Index

0.07-NA EUV imaging system, 29
0.08-NA Schwarzschild imaging, 15
0.0825 NA \text{mask}, 241
0.25 NA, 2, 25, 603
0.33 NA, 229, 237, 242, 248–253, 295, 447, 599–600, 603, 605, 609–610, 616
0.45 NA, 2, 242, 248, 266, 473
0.5-NA six-aspherical-mirror imaging system, 27
0.50-NA ring-field imaging system, 28
0.5 NA MET, 232
0.5 \sigma, 232
0.55 \sigma, 266
0.55 NA, 251–253, 600, 603, 610, 616, 618–619, 655
0.7 \sigma, 652
2-butanone, 540
2 tert-butoxycarbonyl (tBOC)-protected functional groups, 524
2,2,2-trifluoroethyl a-chloroacrylate (EBR-9), 37
2D disk, 383
2D PSD of the surface topography ($PSD_{2D}$), 31, 274, 282, 285, 288, 293
3D EUV mask effects, 314, 412, 429, 461, 473, 611, 614, 615, 621
3D spherical target, 135
4X reduction, 241
5X reduction, 16
10X-II Schwarzschild, 15
10X reduction microstepper, 67
20X reduction Schwarzschild optics, 19

A
Abbe, Ernst, 26, 598
aberration correction, 25–26
ABRIXAS mission, 259
absolute figure uncertainty, 28
absorbance $A$, 500–501
absorbed power density, 270
absorber-over-layer reflection masks, 19
absorber patterning 35, 91, 102
absorber shadowing, 247, 249
absorber thickness, 247, 429, 444, 459, 468
absorption coefficient, 37
—of PMMA, 24
absorption data, 690
absorption edge of C, 7, 351
absorption edge of Si, 5, 33, 37
acceptance testing procedure (ATP), 316
acetal blocking groups, 520
acetal protecting groups, 521
acid amplifier (AA), 526
—3BH, 527
acid-catalyzed deblocking, 520
acid-catalyzed crosslinking, 523
acid quantum yield, 512, 513
acid-sensitive dye (Coumarin-6), 509, 511
acrylate polymer, 521
actinic blank inspection (ABI), 421, 433–435
actinic wavefront metrology, 39, 625
action requirement (AR), 66
actuators, 105, 131, 626, 627
acyclic-fluorine-containing monomer, 522
aerial image 112, 246, 249, 449, 661
—contrast, 35, 429, 462, 520, 597, 610, 612, 628, 654, 645, 680
—LER PSD, 661
—metrology, 230, 233
—microscope, 311
—modeling, 653, 660, 669
—PSD, 661
—scanner, 309, 310
—shape, 561
—simulation, 441, 669
—slope, 673
Aerial Image Measurement System (AIMSTM), 227, 308
—typical use, 310
AES, 68
Airy disk, 289
Airy function $PSF_0(r)$, 289
aliphatic esters, 502
Alpha Demo Tool (ADT), 228, 232
—metrology, 233, 565, 606, 608
alternating phase shift mask, 461, 470
—modified, 461
ambient hydrocarbons, 345
AMD Typhoon, 233
amorphous-titanium–doped fused silica, 275
amplified spontaneous emission (ASE), 177
amplified spontaneous emission (ASE), back-propagating, 176
amplitude defect, 433
—repair, 439
anamorphic imaging, 249, 253, 614
anamorphic system, 614
—high-NA, 615
angle-resolved scattering (ARS), 281
annulus (or ring field), 271
antireflective coating (ARC), 413
a-periodic multilayer coatings, 300
aplanatic design, 255
ArF resist polymers, 522
Arrhenius law, 302
asphere, 17, 27, 227, 272
—fabrication, 19, 28
aspheric departure, 26
aspheric surfaces, 2
Association for Super-Advanced Electronics Technologies (ASET), 20
astigmatic errors, 273
astigmatism, 25
at-wavelength inspection, 35, 37
atomic force microscopy (AFM), 10, 275, 525
atomic hydrogen cleaning, 390
atomic scatter factors, 689
attenuated phase shift mask, 461, 466
Au-drum target, 39
AZ PN114, 38

B
backscattered primary electron (BSE), 444
backside conduction layer, 413
barrier layers, 301
beam transport system (BTS), 114
Beer–Lambert law, 629
Berkeley direct contrast tool (DCT), 540
Bessel function of the first kind, 289
BESSY, 230
Biafore full stochastic model, 556
Bicerano’s graph-theoretical method, 503
bidirectional scattering distribution function (BSDF), 281–283, 285
bipyridine ligands, 542
bismuth oligomers, 541
bis-phosphine palladium oxalates, 543
BL1b, beamline, 346
BL8, beamline, 350
blazed-grating filter, 259
bore geometry, EQ-10195
Boremann effect, 372
boron carbide (B₄C), 302, 423, 455, 500
Bossung curve, 460, 461
bright-field image, 432
bright-field masks, 281, 543
bright-field signals, 434
Bragg reflection, 370, 412
Bragg wavelength, 23
Bragg’s law, 419
broadband coatings, 301
broadband mirrors, 300
buffer gas, 401
—specific heat capacity, 147
—alternatives, EUV transmission, 148
—alternatives, heat conductivity, 148
—mitigation, 385–387

