

## INDEX

- Absorption coefficient, 366  
AC Bridge, 483  
Acceptor, 200  
    diffusion, 51  
Accumulation layer, 461  
Acheson process, 397  
Activity, 48, 156, 327, 349  
Adsorption, 302, 352, 356  
Aging, 280  
    overaging, 385  
Amorphous solid, 277, 355–356, 359–363, 385  
Anelasticity, 89–91  
Angular momentum  
    quenching of, 78, 85, 271, 283  
Annealing, 347, 371–372, 382  
    rapid thermal, 368, 372  
    spheroidizing, 382  
Anodization, 157, 388  
Antibonding state, 110  
Antiferroelectric, 204  
Antiferromagnetism, 82, 223–224, 262  
Atomic absorption spectroscopy, 429  
Atomic emission spectroscopy, 429  
Atomic force microscope (AFM), 340, 366, 471, 512  
Atomic form factor, 27, 418  
Atomic orbital, 7–9  
    s, 7–9, 228  
    p, 7–9, 228–229  
    d, 7–9, 75, 228–229  
Auger emission spectroscopy (AES), 357, 462  
Austenite, 159–160, 374–378, 389  
Autodoping, 352
- Bainite, 374–382  
Baliga figure of merit, 122  
Band bending, 327  
Bandgap, *see* Electronic energy bandgap  
Band structure, *see* Electronic energy band structure  
Battery, 155, 212, 215, 405  
    Daniell cell, 155–156  
    fuel cell, 214, 217  
    lithium ion, 212  
Beer's law, 409, 427, 461  
Bingham stress yield, 180
- Birefringence, 67  
Bloch equations, 505–506  
Bloch wavefunction, 229  
Boltzmann equation, 55, 59  
    relaxation time approximation, 55  
Bond  
    disorder, 35  
    energy, 20, 411  
Bonding, 14–17, 88, 226, 359–361  
    covalent, 17, 89, 110, 226  
    hydrogen, 17–19  
    ionic, 17–18, 89, 110, 226  
    metallic, 89  
    mixed ionic-covalent, 110, 226, 228  
    van der Waals, 177  
Bonding state, 110  
Bonding unit, local atomic  
    A-B<sub>2</sub>, 365  
    A-B<sub>4</sub>, 364  
    A-A<sub>12</sub>(cub), 5  
    A-A<sub>12</sub>(hex), 5  
    A-A<sub>12</sub>(icos), 3, 5, 31–32  
    A-H···B, 18  
Born solvation energy, 213  
Bose-Einstein distribution, 37, 426, 521  
Bragg diffraction, 414, 448  
Bravais lattice, 41  
Bridging oxygen, 175  
Bright field imaging, 447  
Brillouin function, 86  
Brillouin zone, 229  
Brittle material, 99, 377, 381  
Bulk modulus, 88–89, 101  
Burgers vector, 93, 381
- Capacitor  
    electrolytic, 203  
    multilayer ceramic, 203  
Carbon nanotube, 63  
Catalyst, 215, 308–309  
Ceiling temperature, 408  
Cement, 179  
Cementite, 374–376, 380–382, 389–390, 411  
Ceramic, 271  
Characterization, 413–511  
Charge-transfer organic solid, 235

