

## Index

### **a**

- acoustic cross talk 78–81
- acoustic monitoring 145
  - air bubbles 153–156
  - dirt 152–153
  - drop formation, refill, and wetting 150–152
  - printhead control 156–157
  - self sensing 145–150
- acoustic signal 146
- active tags 314
- aerosol jetting 285, 290
- air bubbles 153–156
- all-oxide invisible transistors 251–254
- amorphous oxide semiconductors (AOSs) 238
- amperometric sensors 296–297
- Ansys 51
- aptamers, DNA 67
- aspherical microlenses 338
- assembly and packaging 13–14
- atomic force microscopy (AFM) 63, 65, 68, 222–225
- automated optical inspection (AOI) system 264

### **b**

- ball grid array (BGA) mounting array 270, 271
- bend mode 74–75
- Ben Q Corporation 44
- bias-stress effects 248, 250, 251, 254
- bimorph actuator 75
- binary conversion, of gray droplet image 130
- binary image processing 131
- binders 181
- biocides 182

### bio-MEMS devices 12–13

- biomolecules 305–306
- biosensors, using DNA microarrays 67, 68
- blood glucose biosensor 295, 296, 298
- Bond number 99
- bulging 93
- bulk heterojunction (BHJ) 282, 283, 286, 287
- bump mode 75, 76, 81

### **c**

- Canon 41, 44, 46, 47, 54
- cantilevers 341
- carbonnanotubes (CNTs) 301–304
- catalytic ink 273
- CdTe 280, 282
- cell-based biosensors 306
- charge-coupled device (CCD) cameras 127, 130, 131, 132, 133, 200
- chemical sensors 9–10, 341
  - definition of 295
- chemical vapor deposition (CVD) 63
- chemresistor 341
- circuit patterning of copper 263–264
  - copper etch resist materials 264–265
  - substrate modification 265–266
- clogged jets 287
- coffee-ring effect 22, 242, 354
- coffee stain 90
- color filter fabrication issues with inkjet
  - printing 191
  - background 191–195
  - printing swathe due to droplet volume variation 199–204
  - printing technologies comparison 195–199
  - subpixel filling with designed surface energy condition 204–212
  - technical issues 212–213

- combinatorial screening of materials 19–20
- inkjet printing, from dots to homogeneous films 20–25
- for organic solar cells 28–34
- thin-film libraries 25–28
- commercial inkjet 289–291
- computational fluid dynamics (CFD) 205
- conductimetric sensors 297
- conducting polymers 300, 301, 303, 305
- conductive inks 173, 174, 176, 177, 186
- contact line 97–98, 100, 101–109
- continuity equation 98
- continuous mode inkjet (CIJ) technology 2
- convection–diffusion equation 101
- CuIn<sub>1-x</sub>GaxSe<sub>2</sub> (CIGS) 280, 282, 284, 288
- copper plating resist 266–268
- Crank–Nicolson method 103
- critical flocculation temperature (CFT) 352
- cross talk, and piezo inkjet 73
  - acoustic 78–81
  - direct 74–76
  - electrical 73
  - pressure-induced 76–78
  - printhead resonance 81–83
  - residual vibrations 83–84
- d**
- Dainippon Screen Mfg. Co., Ltd. 42
- damping 82
- demand mode inkjet technology 2–3
- designed surface energy condition, subpixel filling with 204–212
- direct cross talk 74–76
- dirt 152–153
- dispensing mode 21
- DJ1200 printer 41
- DNA 67, 68
- drive-per-nozzle (DPN) function 161, 162
- drop formation 136, 150–152
- droplet. *See also* drying, of inkjet droplets
  - captured image distortion 166
  - formation 221–222
  - measurement 138
  - impact, and final radius 88–90
  - inkjet-printed evaporation, at room temperature 90–91
  - light intensity influence on 201
  - locations in image of 137
  - magnified gray image 133
  - morphological control for ink, lines, and films 91–94
  - reduction, in size and volume 202
  - size and threshold effects 133
  - solution 87
- solvent 87, 90
- speed
  - measurement 164
  - variation 165
  - uniformity 165
- volume equalization and sessile 166–167
- light transmittance 170–171
- measurement 167–170
- volume measurement 132, 159, 162
- volume variation 199–204
- drop-on-demand (DoD) 239
  - drop formation 136
  - inkjet printers 21, 198
  - mode printing 60–62
- drop watcher components 160
- drum-side-treated foil (DSTF) 266
- dry film photoresist 268
- drying, of inkjet droplets 97–98
  - modeling 98
    - evaporation velocity 102–103
    - fluid model 98–99
    - lubrication approximation 99–101
    - numerical method 103
    - solute concentration 101–102
    - results 103–104
    - diffusion effect 108–109
    - droplet shape evolution 104–105
    - layer thickness 106–108
  - dye inks 175–176
  - dynamic random access memory (DRAM) device 7
- e**
- edge detection techniques, meniscus location by 142
- electrical cross talk 73
- electrical repulsion 176
- electrochemical sensors, inkjet printed 295–297
  - applications 306, 307–308
  - future commercial projection 306, 309
  - inkjet printing, of sensor components 298–299
    - biomolecules 305–306
    - conducting tracks 300
    - substrates 299
    - transducer materials 300–304
  - printed sensor manufacturing 297–298
- electrohydrodynamic inkjet, high-resolution 57
  - applications in electronics and biotechnology 64–69
  - drop-on-demand mode printing 60–62
  - high-resolution printing of charge 69–70