C
CaF₂ birefringence, 74
capping layer, 185, 305, 340, 341, 413, 423, 427, 431, 437, 443, 466
—carbon, 338
—ruthenium, 342, 345, 432, 457
—SiN, 398
—standard benchmark, 341
—TiO₂, 342, 343
—ZrN, 398, 399, 401
carbon (C), 3, 34, 302, 423
carbon-based resists, 24
carbon contamination, 37, 337
carbon deposition, 336
carbon growth rate, 350
—for several wavelength bands, 350
carbon K x-rays, 5
carbon layer, 305, 336
carbon nanotube (CNT), 455
carbon removal, 336
carbonaceous film, 351
carbonaceous layer, 339
carbonization, 336, 338, 339, 345
carboxylate ligands, 537
Cassegrain multilayer telescope, 33
Cassegrain reflector, 256
catalytic probes, 395
Center for Plasma-Material Interactions (CMPI), 376
centroid wavelength shift, 437
charge-and-deflect concept, 132
charge exchange collision, 381
chemical mechanisms of EUV exposure, 505, 508, 517
chemical sensitivity, 505
chemically amplified resist (CAR), 356, 497, 505
—non-CAR, 503, 563, chief ray angle (CRA), 473
chief ray angle at object side (CRAO), 241–243, 246–248, 271–272, 610, 621
chipmakers, leading-edge, 82
chirp rate, 177
chromatic vignetting, 24
CLEARCERAM®, 275
clearing dose $E₀$, 497
CO₂ laser, 166, 178–179
—amplifier, 120
—beam diameter, 169
—high-power, 114, 120
coating influence on the PSD, 305
coefficient of thermal expansion (CTE), 256, 626
coherence time, 664
coherent scattering microscopy (CSM), 472
collector contamination, 370
collector lifetime, 40, 142, 146, 219, 371, 386, 401
colloidal graphite-coated target, 4
counter-controlled optical surfacing, 17, 28
counter-controlled polishing (CCP), 274
counter-generated holographic nulls, 17, 29
COMSOL Multiphysics®, 396
concave spherical mask, 7
condenser mirror, 39
—lifetime, 41
contact hole (CH), 240, 443, 457, 543, 554, 557, 559, 594
contact hole printability, simulation, 619
contamination growth, 349, 355
contamination rates, 345, 347, 349
continuous slowing-down approximation (CSDA), 510
continuous-wave source, 346
continuum model of absorption, 549
conversion efficiency (CE), 10, 38, 116, 120, 123, 136, 166, 182, 198, 213, 383
cooperative research and development agreement (CRADA), 13, 59
COSTAR correction optics, 28
Coulombic acceleration, 376
cracking efficiencies, 388
critical dimension (CD), 22, 112, 597
critical dimension uniformity (CDU), 271, 281, 598, 604, 659
critical illumination, 13, 265
cryogenic pellet targets, 41
dibenzyl tin dibenzoate, 544
—imaging capabilities, 544
diffraction-limited imaging, 8
dilatometer, 415
Dill A parameters, 501
Dill B parameters, 497, 501
Dill C parameters, 497
Director of Defense Research & Engineering (DDR&E), Office of the, 67
discharge-produced plasma (DPP), 75, 113, 193, 207, 214, 254, 370, 422
discrete model of absorption, 549
discrete stochastic models, 548
disk-shaped electrodes, 207
disk target, 135, 170, 171
dome target, 171
dose-controlled EUV power, 129
dark-field scanning mode, 432
dark-field signal, 434
debris mitigation, 38, 40, 142
—magnetic, 150, 166, 381
debris shields, 209
decadic TISD, 289
defect reduction trend of EUV mask blanks, 426
defect signal enhancement, 438
defect signal intensity (DSI), 433–435
defect smoothing, 425
Defense Advanced Research Projects Agency (DARPA), 67
Department of Commerce (DOC), 67, 88
Department of Defense (DOD), 67
Department of Energy (DOE), 67
deprotection strategy, 533
depth-graded multilayer coatings, 300
depth of focus (DOF), 22, 240, 461, 600, 652
diamond grinding wheel, 28
disk-shaped electrodes, 207
disk target, 135, 170, 171
dose-controlled EUV power, 129
Index

Dose error, 118, 281, 598
Dose stability and control, 118, 155, 183, 215, 221
Dose tolerance, 240
Double-logarithmic PSD curve, 286
Drive laser, 110, 118, 119, 121, 123, 124
—high-power, 126
Droplet generator (DLG), 114, 131
—parameters, 131
—steering system (DGSS), 154
Droplet steering, 154
dual stage, 628
duty cycle, 116, 119, 136, 183, 212
DUV binary mask, 413
DUV plasma spectra, 140
DUV ZEISS AIMS, 309
dynamic gas lock, 357