- Chemical potential, 53, 146, 325, 327–329, 334, 349–356, 455
- Chemical shift, 498
- Chemical vapor deposition, 158, 351–363, 368–369, 391–394, 397, 455
- atmospheric pressure (APCVD), 352
  - metal-organic (MOCVD), 359
  - plasma-enhanced (PECVD), 359–363
  - reduced pressure (RPCVD), 352
  - UHV/CVD, 354–355
- Chemisorption, 309, 358
- Clausius-Mossotti formula, 330
- Clay, 177
- Cluster, 239, 256
- Coating, 157
- Coercive field, 209, 236–237, 251–252, 265–266, 268, 271, 277–278
- Cohesive energy, 19–20, 155
- Cold work, 379
- Collision time, electronic, 60
- Commutation relations, 40
- Compensation point (temperature), 277
- Compliant substrate, 340
- Composite fermion, 137
- Conductivity
- electrical, *see* Electrical conductivity
  - thermal, *see* Thermal conductivity
- Contact potential, 164, 311, 473
- Continuous-cooling transformation (CCT) diagram, 377–378
- Continuous random network, 32–33, 115, 359
- Coordination number, 13
- Corrosion, 154, 157
- resistance, 383, 388, 390
- Cottrell atmosphere, 379
- Coulomb
- blockade, 63
  - interaction, 17–18, 81–82, 88, 110, 229
- Covalent bonding, *see* Bonding, covalent
- Crack
- extension force, critical, 101
  - propagation, 100–101
- Creep, 95–96
- Coble, 96
  - Nabarro, 96
  - primary, 96
  - rate, 95
  - secondary, 96
  - strength, 96
  - tertiary, 96
- Critical thickness, 322, 324, 344
- Crystal field, electric, 75–78, 82, 271, 273
- splitting, 77, 85
  - stabilization energy (CFSE), 85
  - strong-field limit, 75
  - weak-field limit, 75
- Crystal growth, 342
- Crystal structure
- beta-tungsten (beta-W), 3, 222, 249
  - body-centered tetragonal, 376
  - cesium chloride (CsCl), 17
  - hexagonal, 268–269
  - inverse spinel, 273, 281
  - magnetoplumbite, 274
  - oxide crystals, 22
  - perovskite, 203
  - sodium chloride (NaCl), 17, 222
  - spinel, 281
  - tetragonal, 270
  - trigonal (rhombohedral), 268–269
  - zincblende (cubic ZnS), 17
- Crystallite, 275
- Curie
- constant, 78–79, 86
  - law, 78–79
  - temperature, 259, 266
- Curie-Weiss
- law, 79–81, 86
  - temperature, 79, 86
- Cyclotron frequency, 145
- Czochralski growth, liquid-encapsulated, 358
- Dangling bond, 113, 115, 310, 347
- Daniell cell, 155–156
- Dark-field imaging, 447
- Daumas-Herold domain, 333
- Debye-Huckel theory, 326
- Debye screening length, 326
- Debye temperature, 499
- Debye-Waller factor, 36–37, 418, 497
- Defect 118, 354, 356. *See also* Dislocation, Vacancy, etc.
- Demagnetizing
- curve, 264–265, 267
  - factor (magnetic material), 265, 286
  - field, 260, 264
- Density
- atomic, 5
  - mass, 5, 211
- Density functional theory, 149–150
- Density of states
- electronic, 113, 221–222, 474
  - phonon, 35–36, 43
- Dephasing time, 506
- Deposition, 303
- pulsed laser 395
  - sputtering, 158, 344–345
- Desorption, 304, 354
- Dichroism, 288
- Dielectric, 364
- Dielectric constant (or function), 72–73, 110, 113–114, 205, 207–208, 211, 213, 258, 361, 511
- anisotropic, 67
  - nonlocal, 72
  - tensor, 67

- Dielectric strength, 203
- Diffraction  
 amorphous solid, 31–32  
 Bragg, 414, 448  
 electron, 419, 422, 513  
 Laue, 415  
 powder, 415, 514  
 x-ray, 413–414, 418
- Diffusion, 45–51, 53–54, 162, 164, 350, 352, 354–355, 357, 359, 364, 366–367, 374, 379, 381, 383, 389  
 barrier, 369  
 chemical, 46  
 coefficient, 45, 50, 367, 371  
 constant-source, 367  
 grain boundary, 369  
 length, 45, 124  
 oxidation-enhanced (OED), 367  
 self-, 48–51, 96  
 self-interstitial mechanism, 50  
 transient-enhanced (TED), 367  
 two-step, 367  
 vacancy mechanism, 51, 96  
 velocity, 386  
 zone, 390
- Dislocation, 93, 95, 100, 322–323, 336, 348, 358, 376, 379, 381  
 density, 93–94, 99  
 edge, 94, 379  
 line tension, 381  
 loop, 381  
 misfit, 355  
 pinning, 94, 378–380  
 screw, 340, 379, 472  
 slip, 93
- Disorder  
 amorphous, *see* Amorphous solid  
 nanocrystalline, 31
- Dispersion strengthening, 94–95, 380–381, 383, 389
- Distance, polymer end-to-end, 183–185
- Distribution (segregation) coefficient, 349–351, 356, 387, 411
- Domain wall, 199, 208, 210
- Donor, 200  
 diffusion, 51
- Doping and dopants, *see* Semiconductor, doping and dopants
- Ductility, 100, 374, 378, 381–383
- Dupre formula, 321
- Dynamical matrix, 42
- Dynamical structure factor, 427
- Eddy currents, 260, 262–263, 278–280
- Edge state, 134
- Effective magneton number, 77
- Effective mass, 228, 231, 291  
 band curvature, 234
- Elastic  
 aftereffect, 90–91  
 constant, 211  
 energy, 100–101  
 modulus, *see* Young's modulus
- Electret, 201
- Electrical conductivity, 196  
 conductance, 63  
 tensor, 257  
 two-dimensional, 61
- Electrical resistance of alloys, 478
- Electrode half-reaction, 155
- Electrode potential, *see* Standard electrode potential
- Electrolyte, 213–215
- Electromigration, 50, 369
- Electron affinity, 20–23  
 negative, 21
- Electron configuration, valence, 10
- Electron paramagnetic resonance, *see* Electron spin resonance
- Electron spin resonance, 495
- Electronegativity, 23, 111, 228  
 Mulliken, 23  
 Pauling, 23–24, 26  
 Phillips, 24
- Electronic device, 349, 351, 373  
 fabrication, 363–372  
 feature size, 371  
 figure of merit, 122–123  
 planar technology, 123
- Electronic energy bandgap, 293, 438
- Electronic energy band structure, 228. *See also* Semiconductor, energy band structure
- Electrons  
 itinerant, 81  
 $d$ -, 22, 85
- Electrooptic tensor, 442
- Ellipsometry, 430, 433
- Embedded atom method, 151–153
- Energy band, 257
- Energy, cohesive, *see* Cohesive energy
- Energy distribution curve, 320, 455–456
- Enthalpy, 360, 515  
 change, standard, 19  
 of formation, standard, 19, 52, 411  
 of melting (fusion), 349, 386  
 of migration, 50  
 of vaporization, 52
- Entropy, 18, 325, 360, 515, 517, 520  
 of melting (fusion), 386  
 of vaporization, 52
- Epitaxial  
 growth, 337, 351–359