- jet motions control 59–60
- printing system 57–59
- versatility of printable materials and
  - resolutions 62–64
- electroluminescence 225–229
- electrolytes and pH 180
- electron-transport layer (ETL) 219
- energy dispersive X-ray spectroscopy (EDS) 253
- epoxy 262
- etching 332–333
- resist materials 264–265
- ethylenediaminetetraacetic acid (EDTA) 180
- evaporation velocity 102–103
- exciplex formation 225, 228, 232
- external quantum efficiency (EQE) 218, 219, 225, 231–232, 233

**f**

- ferroelectric domains 148
- flexible electronics 64, 65
- flexography printing 195
- Flow 3D 51, 52
- fluid/substrate interaction 5–6
- fluidic free boundary calculation, based on finite differentiation method 51–53
- fluid model 98–99
- fluid requirements 3–5
- foaming and defoamers 181
- forming gas 274
- FujiFilm Corporation 42
- Fujifilm Dimatix Inc. (Spectra) 42, 290

**g**

- graphene 303
- gravure printing. *See* flexography printing

**h**

- head normalization and condition monitoring 139–141
- heterophase ink 175
- Hewlett-Packard (HP) Development Company 41, 55
- high frequency (HF) tags
  - antenna considerations 320–321
  - versus ultrahigh frequency (UHF) tags 318
- high-resolution transmission electron microscopy (HRTEM) 249, 250, 251, 253
- hole plugging 267
- hole transport layer (HTL) 219
- hot-melt (phase-change) inks 178, 182
- humectants 181

**i**

- indium gallium zinc oxide (IGZO) 238–239
- inductive coupling 316, 320
- industrial inkjet printer 260
- inkjet etch resist 265
- inkjet ink formulations 173–174
  - additives and ink parameters
    - binders 181
    - biocides 182
    - electrolytes and pH 180
    - foaming and defoamers 181
    - humectants 181
    - rheology control 179
    - surface tension modifiers 180
    - examples 182
  - functional materials 176–177
  - hot-melt (phase-change) inks 178, 182
  - ink interaction with substrates 185–186
  - jetting performance 182–183
  - drop formation 183
  - ink latency 183–184
  - ink supply 184–185
  - recoverability 184
  - nongraphic applications 186–187
  - solvents
    - solvent-based inks 177–178, 182
    - water-based inks 178, 182
  - types of 175
  - UV-curable inks 178–179, 182
- inkjet printing issues
- ink printability 239–241
- substrate preheat temperature influence 242–246
- inkjet technology 1
  - continuous mode inkjet (CIJ) technology 2
  - demand mode inkjet technology 2–3
  - materials deposited using 5
- interconnects and contacts inkjet printing, based on inorganic nanoparticles 347
- in high resolution
  - inkjet-printed ionogels 359–361
  - physical surface treatment 357–359
  - reduced printed droplet diameter 353–357
  - surface wetting and ink modifications 351–352
  - for microelectronic applications 348–351
- International Solar Electric Technology (ISET) 288
- ion-selective electrodes (ISEs) 297
- i-STAT<sup>®</sup> 295, 296