E
\(E_{size}\), 542
economic downturn, 85
Edge placement error (EPE), 604
Effective attenuation length (EAL), 351
Eight-mirror shell collector, 257
Elastic scattering, 507
electro-optical modulation, 175
electron-beam deposition repair, 446
electron-beam evaporation, 304
electron-beam-induced deposition of carbon, 337
electron-beam projection lithography (EPL), 68, 84
electron-beam repair, 442
electron binding energies, 689, 699
electron density, 97, 171, 395, 418
electron ionization, 506
electron temperature, 114, 171, 378
electron trapping, 513
electron travel range, 515
electrostatic clamp, 634
electrostatic repeller field, 40
electrostatic wafer chuck, 15
Ellipsoid collector, 260
Ellipsoid mirror, 256, 260
Embedded phase shift mask structure, 469
Energy extraction efficiency, 178
Energy overhead, 155
Energy sector analyzer (ESA), 376–377
EMF, 195
Engineering Test Stand (ETS), 17, 58, 110, 308, 660
Environmentally stable chemically amplified resist (ESCAR), 518–519
EQ-10, 193
ESA’s XMM-Newton x-ray observatory, 259
ESPRIT, 229
Etch selectivity, 465
Etch stop layer (ESL), 465–467
Etched binary mask, 464
Etched flux, 388
\(\text{étendue}\), 116, 118, 196, 198, 212, 255, 265, 312
EUCLIDES, 20, 229
EUREKA, 299
EUV-2D, 504
EUV beam analyzer, 210
EUV blank multilayer requirements, 413
EUV camera, 211
EUV chemically amplified resist (CAR), 508
—electron trapping, 508
—hole-initiated, 508
—internal excitation, 508
EUV dual pods, 314
EUV emission
—position stability, 216
—volume, 208
EUV illuminator, 622
EUV-induced cracking, 351
EUV interferometry, 32
EUV light
— film absorbance, 504
— incoherent sources, 113
EUV LLC, 2
— risk-level definitions, 70
EUV mask
— defects on, 311
— fabrication process flow, 414
— shadowing effect, 459
EUV Mask Infrastructure (EMI) consortium, 308
EUV multilayer, TEM image, 337
EUV multilayer, microstructure, 342
EUV optical density, 502
EUV optical system, 227, 241
— resolution, 241
EUV pellicle, 428, 454, 635
— guidelines and requirements, 453
— mounting, 637
— principle, 637
— temperature profiles, 455
EUV penetration region, 667
EUV polarimeter, 299
EUV power at IF, 120, 129
EUV projection system, first, 605
EUV reflectance spectra, theoretical and experimental, 420
EUV reflectivity, 300
— measurement, 395
EUV reflectometers, 422
EUV resist absorbance, 503
EUV scanner, optical column, 611, 614–615
EUV scanner, optical train, 228
EUV scanner ring field, 313
— emulation, 313
EUV source, Sn-based, 622
EUV source requirements, 116
— cleanliness, 116
— EUV power (inband), 116
— integrated energy stability, 116
— size, 117
— output, étendue, 116
— max. solid angle input to illuminator (sr), 116
— repetition frequency, 116
— spectral purity, 116
EUV source–scanner interface, 153
EUV source tin consumption, 152
EUV source vessel, 113, 115
EUV spectrometer, 201
EUV step-and-scan system, 595
— principle, 594
— productivity, 595
EUV–visible scintillator, 211
EUVL exposure tool overview, 620
even aberrations, 625
Evolving nano-process Infrastructure Development Center (EIDEC), 355
Exitech Ltd, 232, 311
exposure latitude, 118, 240, 521, 528, 600, 623
exposure wavelength, 22, 227, 233, 369
extinction coefficients of materials at 13.5-nm wave length, 453
extracavity modulation, 175
extreme-ultraviolet lithography (EUVL), 2, 3, 11, 21, 22
Extreme Ultraviolet Lithography System Development Association (EUVA), 20
EXULT project, 20, 299

F
f, 120
fabrication tolerance, 276
far-field test tool (FFTT), 138
Faraday cup (FC), 379
fast axial flow (FAF)
fast electrical pulse, 194
figure, 28, 230, 271, 272, 279, 305
— control, 277–278
— correction, 274
—errors, 29, 34, 273, 275, 280, 289, 293, 305, 307
—metrology, 276
fast transverse flow (FTF), 121, 178
field facet module, 622
field of view (FOV), 309
film quantum yield (FQY), 509
Fizeau interferometer, 11, 19, 277
flare, 16, 32, 236, 239, 291, 297
—density $FD^{(n)}$, 296
—efficiency function, 295–296
—sources, 279
flexible illumination, 237, 268, 609
—modes, 623
flexure-suspended balance masses, 627
fluoropolymers, 502, 504
fly’s eye integrator unit, 266
focus offset optimization, 438
focused ion beam (FIB), 429, 437, 446
footprint, 209, 221
Foucault testing, 32
four-aspherical-mirror reflective imaging system, 26
four-mirror EUV imaging system, 17
fractal, 31
fragments, number of, 173
Fraunhofer Institute for Laser Technology (ILT), 207
free-radical polymers, 522
frequency-doubled Nd:YAG laser, 39
Fresnel number, 179
front-opening unified pod (FOUP), 634
full-aperture interferometer, 275
full-field production tools, 609
full-field tools, 228, 606, 608–609
—EUV1, 228, 234, 608
full scanner emulation, 312
full-time equivalent (FTE), 83

