor
DAP	donor acceptor pair
dc	direct current
DDLTS	double correlated DLTS
dir	direct
DLTS	deep level transient spectroscopy
DPS	deformation potential scattering
DTA	differential thermal analysis
e	electron
EELS, ELS	electron energy loss spectrum
eff	effective
EHL	electron hole liquid
EHP	electron hole plasma
EM	exciton molecule
emf	electromotive force
endor	electron nuclear double resonance
ENP(NENP)	ellipsoidal non-parabolic (non ellipsoidal non-parabolic)
EPM	empirical pseudopotential method
ER-OPW	extended relativistic orthogonalized plane wave (method)
ESCA	electron spectroscopy for chemical analysis
esr, ESR	electron spin resonance
epr, EPR	electron paramagnetic resonance
ex	exciton
exc	excitation
exp	experimental
fcc	face centered cubic
FE	free exciton
fir, FIR	far infrared
g	gaseous
h	hole
hex	hexagonal
$I_{1, 2, 3, \dots}$	excitons bound to neutral or ionized impurities (see corresponding section for special meaning)
IIS	ionized impurity scattering
ind	indirect
INDO	intermediate neglect of differential overlap
ion	ionic

(continued)