Appendix A

Table of Fundamental Physical Constants

(updated: July 31, 2012)

Physical constant	**Symbol**	**Value** SI units	"microelectronic" units
Boltzmann constant	k	$1.38 \times 10^{-23}\ J/K$	$8.62 \times 10^{-5}\ eV/K$
Electron charge	q	$1.60 \times 10^{-19}\ C$	$1.60 \times 10^{-19}\ C = 1\ e$
Electron rest mass	m_o	$9.11 \times 10^{-31}\ kg$	$5.69 \times 10^{-16}\ eV \cdot s^2/cm^2$
Planck constant	h	$6.63 \times 10^{-34}\ J \cdot s$	$4.14 \times 10^{-15}\ eV \cdot s$
Speed of light in vacuum	c	$3.00 \times 10^{8}\ m/s$	$3.00 \times 10^{10}\ cm/s$
Permittivity of vacuum	ϵ_o	$8.85 \times 10^{-12}\ F/m$	$8.85 \times 10^{-14}\ F/cm$

CONVERSION BETWEEN BOTH SYSTEMS

$$\begin{aligned} 1\ eV &= 1.60 \times 10^{-19}\ J \\ 1\ kg &= 6.24 \times 10^{14}\ eV \cdot s^2/cm^2 \end{aligned}$$

Values of fundamental constants taken from *E. R. Cohen and B. N. Taylor, Physics Today, BG9 (August 1994).*

Appendix B

Table of Important Material Parameters of Si and GaAs at 300 K

(updated: July 31, 2012)

Physical parameter	Symbol	Si value	GaAs value	units
lattice constant	a	0.543	0.565	nm
interatomic distance		0.235	0.245	nm
atomic density	N_a	5.0×10^{22}	4.4×10^{22}	cm^{-3}
density	d	2.33	5.32	$g \cdot cm^{-3}$
linear thermal expansion coefficient	α	2.59×10^{-6}	5.73×10^{-6}	K^{-1}
dielectric constant	ϵ	11.7	12.9	-
electron affinity	χ	4.04		eV
bandgap energy	E_g	1.124	1.422	eV
DOS electron effective mass	m^*_{de}	1.09 m_o	0.066 m_o	$eV \cdot s^2/cm^2$
DOS hole effective mass	m^*_{dh}	1.15 m_o	0.52 m_o	$eV \cdot s^2/cm^2$
effective DOS of the conduction band	N_c	2.86×10^{19}	4.21×10^{17}	cm^{-3}
effective DOS of the valence band	N_v	3.10×10^{19}	9.51×10^{18}	cm^{-3}
intrinsic carrier concentration	n_i	1.07×10^{10}	2.25×10^{6}	cm^{-3}
optical phonon energy	E_{opt}	0.063	0.035	eV
conductivity electron effective mass	m^*_{ce}	0.28 m_o	0.070 m_o	$eV \cdot s^2/cm^2$
conductivity hole effective mass	m^*_{ch}	0.41 m_o	0.44 m_o	$eV \cdot s^2/cm^2$
phonon-limited electron mobility	μ_e	1430	8000	$cm^2/V \cdot s$
phonon-limited hole mobility	μ_h	480	320	$cm^2/V \cdot s$
electron saturation velocity	v_{esat}	1.0×10^7	$1 - 1.5 \times 10^7$	cm/s
hole saturation velocity	v_{hsat}	6.0×10^6		cm/s
optical G/R rate coefficient	r_{rad}	2.0×10^{-15}	7.2×10^{-10}	cm^3/s
electron-electron Auger coefficient	r_{eeh}	1.8×10^{-31}	1.8×10^{-31}	cm^6/s
hole-hole Auger coefficient	r_{ehh}	9.5×10^{-32}	4.0×10^{-30}	cm^6/s
impact ionization threshold energy	E_{ii}	1.12	1.72	eV

Appendix C

Table of Acronyms

(updated: July 31, 2012)