- Epitaxial (*Continued*)  
 temperature, 356  
 thickness, 356
- Equilibrium constant, thermodynamic, 33–34, 391, 411
- Error function, 46–48
- Etching, 363, 370–371, 391–392  
 chemical, 370, 373  
 dry, 371–373  
 inhibitor, 370  
 isotropic, 370  
 physical, 370  
 plasma, 396, 409  
 reactive-ion, 370, 372–373  
 selective, 370  
 wet, 371–373
- Euler relation, 516
- Euler theorem, 63
- Eutectic  
 alloy, binary, 53  
 composition, 162–163  
 temperature, 167, 170, 172
- Eutectoid, 374, 381, 389, 411
- Ewald sphere, 448, 421
- Exchange energy (integral), 81, 86, 229
- Extended x-ray absorption fine structure (EXAFS), 461, 512
- Failure, 96
- Faraday balance, 483
- Faraday effect, *see* Magneto-optical effect
- Fatigue, 97–98  
 life, 97  
 strength, 98
- Fermi  
 circle, 133  
 energy, 134, 455  
 level, 256, 371, 455, 473  
 sphere, 133  
 velocity, 60
- Fermi-Dirac distribution, 65, 455, 473, 521
- Fermi golden rule, 319, 455, 528
- Fermi integrals, 64
- Ferrimagnetism, 262, 271, 281
- Ferrite  
 acicular, 374–375, 378  
 ceramic, 86, 271, 274–275, 281  
 phase of iron, 374–378, 381–382, 389–390, 411
- Ferroelectric, 204, 332  
 nonvolatile random-access memory, 208  
 phase transitions, 206
- Ferromagnetic resonance, 260–262
- Fick's laws, 45, 389
- Field emission, 445
- Float-zone purification, 348–351
- Fluorescence, 438
- Foner magnetometer, 481
- Fourier transform infrared spectroscopy (FTIR), 433
- Fowler-Nordheim tunneling, 314, 405, 445
- Fractional charge, 137
- Fracture  
 brittle, 100, 166  
 ductile, 100  
 stress, 96, 100–101  
 toughness, 100
- Frank-Kasper phase, 3
- Frank-van der Merwe growth, 341–342
- Free-energy model, 360
- Free volume, 191, 194
- Friction, 310
- Fuel cell, 214, 217
- Fullerite, 234
- g factor  
 Landé, 86, 261
- Galvanomagnetic effect, *see* Magnetoresistance
- Gaussian diffusion profile, 45–48
- Geometric structure factor, 36, 418
- Gettering, 51, 349, 372
- Gibbs-Duhem formula, 516
- Gibbs free energy, 156, 328, 375, 387, 516  
 of formation, standard, 391
- Gibbs phase rule, 53, 169
- Gibbs triangle, 169–170, 207–208
- Ginzburg-Landau theory (of superconductivity), 236
- Glass, metallic, 31, 162–164, 281–282, 284, 385–388
- Glass transition temperature, 191, 194, 201, 387, 409
- Grain boundary, 99, 235, 240, 246, 271, 275, 369, 374, 378, 380  
 barrier layer, 204  
 pinning, 380, 383
- Grain size, 380  
 reduction, 380
- Graphite intercalation compound, 233–234, 333
- Griffith criterion, 100
- Guinier-Preston zone, 384
- Gyromagnetic ratio, 261
- Haber process, 308–309
- Hall  
 coefficient, 60, 146, 477  
 effect, 59, 132, 476  
 resistivity, 132, 136
- Hall-Petch relation, 99–100, 380–381
- Hardening  
 age, 381, 383  
 case-, 389  
 precipitation-, *see* Precipitation hardening

- secondary, 381
- work-, *see* Work hardening
- Hardness, 95, 98–99, 377, 382, 388, 390
  - Knoop, 99
  - Vickers, 89
- Harker-Kasper inequality, 30
- Harmonic oscillator, 39–40, 525
- Heat capacity, 517
- Heat treatment, 95, 267, 381–384, 389
- Heavy fermion, 234–235
- Heisenberg exchange interaction, *see* Magnetic interaction
- Helmholtz free energy, 324, 334, 515, 520
- High-resolution transmission electron microscopy (HRTEM), 449
- Hohenberg-Kohn theorem, 149
- Holes, 146
- Hooke's law, 87–89, 91
- Hot carrier, 128
- Hot isostatic pressing (HIP), 396–397
- Hubbard model, 81–82, 229
- Hume-Rothery rules, 268
- Hund's rules, 76, 85
- Hybrid orbital, 9–13
  - $dsp^2$ , 12–13, 228–229
  - $d^2sp^3$ , 12–13
  - $d^4sp$ , 13
  - $sd^3$ , 12
  - $sp$ , 11–12, 21
  - $sp^2$ , 12–13
  - $sp^3$ , 12–13
  - $sp^3d^3f$ , 13
- Hydrophobic interaction, 301–302
- Hydrophilic interaction, 301
- Hydrothermal synthesis, 399
- Hysteresis, 91, 159, 208–209, 237
  