G
g-line of mercury (Hg), 5
gain switching, 174
gallium ions (Ga$^+$), 446
gas chromatograph with a mass spectrometer (GC-MS), 354
gas field ion source (GFIS), 446
gas jet, 40
gas puff targets, 41
GC-MS with cryofocusing, 354
glass ceramics, 275
glass transition temperature $T_g$, 522, 523
grazing-incidence collector, 255, 375
—Wolter type, 255, 256
grazing-incidence optical system, 15
grazing-incidence Ru collector, nested, 219
grazing-incidence Ru collector lifetime, 219
grazing-incidence Ru mirror, 220

H
H$_2$ bubbles, 147, 400
hafnium oxide, 535
hafnium oxide sulfate (HafSOx), 535
Halbach array, 379
Han stochastic model, 553
Henke elemental absorption coefficients, 503
Henke tables, 37
hexafluorine (SF$_6$), 431
Hidaka Koukaku, 11
high-density gas clusters, 41
High Energy Physics Laboratory, 5, 19
high NA, 232, 241, 244, 246, 249
—DUV ZEISS AIMS tool, 309
—multiple-patterning extension, 639
—QF, 613
—scanner, 600, 619
High Power EUV Irradiation Tool, 357
high-power seed system (HPSS), 126
high-precision metal replica process, 258
high-pupil-frequency aberration, 291
high-resolution encoder sensor, 626
high-spatial-frequency roughness (HSFR), 17, 31, 273, 279, 305, 415
Himeji Institute of Technology (HIT), 20
HiNA, 232
Hinsberg stochastic model, 553
hole-initiated chemistry, 511
homolysis of tin–carbon bonds, 540
homolytic cleavage of the M-carboxylate bond, 545
honeycomb mesh structure, 454
horizontal/vertical (H-V) bias, 234
hot filament hydrogen radical source, 388
hydrogen-based cleaning, 373
hydrogen buffer gas pressure, 144
hydrogen etching of Sn, 388
hydrogen implants, 401
hydrogen penetration, 185
hydrogen radical, 336, 358—cleaning, 391
hydrogen silsesquioxane (HSQ), 562
hyperboloid reflector, 256
image quality, 250
IMEC—Interuniversity Microelectronics Centre, 228
in situ cleaning, 40, 102, 105, 156, 371, 387
inband EUV brightness, 198, 213
inband EUV output power, 213
inband EUV spectrum, 117
inplane distortion (IPD), 430
intensity dependence, 345–349
intensity uniformity, 263
interdiffusion, 301, 338
interface roughness, 301, 424
interferogram, 231
interferometry-based metrology, 231
intermediate focus (IF), 112, 153, 219, 228, 621
internal excitation, 514
inverse Cassegrain, 25
ion average charge state, 171
ion-beam figuring (IBF), 274
ion-beam projection lithography (IPL), 68, 84
ion-beam sputter deposition (IBD), 36, 304, 420
ion polishing, 425
ion spectra, 378
ion wind, 134
ionization rate of Sn, 173
IR drive laser, 262
IR-suppression grating, 262
iridium (Ir)-coated Schwarzschild optic, 8
isomorphic system, 614
ITRS, 42, 60, 602

J
joint development agreement (JPA), 68
joint development program (JDP), 61
**K**
- $k_1$, $k_2$, 22, 226, 597, 600
- ketal protecting group, 532
- ketone, 532
- kinetic traces, 511
- Kirchhoff mask, 463
- Köhler critical-illumination system, 20, 265–267
- Köhler design, 10
- KrF excimer laser, 10
- KrF laser-induced soft-x-ray source, 20

**L**
- L$_4$Pd complex, 544
- large-scale integration, 42
- Larmor movement, 166
- laser amplifier, 120
- laser-assisted discharge-produced plasma (LDP), 207
- laser-induced fluorescence, 172
- laser plasma source, 10
- laser power, 120
- laser-produced plasma (LPP), 38, 40, 109, 112, 113
  - sources, 113, 115, 126, 166
- laser shockwave cleaning (LSC), 457
- laser-to-droplet targeting, 155
- laser-to-droplet timing, 154–155
- layered synthetic microstructure (LSM), 4
- lifetime, 118
- lifetime studies, 338
- line-edge roughness (LER), 38, 43, 415, 539, 549, 556–557
  - modeling, 671
- line-edge roughness transfer function (LTF), 660–663
- linewidth roughness (LWR), 503, 526, 529, 533, 563, 569, 604
- liquid-droplet target system, 20, 41
- liquid metal ion source (LMIS), 446
- liquid tin, 208
  - bath, 207–208
  - thermal conductivity, 209
- lithium salt of ethylenediamine (LiEDA), 37
- lithographic resolution, 652
- load mismatch, 201
- local-oxidation-of-silicon (LOCOS), 17
- local critical dimension uniformity (LCDU), 598–599, 604, 618
- long-term aberration drifts, 626
- longwave surface figure errors, 275
- low-activation-energy system, 521
- low-departure aspheric reflectors, 16
- low-energy electron scattering in solids (LESiS), 510, 516
- low-étendue source, 265
- low-LER dibenzyl tin complexes, 544
- low-spatial-frequency roughness (LSFR), 280
- low-thermal-expansion material (LTEM), 34, 413

