INDEX

0.18 \( \mu \text{m} \) optical lithography, 117
0.25 \( \mu \text{m} / 256 \) Mbit generation: KrF step-and-scan, 111
0.35 \( \mu \text{m} / 64 \) Mbit generation: high NA i-line and DUV, 109
193-nm lithography, resists, 352–372
1994 SIA Roadmap, 383
250-nm metrology, 582
3D process modeling, 664

Acid diffusion, 334
Adhesion, 457
Advanced probe linewidth metrology, 571
Aerial image, 24, 637
Alignment, 94, 195, 299, 696
Automation, 568

Backscattering, 158
Basic yield formula, 751
Beam blanking, 154
Beam delivery systems, 276
Beam heating, 696

CAD programs, 197
Calibration, 483
Cameras, 508
Cascaded systems, 259
CD SEM system, 553
Cell projection, 188
Charge dissipation, 204
Charged particle, 691
Charging, 696
CIF, 199
Computational models, 264
COP, 210
Critical dimension control, 382

Data analysis, 509
Data preparation, 193–201
Deep-UV resists, 321–375
Defect printability, 658
Defects, and pattern fidelity, 383
Defects, hard, 447
Defects, PSM, 448
Defects, soft, 447
Depth of field, 505
Depth-of-focus, 748
Development, 627
Diffraction, 530
Diffractive optics, 304
Divergence, 335
Dose modulation, 162
Dry-etch damage, 740
DUV process considerations, 346
DXF, 200

E-beams, 692
EBR-9, 206
EL-4 system, 417
Electrical linewidth metrology, 543
Electron beam lithography, 139–249
Electron beam lithography, systems, 164–193
Electron beam deflection, 153
Electron gun designs, 559
Electron image formation, 564
Electron lenses and detectors, 151, 557
Electron optical elements, 152
Electron optics, 147–157
Index

Electron sources, 147, 553
Electron-solid interactions, 157–161
Environment, 164
Error analysis, mask, 464
Etch resistance, 345
Etec MEBES systems, 181
Etec Systems Excaliber and Leica, 186
Exposure, 295, 421, 601, 623, 662
Extreme ultraviolet lithography, 717

Feature measurement, 443
First-order correction, 649
Focus, 57, 507, 632
Forward scattering, 158
Fresnel diffraction, 261
Full scalar model, 650
Fundamental limits, 685

Gaussian spot mask writers, 181
Gaussian vector scan systems, 171
GDSII, 198
GDSII stream format, 218–231
Geometrical image, 260
GHOST, 163
Global mask optimization, 291

High penetrating power, 304
High-numerical-aperture effects, 648
High-resolution lithography, 302

IBM EL-4, 186
Illumination systems, 91, 505
Image processing, 508
Image thermal stability, 338
Images at the small feature limit, 615
Images in projection printing, 605
Imaging, 13–82
Imaging materials, 421
Imaging models, 601–618
Inorganic and contamination resists, 216
Inspection, 447
Ionizing radiation effects, 738

JEOL systems, 174, 187

Leica EBL Nanowriter, 171
Leica lithography systems, 176, 178

Lens effects, 503
Lepton EBES4, 183
Linearity, 488, 581
Linearity metrology, 527–581
Lithographic Systeme Jena ZBA 31/32, 186
Low/high molecular weight PMMA, 213
Low-level formats, 201
Lumped parameter model, 642

Magnification/field of view, 562
Mask defects and inspection, 447
Mask distortion, 282
Mask fabrication, 286, 420–442
Mask parameters, 381
Mask processing, 453–463
Mask transmission, 262, 663
Mask types, 385–390
Masks, 381. See also Photomasks.
Masks, binary, 385
Masks, halftone and embedded phase shift, 389
Masks, optical proximity correction, 387
Masks, phase shift, 388
Masks, proximity effect corrections, 386
Masks, x-ray, 280–297
Materials manufacturing, 350
Measurement algorithms, 519
Measurement optimization, 523
Measurement systems, 501
Metrology, 442, 475–596
Metrology, limits of, 728
Metrology, linewidth, 527–581
Metrology, overlay, 496–527
Metrology standards and artifacts, 478
Microlithography, history, 3–9
Minimum resolved period, 749
Mix-and-match strategies, 108
Modeling, 597–680
Modeling, electron beam, 160
Modified illumination, 644
Multibeam direct-write systems, 694
Multilayer resists, 369
Multilayer systems, 213