**j**

- Jet Press 720, 42
- jetting performance 159, 182–183
  - drop formation 183
  - droplet volume equalization and sessile droplets 166–167
  - light transmittance 170–171
  - measurement 167–170
  - droplet volume equalization on fly 160
  - captured droplet image distortion 166
  - drop watcher components 160
  - droplet volume measurement results and equalization process 161–163
  - equalization through volume control 160–161
  - relation between droplet volume and speed 166
  - speed equalization 164
- ink latency 183–184
- ink supply 184–185
- recoverability 184
- jetting speed measurement 134–139

**k**

- Kelvin force microscopy (KFM) 69
- kogation 53–54

**l**

- large area display 191, 192, 202
- laser direct imaging (LDI) 270, 276
- laser transfer 197–198
- latency 184
- lead zirconate titanate (PZT) 148
- legend-marking processes 261–262
  - cost comparison 262
  - printing materials 262–263
- light-emitting diode (LED) 127, 129, 131, 166, 200–201
- light transmittance and 170–171
- liquid photoimageable (LPI) 268
- lubrication approximation 99–101

**m**

- magnetic resonance imaging (MRI) 350
- making holes conductive (MHC) process 266
- Maxwell–Wagner polarization 118
- MediSense ExacTech® 295
- meniscus motion measurement and application 141–144
- metal–insulator–semiconductor field-effect transistors (MISFETs) 238
- metallic ink inkjet printing, for contacts and interconnects
  - for microelectronic applications 348–351

metallic inks 273–275

- metallic pastes 324
- metal–organic decomposition (MOD) inks 112, 114, 115, 121, 284, 300
- metal-oxide thin-film transistor inkjet printing 237
  - all-oxide invisible transistors 251–254
  - inkjet printing issues
  - ink printability 239–241
  - substrate preheat temperature influence 242–246
  - materials for semiconductors 237–239
  - solution-to-solid conversion, by annealing 247–251

(1-[3-(methoxycarbonyl)propyl]-1-phenyl)-[6,6]C61(PCBM) 29, 31, 33, 282, 283, 286

- microelectromechanical systems (MEMS) 6–7, 9, 10, 150, 331
- bio-MEMS devices 12–13
- direct materials deposition 333–336
- etching 332–333
- functionalization and novel applications 340–342
- optical 10–12, 336–339
- packaging 339–340
- photolithography and 331, 332
- microlens 337–339
- micromanufacturing 6–7
- inkjet benefits, in microfabrication 8–9
- inkjet examples in 9–14
- limitations and opportunities in 7–8
- micro-optical electro-optical mechanical systems (MOEMS) 7
- micropipette mode 21
- microwave tags 316
- modal analysis 82
- monomorphs 75
- Moore’s law 319
- multilayer boards (MLBs) 258, 263
- mushroom plating. *See* overplating

**n**

- nanoparticle 116, 117
- inks 112, 115
- National Renewable Energy Laboratory (NREL) 284
- Navier–Stokes equation 52, 98, 99, 100
- NovaCentrix 118
- nucleation 46
  - spontaneous 45
- numerical method 103

***o***

- Ohnesorge number 89  
 – inverse of 240  
 optical MEMS 10–12, 336–339  
 Optomec 290  
 organic light-emitting diode (OLED) 217,  
 348, 349  
 organic solar cells 28–34, 282  
 organometallic precursors 326–327  
 Orphis HC5000 42  
 Ostwald ripening 115  
 overplating 268