**M**
- magnetic debris mitigation, 150, 166, 381
- magnetic plate, 627
- magnetically levitated wafer stage, 15
- magnetorheological figuring (MRF), 274
- magnetron sputtering, 304
- magnification (MAG), 230, 241–243, 251
- mandrels, 258
- Maréchal criterion, 32, 276
- Marshall Space Flight Center, 3
- mask effect on high-NA imaging, 247
- mask efficiency, 250
- mask error enhancement factor (MEEF), 470
- mask (reticle) handling, 636
mask heating, 632
mask MSFR (slope error), 415
mask stage, 628
mask writing errors, 598
mass-limited target, 40, 114
master oscillator power amplifier (MOPA), 110, 114, 121, 175
—architecture, 123
—with pre-pulse, 121
mechanism for the generation of acid in CARs, 512
MEDEA+ Extreme UV Alpha Tools Integration Consortium (EXTATIC), 21
Media Lario Technologies, 259
megasonic cleaning, 418
MET5, 232, 606
metal-containing resists, 568
metal-oxide films, 535
metal-oxide model, 559–560
metal–oxide semiconductor (MOS), 12
methacrylate \([-\text{O}_2\text{CC(CH}_3\text{)=CH}_2]\), 539
metrology source requirements, 198
Microelectronics Development for European Applications+ (MEDEA+), 21
micro-exposure tool (MET), 67, 228, 230, 563, 670
—image field, 228
micro-interferometers, 274
microscope, resolution limit, 226
mid-spatial-frequency roughness (MSFR), 16, 17, 32, 273, 279, 305, 415, 655
Mie scattering, 172
mirror surface errors, 655
mitigating gas, 357
Mo/Si coating at normal incidence, —peak reflectivity, 419
Mo/Si mirror reflectivity, 118, 227
Mo/Si multilayer, TEM image, 423
Mo/Si multilayer mirror
—long-term stability, 338
—planar, 211
—spherical, 211
Mo/Si stack, cross-sectional TEM image, 419
MoSi2, 342
mode-locking, passive or active, 174
modeling of resist
—development, 552
—exposure, 552
—image intensity distribution, 551
—initial resist rate, 551
—post-exposure bake, 552
modulation transfer function (MTF), 660, 662–663
moiré alignment system, 15
molar metal-to-sulfate ratios, 535
molecular dynamic simulation, 558–559
Molecular Organometallic Resists for EUV (MORE), 542
mononuclear organometallic complexes, 542
Monte Carlo modeling, 510, 533
multilayer defect avoidance (MDA), 440
multilayer mirror lifetime, 373
multilayer mirror reflectivity, 374
—theoretical, 373
multilayers as Bragg reflectors, 227
multiple-epoxy-containing crosslinker, 524
multiple patterning, 226
Multivariate Poisson Propagation Model (MPPM), 675, 678
—predicted LWR and CDU terms, 680
N
nanomachining, 444
nanoradian, 272
NaOH, 497
National Institute for Standards and Technology (NIST), 67, 344
Nd:YAG lasers, 208
negative chemically amplified resist AZ PN114, 497
negative-tone sensitivity of resists, 542
New Energy and Industrial Technology Development Organization (NEDO) Japan, 179, 185
next-generation lithography (NGL), 64, 230
niobium oxide, 305
no master oscillator (NOMO), 121
nonlinear coupled oscillator, driven, 195
non-null Fizeau interferometer, 29
nonstochastic continuum models, 548, 553, 569
normal-incidence
—design, 136
—collector, 375
—ellipsoid collector, 261
—EUV collector, 111, 114, 137, 255
—reflective optics, 3
—reflectivity, 6
normalized image log slope (NILS), 246, 264, 597, 612
Northrop Grumman, 87
novolaks, 502
NTT superconducting storage ring in Atsugi (Super ALIS), 13
nuclear magnetic resonance (NMR), 530
NuFlare Technology, Inc., 235
null corrector, 277
numerical aperture (NA), 2, 226
—further increase, 639
NXE:3100, 608
NXE:3300B, 109, 229
—illumination settings, 238
NXE:3350B, 109, 229, 237, 240, 599, 609
NXE:3400B, 109, 229, 609–610
—illumination settings, 238
O
obscuration impact on imaging, 246
odd aberrations, 625
off-axis illumination, 117, 226
off-axis Schwarzschild system, 25
Offner ring-field imaging system, 8, 16
on-product overlay (OPO), 602–603
—typical budget, 603
open-frame exposure, 248
open-loop power, 129
optical constants, 690
optical proximity correction (OPC), 234, 267, 553
optical transfer function (OTF), 660
optical triangulation, principle, 630
optics contamination, 335
—summary and outlook, 358
organometallic tin dicarboxylates \([R_2Sn(O_2CR)_2]\), 544
organosilane monolayer film, 37
out-of-band (OOB) energy monitor, 210
out-of-band (OOB) light, 173
out-of-band (OOB) radiation, 138
—power measurements, 215, 140
out-of-band (OOB) spectrum from EUV plasma, 174
out-of-plane distortion, 427, 428
overhead, 120
—time, 119
overlay errors
—application-specific, 602
—dedicated chuck, 602
—matched machine, 602
—related to customer process, 602
oxalate ligands, 545
oxalate loading, 542
oxidization, 338