- Icosahedra, *see* Bonding unit, local atomic
- Impurity, 351, 379
- Incommensurate lattice, 310
- Index ellipsoid, 67–68, 441
- Index of refraction, 70, 257, 293, 296, 427–428, 431
  - extraordinary, 69
  - ordinary, 69
- Inert-gas solid, 21
- Initiator, 194
- Interface, 374–375, 386
  - energy, 386
  - Si/a-SiO<sub>2</sub>, 364, 367
  - solid-electrolyte, 326
- Intermetallic compound, 166, 268
- Internal energy, electronic, 515, 520
- Internal friction, 90–92
- Interstitial, 33, 367, 376
  - impurity, 379
  - self-, 50–51
- Interstitial site, 164–165, 269, 281
  - BCT, 374, 376
  - FCC, 34
- Invar anomaly (effect), 279–280
- Ioffe-Regel criterion, 60–62
- Ion beam processing, 344
- Ion channeling, 344
- Ion implantation, 158, 367–368, 411
  - intense-pulsed-ion beam (IPIB), 390
  - plasma-immersion (PIII), 367, 390
  - range, 367
  - SIMOX, 368
- Ionic
  - bonding, *See* Bonding, ionic
  - solution, 324
- Ionicity, 21, 24, 26, 111–112
- Ionization energy, 20–21, 23
- Ion slicing, 348
- Isomer shift, *see* Chemical shift
- Isotropic solid, 101
  
- Jahn-Teller effect, 75
- Jellium model, 152
- Johnson figure of merit, 122
- Johnson-Mehl equation, 381
- Josephson effect, 241–245
  - ac, 243–244
  - current, 241, 243
  - dc, 243
  - frequency, 244
  - inverse ac, 244
  - junction, 241–242, 246
  - quantum interference, 244–245
  - relations, 241–243, 249
  
- Kauzmann temperature, 191, 194
- Kelvin probe technique, 473
- Kelvin relation, 107
- Kerr effect, *see* Magneto-optical effect
- Keyes figure of merit, 122
- Kikuchi line, 447
- Kinetic effect, 391
- Knight shift, 491
- Kohn-Sham equation, 150
- Kondo
  - effect, 79–80, 85
  - temperature, 80
- Kramers doublet, 75
- Kramers-Kronig relations, 511
- Kronig-Penney model, 57–58
  
- Landau level, 133–136, 145
- Landau theory of phase transitions, 206
- Langmuir adsorption isotherm, 305–306
- Laser, 76