***p***

- PaintJet 41  
 parasitic mode 80  
 particle-based inks 325  
 particle–particle interactions 26  
 passive tags 314  
 pattern formation. *See* fluid/substrate  
 interaction  
 patterning 87  
 – droplet impact and final droplet radius  
 88–90  
 – inkjet-printed droplets evaporation, at room  
 temperature 90–91  
 – morphological control for ink droplets, lines,  
 and films 91–94  
 pattern plating 267  
 phospholipids 303  
 photolithography and 331, 332  
 photonic curing 274  
 photonic sintering 118, 120, 122  
 photovoltaics 279, 280  
 – commercial inkjet for 289–291  
 – device structure 280–283  
 – small- and large-area printing for 283–289  
 pigment-based inks 175  
 PixDro 290  
 plasma display panels (PDPs) 195  
 plasma sintering 116, 117, 122  
 PM700 device 41  
 Poiseulle-type equation 59  
 (poly[4,4'-bis(2-ethylhexyl)-dithieno(3,2-  
 b;2',3'-d)silole]-2,6-diyl-*alt*-(2,1,3-  
 benzothiadiazole)-4,7-diyl]) (PSBTBT) 33  
 (poly[2,6-(4,4-bis(2-ethylhexyl)-4H-cyclo-  
 penta[2,1-b;3,4-b']dithiophene)-*alt*-4,7(2,1,3-  
 benzothiadiazole)] (PCPDTBT) 33  
 poly(3,4-ethylenedioxy-thiophene):  
 poly(styrene-sulfonate) (PEDOT:PSS) 22,  
 27–28, 35, 62, 93, 94, 229, 282, 287, 300,  
 305, 348, 349, 352

- poly-(3-hexylthiophene) (P3HT) 29, 31, 282,  
 283, 286, 287  
 poly(*p*-phenylene-ethynylene)-*alt*-poly(*p*-  
 phenylene-vinylene)s (PPE-PPVs) 20, 25,  
 35  
 poly(vinylalcohol) (PVA) 26  
 polyimide 340  
 polymer/fullerene library 32  
 portable electronics 217  
 postprinting processes for inorganic inks, for  
 plastic electronics applications 111  
 – inkjet printing 111  
 – metallic inks  
 – – alternatives and selective sintering  
 methods 116–119  
 – – conventional sintering techniques 116  
 – – for inorganic precursor ink conversion  
 115  
 – – metal choice 112–114  
 – – room-temperature sintering 119–121  
 – printed electronics 111–112  
 potentiometric sensors 297  
 power conversion efficiency (PCE) 29, 31,  
 33  
 prepatterning 351  
 pressure-induced cross talk 76–78  
 print, pattern-plate, and etch 258  
 print and etch process 263, 266  
 printed antennas 319  
 – HF tag antenna considerations 320–321  
 – organometallic precursors 326–327  
 – printed antenna materials 323–326  
 – printing application to antenna fabrication  
 322–323  
 – UHF tag antenna considerations 321  
 printed circuit boards 257  
 – copper circuit patterning, inner layer  
 263–264  
 – – copper etch resist materials 264–265  
 – – substrate modification 265–266  
 – copper plating resist 266–268  
 – digital printing alternatives to inkjet  
 fabrication 276  
 – fabrication process 259  
 – future applications 276–277  
 – legend-marking processes 261–262  
 – – cost comparison 262  
 – – printing materials 262–263  
 – metallic inks 273–275  
 – solder mask printing 269–273  
 – theoretical printing example for  
 manufacturing of 275–276  
 – traditional processes 257–261  
 – types of 258

- printed circuit boards (*contd.*)
  - waste reduction, using inkjet printing 268–269
- printed electronics 64, 111–112, 173, 174, 181, 186, 187, 298
- printhead control 156–157
- printhead resonance 81–83
- printhead structure and thermal inkjet 44
  - printing swath due to droplet volume variation 199–204
- printing swath marks 159
- push mode. *See* bump mode
  
- q**
- quantum dot-hybrid LEDs, application in high-density pixelated RGB 217
- background 218–220
- experimental procedure and results 220–221
- atomic force microscopy 222–225
- droplet formation 221–222
- electroluminescence 225–229
- matrix 229–233
  
- r**
- radio frequency identification tags (RFID) 14, 111, 313–314
  - block diagram 318
  - classification 314–317
  - HF versus UHF 318
  - printed antennas 319
  - HF tag antenna considerations 320–321
  - organometallic precursors 326–327
  - printed antenna materials 323–326
  - printing application to antenna fabrication 322–323
  - UHF tag antenna considerations 321
  - silicon-based construction 319
- rapid boiling research and thermal inkjet (TIJ) 44–47
- Rayleigh–Plesset equation 154
- reactive inkjet printing 122
- refill 150, 152, 154
- region of interest (ROI) 130
- residual vibrations 83–84
- reverse offset printing 196–197
- reverse-treated foil (RTF) 266
- Riso Kogaku Corporation/Olympus Corporation 42
- roll printing 195
- roll-to-roll (R2R) production 111
- rotating mirror-type scanning system 141
- R<sub>series</sub> 321
  