P
PAG triphenylsulfonium tris (trifluoromethansulfonyl) methane, 511
palladium (Pd), 258, 342, 544
para-amide-styrene, 531
paraboloid mirror, 256
parasitic reflections, 122
parasitic seeding, 175
partial coherence (σ), 228, 229, 232, 264, 623, 653, 654, 664, 666
patents
—environment, 102
—ETS and illuminator, 103–104
—lithography, 104
—mask, 103
—metrology, 100
—miscellaneous, 105
—multilayer, 101–102
—optics, 100–101
—source, 104
Paul Scherrer Institut (PSI), 536
PdAu, 342
PdO, 429
peak brightness, 221
pedestal, 175
pedestal energy, 124–125
pellicle-mounting structure, 456
pellicles, 115, 450
—CNT-based, 456
—membrane, 452
pentafluorobenzene-sulfonic acid (C₆F₅SO₃H, PFBS), 530
perfluorobenzenesulfonate esters (3HC, 3MC, 2MC), 529
perfluorooctane sulfonic acid (PFOS), 530
periodic change relationship to figure change, 307
phase defects, 35, 417, 433
—printable, 436
phase-measuring interferometer (PMI), 28
phase shift error, 466
phase shift mask (PSM), 429
—relief-substrate, 657
phase-shifting point-diffraction interferometer (PSPDI), 22, 30
Ph₃Sb(O₂CH=CH₂)₂, 546
Ph₃Sb(O₂CH₃)₂, 546
Ph₅M(acrylate)₂, 545
photo-acid generator (PAG), 355, 504, 511, 678
—reduction potential, 514
photodecomposable nucleophile (PDN), 523
photo-electrons, 506
photo-ionization, 506
photolysis mechanism, 540
photon energies, 704
photosensitized chemically amplified resist (PSCAR™), 526, 532, 569
photosensitizer (PS), 533
photosensitizer precursor (PP), 532
PHS-type CAR, 508
d Physical constants, 698
physical interactions of electrons with molecular species, 507
Physikalisch-Technische Bundesanstalt (PTB), 298
plasma-assisted cleaning by electrostatics (PACE), 457
plasmon generation, 506
platinum oxalates, 543
point spread function (PSF), 288, 663
Poisson distribution, 548
Poisson number, 305
d poly-4-hydroxystyrene (PHS), 512
poly-4-methoxystyrene (PMS), 512
polybutene-1 sulfone (PBS), 37
polyhydrostyrene, 502
polymer backbone, 355
polymer-bound AAs, 531
polymerization of organic molecules, 337
polymerization olefin loading (POL), 547
poly(methyl methacrylate) (PMMA), 10, 37, 495–498
 —B and C parameters, 498
 —exposure sensitivity curves, 499
 —spectral characteristics, 496
polyphenolic molecule, 523
polystyrene latex (PSL), 458
polyvinyl phenol polymers, 521
positive-tone palladium oxalates, 543
post-exposure bake (PEB), 498, 677
power requirement, source, 116
power spectral density (PSD), 31, 270, 284, 660–661
precision aspheres, fabrication, 22
precision-to-tolerance ratio (P/T), 276
pre-pulse (PP), 110, 154
 —laser, 167
 —technology, 166
pre-pulse, picosecond, 168
pre-pulse-conditioned target, 110
pressure dependence, 347–350
primary growth mechanism due to secondary electrons, 340
process window, 252–253, 270, 599
 —simulation, 616
Programme Extreme UV (PREUVE), 21
projection optics, 228
projection optics box (POB), 67, 594, 606–609, 622
 —heating, 632
PROLITH, 510, 559
proximity effect test patterns, 431
proximity x-ray lithography, 68, 84
$PSF_{\text{flare}}$, 292
pulse count modulation (PCM), 155
pulse-forming system, 194
pulse radiolysis, 510–511
pulse-shaping switch, 124
pulsed-laser deposition, 304
pulsed source, 346
pupil facet mirror, 622
pupil fill ratio, 226, 237, 264, 269, 599, 609–610, 623
Q
Q-switching, 175
 —intracavity, 174
quantum cascade laser (QCL)
 —seeder, 177
quantum cascade laser (QCL), mid-IR emitting, 176
quantum efficiency (QE), 678
quarter-wave stack, 23
quartz crystal microbalance (QCM), 388
quasi-critical illumination, 256
quasi-conventional illumination, 313
quencher, 356
R
radiation hardness, 338
radiation hydrodynamics
 —simulation, 171
radiation-induced processes related to carbon contamination, 338
radical-cation hole, 505
radical flux, 388
RAVE LLC, 444
Rayleigh breakup mechanism, 133
Rayleigh criterion, 32
Rayleigh equation, 597
Rayleigh–Rice vector perturbation theory, 281, 295
Rayleigh theory of jet breakup, 132
reactive ion etching (RIE), 396, 496
reflection against an absorber pattern, 616
reflective Cook triplet, 26
reflective masks, 8
reflective multilayer coatings, 2
reflective triplet, 16
reflectivity from a MLM versus the number of bilayers, 376
refractive index, 226, 273, 280, 299, 302, 418, 429, 459, 467, 689
refractive null, 29
reliability tests, long-term, 217
repetition rate, 118