- Laser damage, 296  
 Latent heat of fusion, *see* Enthalpy, of melting  
 Lateral force microscope, 474  
 Lattice relaxation, 82  
 Laue diffraction, 415  
 Laves phase, 3, 283  
 Law of mass action, 33–34  
 Lely process, 397  
 Lever rule, 172  
 Light-emitting diode, 331, 405  
 Liquidus line, 170–173, 349, 411  
 Lithography, 365–366  
   LIGA process, 366  
   nano-, 366  
   photo-, 205, 364–365  
   photoresist, 365  
 Local density approximation, 150  
 Localization, 60  
   Anderson, 62  
   weak, 61, 134  
 Lone-pair orbital, *see* Molecular orbital, nonbonding  
 Long-range order, *see* Order, long-range  
 Lorentz oscillator model, 70, 291  
 Loss coefficient, 90  
 Low-density microcellular material, 195  
 Low-energy electron diffraction (LEED), 419, 422  
 Low-energy electron loss spectroscopy (LEELS) 459, 512  
 Low-energy electron microscopy (LEEM), 452  
 Luminescence, 438  
   cathodoluminescence, 439
- Madelung**  
   constant, 17  
   energy, 17, 26  
 Magic-angle spinning, 489  
**Magnetic**  
   aftereffect (relaxation), 262–263  
   energy, 251  
   energy-density product, 265–266, 286  
   field, effective internal (molecular), 82, 85, 260, 262  
   hardening, 282  
   microstructure, 262, 267, 271, 276, 278  
   permeability, 260, 278, 281  
   susceptibility, 78–79, 82–84  
   viscosity, 263  
 Magnetic anisotropy, 251–252, 259, 263, 267, 275, 281, 283  
   coefficient, 82, 253, 277, 279, 283  
   energy density, 275  
   field, 251, 260, 262, 284  
   magnetocrystalline, 82, 252, 268, 271–274, 279  
   magnetostrictive, 252, 263, 268, 277  
   pair model (Van Vleck), 82  
   pair-ordering, 277  
   shape, 252–253, 267, 272, 274  
   single-ion, 277  
   uniaxial, 268, 271  
 Magnetic domain, 251, 259–260  
   pinning of, 266, 271, 279  
   wall energy, 251  
   wall thickness, 279, 285  
 Magnetic interaction  
   double exchange, 256, 273  
   Heisenberg exchange, 82, 255  
   indirect, 270  
   RKKY (Ruderman-Kittel-Kasuya-Yosida), 79–80, 83–85  
   *sp-d*, 285  
   superexchange, 229, 256, 284–285  
**Magnetic materials**  
   hard, 264, 269  
   magneto-optical recording, 277–278  
   magnetostrictive, 282–284  
   permanent magnet, 264–272, 286  
   read/write head, 281–282  
   recording media, 272–277  
   soft, 264, 278  
**Magnetic moment**, 234, 253, 261, 280  
   formation, 81  
**Magnetization**, 83–84, 253–254, 256–257, 261, 263, 286  
   curve, 259, 264  
   easy direction for, 251, 253, 272  
   loop, 259, 278  
   quantum tunneling of, 263  
   remanent, 236–237, 265–266  
   saturation, 86  
   spontaneous, 82, 253, 277–278, 280  
   sublattice, 273  
**Magnetoelastic energy**, 283  
**Magnetomechanical damping**, 263  
**Magneto-optical effect**, 257–260  
   Faraday, 257–258, 285, 290  
   Kerr (MOKE), 258–260, 277–278  
   magnetic circular birefringence, 257  
   magnetic circular dichroism, 258  
   magnetic linear birefringence, 258  
   magnetic linear dichroism, 258  
   surface Kerr (SMOKE), 259  
**Magneto-resistance**, 133, 255–257, 281, 285  
   colossal, 255  
   giant negative, 255, 281–282  
   longitudinal, 255  
**Magnetostriction**, 253–254, 279, 281–284  
   giant, 282–283  
   isotropic, 253  
   linear, 253  
   strain, 254, 279  
   volume, 280  
**Magnon**, *see* Spin wave  
**Manson-Coffin relation**, 98  
**Martensite**, 159–161, 374–381, 389, 411

- Martensitic transformation, 16, 268, 376  
 Mass spectrometry, 466–467, 514  
   modulated-beam, 357  
 Materials property chart, 100  
 Maxwell's equations, 71  
 Mean free path  
   electron, 60, 221, 232  
   ferrite path (MFFP), 381  
 Mechanical damping, 284  
 Melting temperature, 50, 52, 214, 349–350  
 Metal hydride, 164  
 Metal-insulator transition, 229, 256  
 Metallic  
   bonding, *see* Bonding, metallic  
   radius, *see* Radius, metallic  
 Metallization, 369–370  
 Metal, transition, 266  
 Micelle, 301  
 Microelectromechanical system (MEMS), 372–373  
 Microporous film, 195–196  
 Microstructure, 240, 363, 374, 376–377, 381–386,  
   388–390  
 Microwave processing, 408  
 Mictomagnetism, 85  
 Mismatch function, 28  
 Mobility, 60, 115, 213  
   edge, 61, 115  
   minimum metallic, 60  
 Modulation doping, 129–130  
 Modulus of elasticity, *see* Young's modulus  
 Molecular beam epitaxy (MBE), 356–359  
 Molecular field theory, Van Vleck  
   (antiferromagnetism), 86  
 Molecular geometry, 27  
 Molecular orbital, 13–17  
   antibonding (ABMO), 17, 228  
   bonding (BMO), 14  
   delta, 15–16  
   nonbonding (NBMO, lone-pair), 16–17, 116  
   pi, 15  
   sigma, 14, 228  
   theory, 75, 228  
 Molecular weight, 183  
 Mossbauer spectroscopy, 496  
 Mueller matrix, 289  
 Mulliken notation, 77  
 Multilayer material, 255, 281, 329  
 Muon-precession spectroscopy, 503
- Near-field optical spectroscopy, 442  
 Necking, 348  
 Néel temperature, 86, 223–224, 229, 234  
 Nernst equation, 327  
 Neutron scattering, 424, 426  
 Noncrystalline solid, *see* Amorphous solid  
 Nonlinear chromophore, 201  
 Nonlinear optical coefficient, 200, 296, 440  
 Nonlinear optical material, 332  
 Nonlinear optical spectroscopy, 439  
 Nonstoichiometry, 34  
 Normal mode, 38  
 Nuclear magnetic resonance, 484, 504  
 Nuclear quadrupole resonance, 491  
 Nucleation, 342, 352, 356, 374, 378, 381,  
   386
- Onsager formula, 133  
 Onsager relations, 56, 478  
 Optical absorption edge, 105  
 Optical band structure, 293  
 Optical spectroscopy, 427  
 Orbital, *see* Atomic orbital, Hybrid orbital,  
   Molecular orbital  
 Order  
   intermediate-range, 31  
   long-range, 112, 359  
   short-range, 112, 163, 359  
 Orowan expression, 95, 381, 385  
 Ostwald ripening, 398  
 Oxidation, 154, 156  
   of Si, 364–365, 411  
 Oxide  
   field, 364  
   gate, 364
- Packing fraction, 191  
   BCC, 3  
   CsCl, 4  
 Paramagnetism, Pauli, 86, 234  
 Passivation, 122, 157, 364  
 Patterson  
   function, 28–29  
   map, 29  
 Pauli exclusion principle, 9  
 Pauli paramagnetism, *see* Paramagnetism, Pauli  
 Pearlite, 374–382, 389, 411  
   coarse, 381  
   fine, 381  
 Peierls instability, 153, 199  
 Peltier effect, 106–109, 140–143, 477, 480  
 Percolation, 256  
 Permittivity, 72  
   relative, 110  
 Persistence length, 189  
 Phase-contrast image, 454  
 Phase diagram, equilibrium  
   binary, 163, 167, 349–350, 383–384, 387,  
   411  
   CVD, 391–393  
   eutectic, 387  
   ternary, 169–170, 394  
 Phase matching, 69, 200, 330, 440–441