Nanolithography, 303, 681–755
Nanometer pattern generation system (NPAC), 168
National Technology Roadmap—stepper requirements, 83
Negative resists, 210, 212
Negative-tone process considerations, 347
Off-axis illumination, 71
Opaque films, 394
Optical components, 502
Optical constants, x-ray, 256
Optical linewidth metrology, 530
Optical lithography, 11–138
Optical lithography, limits of, 686
Optical lithography modeling, 597–680
Optical profiles, 530
Optical proximity effects, 68
Optical waveforms, 536
Overlay, 494
Overlay metrology, 496–527
Overlay registration measurement, 525
Overlay target design, 522

Parallel beam architectures—microcolumns, 192
Particle projection tools, 702
Particle-limited defect yield statistics, 731
Pattern biasing, 163
Pattern inspection and repair, 289
Pattern placement, 443
Pattern position, 382
Pattern recognition, 508
Pattern structure, 193
Patterning, x-ray, 265
PBS, 207
PG3600, 200
Phase-shifting masks, 74
Photomask cleaning, 455
Photomask specifications, 381–384
Photomask substrates, 390–395
Photomasks, 377–474. See also Masks.
Photoreists, history, 327
Photoreists—operational considerations, 38
Pitch, 486
Plasma etching, 366
PMMA, 205
PMMA/copolymer, 214
Point sources, 268
Poisson distribution, 752
Polymers, 365
Positive resists, 205
Positive-tone process, 347
Process asymmetries, 518
Process control, 526
Process latitude, 730
Process-induced damage, 738
Proximal probe electron lithography, 710
Proximity effect, 161–164
Proximity period, 749
Pupil plane filtering, 73

Quality control, 350
Quantum effect devices, 681–755

Raith pattern generators, 169
Reduction lenses, 86
Reflection control, 340
Reflection suppression, 349
Reflectivity control, 367
Resist materials, DUV, 330–346
Resist materials, properties, 334–346
Resist postexposure bake and chemical amplification, 654
Resist processing, 435
Resists, 193-nm lithography, 352–372
Resists, chemically amplified, 334
Resists, deep-UV, 321–375
Resists, electron beam, 201–217, 425
Resists, etch resistant, 359
Resists for quantum device manufacture, 720
Resists, high-performance, 366
Resists, multilayer, 369
Resists, negative, 333, 432
Resists, positive, 330, 425
Resists, single-layer, 357–365
Resists, tool evaluation, 357
Resists, x-ray, 300
Resolution, 155, 505, 697, 746

Scalar modeling, 648
SCALPEL, 189
Scanning probes, 217
Scattering, 530
Second-order correction, 649
Secondary electrons, 159
Self-assembling systems, 744
SEM and STEM conversions, 165, 168
SEM linewidth metrology, 547
SEM resolution/sharpness, 549
Shaped spot and cell projection systems, 184
Shipley SAL, 211
Simulation, 632–653, 664
Software, 163
Specimen effects, 566
Statistical formulas, 751
Stepper productivity, 101
Stepper systems, 83
Stepper total overlay, 97
Steppers, 0.35 µm to 0.18 µm, 109–119
Steppers, x-ray, 297–300
Stigmators, 154
STM writing, 192
Stochastic effects, 694
Stress and distortion, 281
Substrate interactions, 619
Substrate material, 393
Substrate size, 390
Substrate surface quality and flatness, 393
Substrate topography, 663
Substrates, photomask, 390–395
Super-FLEX, 73
Synchrotrons, 269, 278

Target asymmetry, 515
Thin film optics, 42
Thin imaging layers, 217
Top-surface imaging, 369
Trilayer systems, 215

ULSI, 302

Vector model, 652

Wafer handling, 502
Wafer/resist interactions, 619
Wafer stage, 92

Wafer steppers, 82–109
Wave-space view of projection printing, 612

X-ray image formation and modeling, 257
X-ray lithography, 251–319, 704
X-ray lithography, systems and components, 267
X-ray mask design, 289
X-ray properties, 255
X-ray sources, 267–280

Yield assessment, 119, 730–737

ZIP, 208
Zero-order scalar model, 648