residual gas analyzer, 344, 353
residual hydrocarbons, cracking, 34
resists
—bilayer, 38
—chain-scission, 521–532
—electron-beam, 37
—EUV-2D, 519
—hafnium oxide nanoparticle, 537–539
—high-speed negative-tone, 545
—inVia XE151JB and XE151IB, 536
—KRS, 520
—MET-1K, 520
—metal-based, 503
—multinuclear, 542
—negative-tone hafnium oxide nanoparticle, photomechanism, 538
—negative-tone nonpolymeric-based EUV, 523
—noria-based, 523
—OFPR Novolak, 495
—open-source (OS1), 527
—organo-metallic
—inVia/Inpria dehydration mechanism and photomechanism, 536
—outgas test, 336
—penetration depth, 7
—sidewall profile, 24
—soft-x-ray, 8
—surface-imaging, 37
—trilayer, 38
—tri(phenyl)antimony diacrylate (JP-20), 545
—zirconium oxide nanoparticle, 537–539
resist film absorption, 501
resist film transmission, 501
resist–silicon-based positive photoresist (SPP), 495
resolution, 22, 226
resolution, LER, and sensitivity (RLS) tradeoff, 526, 534
rhenium-tungsten (Re-W) alloy, 3
rhodium (Rh), 258, 305
right of first refusal (ROFR), 61, 62
ring field, 27
ring-shaped field, 13
RMS^2 of the roughness, 283–284
RMS values of PSDs, 290
RMS density (RMSD), 286
R_{n}M(O_2C)_{2}, 545
Ronchi testing, 32
ROSAT, 259
rotating mechanical chopper, 40
Ru-capped multilayers, 343
Ru sputter rate, 218
ruthenium (Ru), 258, 305, 423
ruthenium oxide, 305
S
SAL601, 498, 499
scan velocity, 628
scanning electron microscopy (SEM), 308
scanning EUV reflective microscope (SERM), 449
scanning transmission electron microscopy (STEM), 343
scanning tunneling microscopy (STM), 500
Schwarzschild camera, 10, 498, 500
Schwarzschild imaging system, 8, 15
Schwarzschild optics, 2, 10, 25, 311, 495
scraper mirror, 434
second-row elements (e.g., C, O, N, F), 535
second-to-last mirror, 245
secondary debris, 152
secondary electrons, 506
secondary-ion mass spectroscopy (SIMS), 399
seed wavelength, 177
SEMATECH, 67, 228
—EUV Resist Center, 90
—Mask Blank Development Center, 90
—MET, 90
—NGL Task Force, 230
SEMI P37-0613, 412
—substrate requirements, 415
SEMI P38-1103, 428
SEMI P40-1109, 428
Semiconductor Equipment and Materials International (SEMI) standards, 96
Semiconductor Industry Association (SIA), 67
Semiconductor Research Corporation (SRC), 67
SHARP, 312
—microscope, 249
shadowing, 610–612
Si-capped multilayers, 343
SiC, 342
SiH_x, 400
Si/Mo ML reflectivity variation as a function of wavelength, 374
sidewall angle, 38
silane polymers, 504
silicide formation, 423
silicon carbide (SiC), 423
simulated resist image, 441
six-degrees-of-freedom short-stroke actuator, 627
six-mirror optical design, 272
slab-waveguide diffusion-cooled geometry, 178–179
small-field tools, 607
Sn deposition at the intermediate focus (IF), 384
S_N2 and S_N1 reactions, 531
SnH_4, 358
soft-x-ray projection lithography (SXPL), 7, 11
soft-x-ray reduction lithography, 8
Solar and Heliospheric Observatory (SOHO), 337
solid-state laser (SSL), 169
solid-state laser, picosecond, 168
SORTEC, 19
source head module, 207
source mask optimization (SMO), 237, 269, 623
source requirements
—ABI, 198, 212
—AIMS, 198, 212
—APMI, 198, 212
—high-power source for scanner, 116
spatial stability, 200
speckle pattern, 664–665
spectral content, 117
spectral purity filter (SPF), 259
spectroscopic ellipsometry (SE), 346
spherical equivalent volume diameter (SEVD), 417–418
sputtering yields for common MLM materials, 399
standard-mechanical-interface (SMIF), 420
—pods, 314
stannane (SnH_4), 144, 149, 387
Starlih® 3100, 228, 236, 267
Starlith®3300 wavefronts, 239
Starlith®3300/3400, 236
statement of work (SOW), 98
static random-access memory (SRAM) cell, 233
stochastic continuum models, 548
stochastic effects, 112, 549, 554, 675
stochastic model of absorption, 549
stochastic models, 559
stochastic resist chemistry, 569
Stoney equation, 305–307
Stopping of Range of Ions in Matter (SRIM) program, 385, 389
striae, 275
subaperture polishing, 28
substrate material requirements, 413
substrate phase defects, 37
supermirrors, 300
surface chemistry, 341
surface defect, 417
surface figure, 28
surface finish, 28
surface interferometry, 230
surface topography, 292
supersonic gas cluster targets, 41
supersonic hydrocleaning (SHC), 457, 458
SVG Lithography, 13, 63
synchrotron light source, 10, 39
Synchrotron Ultraviolet Radiation Facility (SURF), 197