- Phase transition  
 athermal, 376  
 first order, 206
- Phillips and Van Vechten model, 110–112, 147
- Phonon  
 density of states, 35–36, 43  
 drag, 109  
 monatomic random lattice, 35  
 quantization, 38
- Phosphorescence, 438
- Photoemission, 317  
 angular-resolved spectroscopy (ARPES), 456  
 inverse, 454, 456  
 ultraviolet spectroscopy (UPS), 454  
 x-ray spectroscopy (XPS), 457  
 yield, 317
- Photonic crystal, 296
- Photorefractive, 202
- Photoresist, 409
- Photovoltaic solar cell, 137–140, 360  
 fill factor, 139  
 multicolor, 140  
 open-circuit voltage, 138  
 short-circuit current, 138
- Physical vapor deposition, 368–369
- Physisorption, 309
- Piezoelectricity, 201, 210
- Pilkington process, 400
- Plasma  
 carburizing, 368  
 deposition, 359–363  
 electron cyclotron-resonance (ECR), 262  
 etching, 396, 409  
 frequency, 110, 291, 429, 513  
 nitriding, 368  
 processing, 409
- Plasmon  
 surface, 461, 465  
 two-dimensional, 461
- Plastic deformation, 93, 99, 379
- pn junction, 137, 368  
 built-in voltage, 138  
 J-V characteristic, 138
- Poisson-Boltzmann equation, 325
- Poisson equation, 324–325, 458
- Poisson ratio, 101, 322
- Polariton, 68, 70
- Polarization  
 remanent, 208  
 saturation, 209  
 spontaneous, 206–207
- Polarizer, 287–290
- Polyhedron  
 prism, triangular, 271  
 Voronoi, 27  
 CN14, CN15, CN16, 3
- Polymer, 116  
 cross-linked, 194  
 electrical conductivity, 196, 404  
 foam, 194  
 linear, 183  
 nonlinear optical, 200  
 porous film, 195
- Polymerization, 365
- Porous metal, 166
- Porous silicon, 117, 372–373
- Positron-annihilation spectroscopy (PAS), 499
- Potential energy, 87–88
- Precipitate, 94–95, 267, 278, 369, 380–383, 389, 393
- Precipitation hardening, 95, 266–267, 269, 383–385
- Processing, 337–410
- Pseudobinary compound, 282, 284
- Pseudomorphic growth, 343
- Pyrolysis, 354
- Quadrupole coupling parameter, 493
- Quadrupole mass spectrometer, 467, 514
- Quadrupole moment, 494
- Quadrupole tensor, 493
- Quality factor, 91
- Quantized magnetic flux, 135
- Quantum confinement, 117
- Quantum efficiency, 138
- Quantum Hall effect, 132  
 fractional, 137  
 integer, 133
- Quantum mechanics, 523
- Quantum well, 146, 525
- Quartz crystal  
 deposition monitor, 210, 212  
 microbalance, 476  
 oscillator, 210, 212
- Quasiequilibrium model, 391–392
- Quasiperiodicity, 332
- Radial distribution function, 31
- Radius, 24  
 covalent, 25, 110  
 ionic, 25  
 metallic, 25  
 van der Waals, 25
- Radius of gyration, 186, 202
- Radius ratio and polyhedral coordination, 181
- Raman scattering, 176, 435
- Random close-packing model, 31–32, 386
- Random walk, 185–186  
 self-avoiding, 188–189
- Range, 345–347
- Rapid solidification (quenching), 162, 271, 385–388, 390  
 velocity, 386
- Rayleigh resolution criterion, 442