Acronym	Meaning
AC	Alternating Current
BJT	Bipolar Junction Transistor
CAD	Computer-Aided Design
CCD	Charge-Coupled Device
CET	Capacitance Equivalent Thickness
CLM	Channel Length Modulation
CMOS	Complementary Metal-Oxide-Semiconductor
DC	Direct Current
DOS	Density of States
DRAM	Dynamic Random Access Memory
ECL	Emitter-Coupled Logic
EEPROM	Electrically Eraseable Programmable Read-Only Memory
EOT	Equivalent Oxide Thickness
ESD	Electrostatic Discharge
FET	Field-Effect Transistor
HEMT	High-Electron Mobility Transistor
IC	Integrated Circuit
LED	Light-Emitting Diode
MESFET	Metal-Semiconductor Field-Effect Transistor
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
ppm	part per million
QNR	Quasi-Neutral Region
SCR	Space-Charge Region
SOI	Silicon on Insulator
SRAM	Static Random Access Memory
STI	Shallow Trench Isolation
TTL	Transistor-Transistor Logic
VLSI	Very Large Scale Integration
XPS	X-ray Photoelectron Spectroscopy

Appendix D

Table of Taylor Series Expansions

(updated: July 31, 2012)

Function	Expansion	Around
$\sin x$	$x - \frac{x^3}{6} + \frac{x^5}{120}$	$x = 0$
$\cos x$	$1 - \frac{x^2}{2} + \frac{x^4}{24}$	$x = 0$
$\tan x$	$x + \frac{x^3}{3} + \frac{2x^5}{15}$	$x = 0$
$\sinh x$	$x + \frac{x^3}{6} + \frac{x^5}{120}$	$x = 0$
$\cosh x$	$1 + \frac{x^2}{2} + \frac{x^4}{24}$	$x = 0$
$\tanh x$	$x - \frac{x^3}{3} + \frac{2x^5}{15}$	$x = 0$
$\coth x$	$\frac{1}{x} + \frac{x}{3} - \frac{x^3}{45}$	$x = 0$
e^x	$1 + x + \frac{x^2}{2}$	$x = 0$
$\frac{1}{1-x}$	$1 + x + x^2$	$x = 0$
$\frac{1}{1+x}$	$1 - x + x^2$	$x = 0$
$\sqrt{1+x}$	$1 + \frac{x}{2} - \frac{x^2}{8}$	$x = 0$
$\frac{1}{\sqrt{1+x}}$	$1 - \frac{x}{2} + \frac{3x^2}{8}$	$x = 0$
$\ln(1+x)$	$x - \frac{x^2}{2} + \frac{x^3}{3}$	$x = 0$
$(1+x)^p$	$1 + px + \frac{p(p-1)}{2}x^2$	$x = 0$

Appendix E

Analytical Expressions for Important Material Parameters of Si and GaAs at 300 K

(updated: July 31, 2012)

E.1 Bandgap vs. temperature

The temperature dependence of the bandgap of Si and GaAs is graphed in Fig. 2.20. This is well represented by an equation of the form:

$$E_g(T) = E_g(0) - \frac{\alpha T^2}{T+\beta} \tag{E.1}$$

where $E_g(0)$ is the bandgap at 0 K and α and β are constants. For Si, $E_g(0) = 1.17\ eV$, $\alpha = 3.83 \times 10^{-4}\ eV/K$ and $\beta = 453\ K$. For GaAs, $E_g(0) = 1.519\ eV$, $\alpha = 5.405 \times 10^{-4}\ eV/K$ and $\beta = 204\ K$.

E.2 Bandgap narrowing vs. doping level

The bandgap of Si narrows as the doping level increases. This is graphed in Fig. 2.23. Bandgap narrowing in Si has been found to depend only on the doping level and not on the doping type. A good working expression is:

$$\Delta E_g = A \ln \frac{N}{B} \tag{E.2}$$

where $A = 22\ meV$ and $B = 7 \times 10^{17}\ cm^{-3}$. In Si, to the first order, bandgap narrowing appears to be temperature independent.

In the Si literature it is common to utilize an *effective* or *apparent* bandgap narrowing, ΔE_g^{app}, that lumps the impact of degenerate statistics together with the true bandgap shrinkage. It is common to use

Parameter	Value				Units
	n-type		p-type		
	μ_e	μ_h	μ_e	μ_h	
μ_1	80	130	232	60	$cm^2/V.s$
μ_2	1360	349	1202	420	$cm^2/V.s$
N_o	8×10^{16}	8×10^{17}	8×10^{16}	2×10^{17}	cm^{-3}
α	0.75	1.25	0.9	0.75	no units

Table E.1: Parameters for mobility expressions for Si at room temperature.

Appropriate values for A and B for electrons in Si at room temperature are $A = 7.03 \times 10^5\ cm^{-1}$ and $B = 1.231 \times 10^6\ V/cm$. For holes, $A = 2.0 \times 10^6\ cm^{-1}$ and $B = 1.97 \times 10^6\ V/cm$.