T

T-butyl trifluoromethacrylate, 522
t configuration, 110
Tagawa/Kowaza modeling, 557–558
Tamaru’s redeposition coefficient, 396
TaN absorber layer, 429
target density, 136
target shape, 136
TaSiN, 431
telecentricity, 10, 25, 249, 265, 473, 612
temporal stability, 200
tetrahydrofuran, 511
thermal instability, 424
thermal load, 116, 254, 262, 303, 632
thermal stability of EUV multilayers, 302
Thomson scattering, 171
three-aspherical-mirror ring-field imaging system, 16, 20
through-focus compensation repair, 442
throughput, 22, 43, 115, 116, 595, 609–610, 614–615
tin (Sn)
—circulation modules, 208
—cleaning rate, 149
—cleaning technique, 142
—clusters, mechanism of photolysis, 540
—deposition rate, 184
—droplets, 130
—management inside the vessel, 151
—removal from the vessel, 152–153
tin-ion stopping power, 143
tin jet breakup, 132
tin-oxo cages, 539
tin-oxo cluster
[(n-BuSn)_{12}O_{14}(OH)_{6}], 540
(p-CH_{3}C_{6}H_{4}SO_{3})_{2}, 540
tin-oxo cluster [(RSn)_{12}O_{14}(OH)_{6}] X_{2}, 539
tin plasma, optimum ion density, 169
Tinsley Laboratories, 11, 68
TiO_{2}, 342
TIS density (TISD), 286, 294
TIS values of PSDs, 290
titanium dioxide, 305
TMAH (0.26 N
tetramethylammonium hydroxide), 498, 522
TMAH-developable system, 524
toroidal mirrors, 10
total electron yield (TEY),
509–510, 513
total integrated scatter (TIS), 280, 285, 303, 655
total wavefront error, 625
transition-metal oxalates, 542
transmission image sensor, 631
transmission of 10-nm-thick Sn layer, 145
transmission mask, 10, 231
transverse flow of CO$_2$ gas, fast, 121
triflic acid (CF$_3$SO$_3$H or TfOH), 530
trifluoromethyl (-CF$_3$) group, 529
trigger-body design, 530
Trumpf TruFlow laser series, 178
—amplifiers, 121
TRW Inc., 68
tungsten-carbon ML, 5
turning mirrors, 119
turnover numbers, 546
two-aspherical-mirror imaging system, 10, 12, 13, 19
two-mirror illumination system, 10

U
ULE®, 275
Ultratech, 68
ultraviolet cleaning, 459
uniformity correction module (Unicom), 624
United States Advanced Lithography (USAL), 63
U.S. National EUV Lithography Program, 13, 18
UV-Vis-IR absorbance, 511

V
vacuum vessel, 114
Veeco Instruments, 68
—low-defect-deposition ML tool, 37
Virtual National Laboratory (VNL), 61
—Resource Development Center (RDC), 87
volume sensitivity, 497
—parameter, 505

W
wafer heating, 632
wafer load sequence, 634
wafer stage, 627
wafer throughput model, 115
wafer-to-wafer heat exchange, 119
wafer topology, 630
wafers, cumulative number of exposed, 638
wall angles, 499
wavefront aberration, 271
wavefront error, 14, 273, 669
—aberration-driven, 273
—total system, 32
wavefront metrology, 20, 630
wavelength dependence, 350–351
wavelength reduction, 639
wet etchability, 466
white-light interferometry, 17
white papers, 72
witness sample, 355
Wolter, Hans, 255
Wolter collector, 255, 266
Wolter type-1 system, 256–257
Wolter–Schwarzschild design, 256

X
xMT, 524
x-ray diffraction (XRD), 422
x-ray fluorescence, 218
x-ray photoelectron spectroscopy (XPS), 343
x-ray proximity lithography (XPL), 5, 12
x-ray reduction lithography, 5
xenon plasma, 195

Y
YAG-laser-driven LPP, 214
yttria-stabilized zirconia, 342

Z
Z-parameter, 527–528, 563
Z-pinch, 193
Zernike, Fritz, Jr., 13
Zernike coefficients, 236
Zernike polynomials, 236, 625
zero-crossing temperature (ZCT), 275, 626
ZEROdUR®, 3, 230, 275
zero-valent palladium-phosphine complexes, 544
zirconium (Zr) foils, 196
zirconium dioxide, 305
zirconium oxide sulfate (ZircSOx), 535
zone plate, 8, 311, 434, 449
Zr-coated Si photodiode, 210
ZrHx, 400
ZrN, 400
Zr/Si3N4 filter, 211