- Rayleigh scattering, 436, 446  
 Reactive ion etching, 347  
 Reciprocal lattice vector, 36  
 Recombination, electron-hole, 118–122, 356  
   defect-mediated, 119–121  
   surface, 121–122  
 Reconstruction, 420  
 Recrystallization, 165, 347  
 Redox couple, 326, 328–329  
 Reflection high-energy electron diffraction (RHEED), 357, 423–424  
 Reflectivity, 428, 513  
 Relaxation, 101  
   time, 89–92  
 Relaxor ferroelectric, 203–04  
 Resistivity, 104–105, 132, 205, 230–231, 260, 272, 279, 476–477  
 Resonance valence band model, 229  
 Reststrahlen band, 71  
 Rupture modulus, 205  
 Rutherford backscattering, 467–468, 511
- Scaling law, 83  
 Scanning electron microscope (SEM), 433  
 Scanning tunneling microscope (STM), 366, 373, 472  
 Scattering  
   amplitude, 36, 418  
   Brillouin, 436  
   Raman, *see* Raman scattering  
   spin-dependent, 255  
 Schottky barrier, 139, 369  
 Schottky defect, *see* Vacancy  
 Schrodinger equation, 145, 242, 299, 314, 523, 526  
 Screening, Thomas-Fermi, 111, 346  
 Second-harmonic generation, 69, 330  
 Secondary ion mass spectrometry (SIMS), 466  
 Seebeck  
   coefficient, 106  
   effect, 106–107, 141  
 Segregation, 276  
 Semiconductor  
   amorphous, 112–116  
   carrier concentration, 103–105, 146–147  
   conductivity, 104–105  
   doping and dopants, 129–130, 355, 364, 366  
   energy gap, 139  
   group III–V, 359  
   group II–VI, 284, 359  
   magnetic, 117, 284–285  
   minority carrier lifetime, 118, 121  
   organic, 116–117  
   oxide, 116  
   thermoelectric effects, 106–110  
 Shape-memory alloy, 159–161  
 Shear modulus, 93, 95–96, 101, 163, 322, 381  
 Shockley state, 300
- Short-range order, *see* Order, short-range  
 Shubnikov-deHaas effect, 133  
 Silicate, 174–176  
 Sintering, 94, 271, 396–397  
 Skin depth, 260  
 Skin effect, 260  
 Slip, 376  
   system, 93  
 Snoek effect, 262–263  
 Solder joint, 165  
 Sol-gel synthesis, 399  
 Solid-electrolyte interface, 326, 328  
 Solid solution, 383  
   strengthening, 95, 100, 379–380  
 Solidus line, 349, 411  
 Soliton, 199  
 Solvation energy, 213, 302, 328  
 Sommerfeld model, 317  
 Specific heat, 37, 480  
   electronic, 234  
   magnetic contribution, 83–84  
 Speed of sound, 210, 217  
 Spin, 86  
   free, 78  
   high-to-low transition, 77  
   majority, 256  
   minority, 256  
 Spin coating, 406  
 Spin-flop axis, 82  
 Spin glass, 79–80, 82–85, 263, 285  
 Spin-orbit interaction, 75–76, 82, 253, 271, 283  
 Spintronics, 285  
 Spin valve, 282  
 Spin wave (magnon), 261  
 Spinodal decomposition, 276  
 Sputtering 363, 370, 389, 430, 466. *See also*  
   Deposition, sputtering  
 SQUID, 245–246  
 Stacking fault, 352  
 Staging, 333  
 Standard electrode potential, 155–157, 327  
 Statistical mechanics, 519  
 Steel, 267–268, 278, 374–383, 389  
   high-strength low-alloy (HSLA), 380  
   maraging, 381  
   tool, 411  
 Sticking coefficient, 158, 303–304, 358, 369  
 Stokes parameters, 288  
 Stopping power, 347  
 Straggling distance, 346  
 Strain, 263, 385  
   aging, 379  
   energy, 375, 379  
   field, 379  
   nominal, 101  
   rate, 96–97  
   recovery, 161  
   shear, 94–95, 376