- s**
- saber angle 169
- scaling law 60
- scanning electron microscopy (SEM) 245, 246
- Schmid Group 290
- screen printing 195–196, 283–284
- Seiko Epson Corporation (Epson) 41, 54
- self sensing 145–150
- semiconductors, materials for 237–239
- sessile droplet measurement and equalization process
  - droplet volume 167–168
  - light transmittance and 170–171
  - results 168–169
  - usefulness 169–170
- shear mode principle and deformation 74
- silicon-based RFID construction 319
- silicon solar cell 280, 281, 284, 285, 286
- Silverbrook Research Pty Ltd. 44, 55
- single-sided printed circuit boards 258, 265
- single-walled carbon nanotubes (SWCNTs) 62, 63, 64–65, 66
- single-walled nanotubes (SWNTs) 302–303
- sintering 115, 348–349, 354
  - alternatives and selective methods 116–119
  - conventional techniques 116
  - photonic 118, 120, 122
  - plasma 116, 117, 122
  - room-temperature 119–121
  - thermal 358, 359
- solder mask printing 269–273
- sol-gel solution 238, 240, 242, 245, 247, 251, 252, 254
- solid inks 175
- solute concentration 101–102
- solution droplets 87
- solution-to-solid conversion, by annealing 247–251
- solvent-based inks 175, 177–178, 182
- solvent droplets 87, 90
- Sony Corporation 43
- speed equalization 164
- spin coating 19, 238, 248, 249, 251
- spontaneous nucleation 45
- Stefan number 89
- structure–property relationships 19, 21, 26, 35
- substrate modification 265–266
- SunPower Corporation 281
- Surface Evolver 205
- surface plasmon resonance (SPR) biosensor 305

surface tension modifiers 180  
 surface wetting and ink modifications 351–352

**t**

thermal inkjet (TIJ)  
 – basic jetting behavior of 48  
 – – frequency characteristics 49  
 – – input power characteristics 48–49  
 – – temperature dependence 49–51  
 – behavior analysis, using simulation 51  
 – cylindrical thermal propagating based on finite element method 51  
 – fluidic free boundary calculation based on finite differentiation method 51–53  
 – heads and structures 43–44, 44  
 – history 41–42  
 – inkjetting mechanism of 47–48  
 – market trends for inkjet products and electrophotography 42–43  
 – present and future evolution in 54–55  
 – rapid boiling research and 44–47  
 – reliability issues in 53–54  
 thermal propagation, based on finite element method 51  
 thermal sintering 358, 359  
 thin-film libraries 20, 24, 25–28  
 thin film solar cells 282, 286, 287, 288  
 thin film transistor 237. *See also* metal-oxide thin-film transistor inkjet printing  
 – liquid crystal display (TFT LCD) 191, 192, 193, 195, 202, 208  
 – structure 193  
 – subpixel sizes of 207  
 ThinkJet printer 41  
 Toshiba TEC Corporation 42  
 transducer materials 300–304  
 transistors 64–65, 66, 70  
 transmission electron microscopy (TEM) 250  
 transmission line method (TLM) 244, 245  
 Truepress Jet 520, 42

**u**

ultrahigh frequency (UHF) tags 316, 317  
 – antenna considerations 321  
 – high frequency (HF) versus 318  
 unimorph actuator 75  
 UV-curable inks 178–179, 182

**v**

vertical-cavity surface emitting lasers (VCSELs) 11  
 vision monitoring 127  
 – head normalization and condition monitoring 139–141  
 – image processing 130–133  
 – jetting speed measurement 134–139  
 – measurement setup 127–129  
 – meniscus motion measurement and application 141–144  
 volatile organic compounds (VOCs) 9  
 volume of fluid (VOF) method 52

**w**

Washburn equation 151  
 waste reduction, using inkjet printing 268–269  
 water-based ink 45–46, 175, 178, 182  
 Weber number 99  
 wetting 151, 152, 153, 154

**x**

Xerox Corporation 44  
 XjetSolar 289, 290

**z**

zinc indium oxide (ZIO) 252, 253  
 Z-number 21–22  
 ZnO 239, 240, 241  
 – based materials 238  
 zinc tin oxide (ZTO) 243, 245, 246, 247, 248, 249, 250, 251, 252, 253