- Strain (*Continued*)  
 tensor, 211  
 true, 101
- Stranski-Krastanov growth, 341, 343
- Strength, 321, 374, 378–383
- Stress, 263, 268  
 compressive, 389  
 flow, 381  
 intensity factor for plane stress (strain), critical, 100  
 shear, 93–94, 379  
 thermal, 352, 355
- Stress-strain curve, 88, 92–94
- Sublimation, *see* Vaporization
- Substrate, 205
- Sum rule, 511
- Superconductor  
 coherence length, 249  
 condensation energy, 221, 248–249  
 Cooper pair, 241–244, 247  
 critical current, 232, 235–241, 249  
 critical field  $H_c$ , thermodynamic, 248–249  
 critical field  $H_{c1}$ , lower, 238  
 critical field  $H_{c2}$ , upper, 238  
 electron tunneling, 241, 249  
 energy gap, 232  
 flux creep, 237, 239–240  
 flux flow, 237  
 free energy, 219, 221, 248  
 gapless, 232  
 hard versus soft, 236  
 high- $T_c$ , 223–233, 240–241, 246, 249  
 irreversibility field, 239  
 irreversibility temperature, 239  
 Josephson effect, *see* Josephson effect  
 magnetization, 236–237, 248  
 mixed state, 235, 238  
 penetration depth, 249  
 perfect conductivity, 248  
 quantized flux, 244, 249  
 specific heat, 228, 232, 248  
 SQUID, *see* SQUID  
 surface resistance, 246, 248  
 thermal conductivity, 219–220, 247  
 transition temperature, 223  
 trapped flux, 237, 239  
 two-fluid model, 219, 248  
 type II, 238  
 vortex, 232, 240  
 vortex fluid, 237–239  
 vortex glass, 238  
 vortex lattice, 238  
 vortex pinning, 235–239  
 wavefunction, 242
- Supercooling, 386
- Superelasticity, 161
- Superexchange, *see* Magnetic interaction
- Superlattice, 281
- Supermagnet, 268
- Superparamagnetism, 263, 275
- Supersaturation ratio (SSR), 354
- Surface, 258–259, 353  
 diffusion, 306–307, 356  
 energy, 100, 339, 342, 375, 382, 401  
 enhanced Raman scattering (SERS), 437  
 extended absorption fine structure (SEXAFS), 463  
 force apparatus, 475  
 net, 311, 420  
 plasmon, 461  
 reaction, 355, 362  
 reciprocal net, 422, 431  
 recombination velocity, 121  
 roughening, 356  
 state, 121, 299  
 step, 310  
 treatment (for metals), 388–390
- Surfactant, 301
- Symmetry  
 decagonal, 387  
 icosahedral, 387  
 rotational, 387
- Synthesis, 337–410
- Tail state, 113, 115
- Tanabe-Sugano diagram, 76
- Tauc law, 113–114
- Tempering, 377, 379, 381–382
- Tensile strength, 378, 382
- Thermal conductivity, 310, 386, 397, 477–478, 480  
 ceramic, 203, 205  
 semiconductor, 295
- Thermal diffusivity, 159, 386, 480
- Thermal expansion, 166, 205  
 linear coefficient, 211, 275, 295–296  
 volume coefficient, 191, 194, 397
- Thermistor, 212
- Thermocouple, 140, 479
- Thermodynamics, 515  
 first law, 477, 515, 518–520  
 second law, 517  
 third law, 517
- Thermoelectric  
 device, 140–145  
 field, 478  
 figure of merit, 142  
 power (thermopower), 106–107, 140, 146, 477, 479–480
- Third-harmonic generation, 69
- Third-order susceptibility, 441
- Thomson effect, 107
- Tight-binding model, 62, 82, 152, 154, 229  
 random, 56–57
- Time-temperature-transformation (TTT) diagram, 376, 378

- Torque, magnetic, 261
- Toughness, 321, 374, 378, 381
- Transistor, 112–132, 147, 364
  - bipolar junction, 123–127
  - DRAM, 363
  - field-effect (FET), 123, 127–129
  - gain, 124–125
  - HEMT, 130
  - heterojunction bipolar (HBT), 126–127
  - MESFET, 131–132
  - MODFET, 130
  - MOSFET, 132, 134, 364
  - thin film (TFT), 115, 130–131, 360
- Transition element, 85
- Transition metal, 266
- Transmission electron microscope (TEM), 340, 356, 445
- Traps, 121, 356, 369, 499
- Tunneling, 527
  - energy, 81, 229
- Twin, 376
- Two-dimensional electron gas, 132
  
- Ultraviolet photoemission spectroscopy (UPS), 454
- Unit cell
  - body-centered tetragonal, 374
  - orthorhombic, 224
  - tetragonal, 270
- Urbach edge (tail), 114
  
- Vacancy, 51, 227, 367, 369, 499
  - concentration, 49
  - Frenkel defect, 34
  - Schottky defect, 33–34, 48
- Valence, 22–23
  - electron, 10
  - mixed, 223–224, 253
- van der Pauw method, 477
- van der Waals bonding, *see* Bonding, van der Waals
- van Hove singularity, 42–43
  
- Van Roosbroek-Shockley relation, 118
- Vaporization, 52–53, 411
- Vapor pressure, 52–53, 115, 354, 391, 411
- Variable-range hopping, 115
- Vegard's law, 147
- Velocity, thermal, 120
- Verdet constant, 258, 290, 292
- Vibrating-sample magnetometer, 481
- Viscoelasticity, 180
- Viscosity, 193–194, 213–214
- Void, 113, 275, 369
- Voigt effect, 259
- Volmer-Weber growth, 341–342
- Voronoi polyhedron, 27
  
- Wear resistance, 388, 390
- Weertman-Ashby map, 96–97
- Welding, 383
- Wigner crystal, 62
- Wigner-Seitz cell, 41
- Williams-Landel-Ferry equation, 193–194
- Work function, 331, 454
  - negative, 501
- Work hardening, 92–94, 96, 378–379
  - Taylor's theory of, 94
  
- X-ray diffraction
  - Laue, 415
  - powder, 415, 514
  - rotating crystal method, 415, 418
  
- Yield
  - stress (strength), 95, 163, 379–383
  - stress, shear, 93, 95, 99
- Young's modulus, 87–91, 100–101, 339, 397
  
- Zeeman effect, 493
- Zener model, 89–91
- Zero-point energy, 41