

Subject Index

A

- Adhesion**
 coatings on aluminum, 333–334, 335 (table)
Elcometer tester, 333
 films and coatings,
 bibliography, 343–362
 metal coatings, 320–328, 322 (table)
 various metal substrates, 320–328, 322 (table)
- Alloys**, coating *See also* Powder coatings
 adhesion of, 320–328, 322 (table)
 bibliography, 343–362
 aluminum, 135–143, 150–166, 246–264
 chromium-nickel, 181–182, 189
 copper-nickel-chromium, 265–271
 nickel, 168–175
 nickel-molybdenum, 11–18, 16 (table)
 nickel-phosphorus, 11–18, 16 (table), 112–121
 tribology applications, 295–301, 294, 298, 299 (tables)
 zinc-aluminum, 246–264
 zinc-magnesium, 213–234
- Alodine** 1000/2000 processes, 143–146
- Aluminum**
 adhesion of coatings on, 326, 333–341
 anodic oxide coatings on, 130–149, 148 (table), 150–166
 coating on steel, 246–264
 ring shear test data, 326 (table)
 surface contamination of, 333–341
 zinc immersion surface preparation, 326
- Anodic oxide coatings** *See* Oxide coatings on aluminum, anodic
- Anodic polarization measurements**
 ASTM Standard G5: 215
- Anodized aluminum** *See* Oxide coatings on aluminum, anodic
- Area density and coating thickness measurement**, 124–125, 127–128
- ASTM Committee B-8 on Metallic and Inorganic Coatings**, 1–3, 8, 97
- ASTM Standards**
 B 117: 185, 186, 187
 B 136: 161, 185, 187
 B 137: 151
 B 244: 153
 B 287: 185
 B 368: 185, 187

- ASTM Standards (*continued*)**
- B 380: 187
 - B 457: 185, 187, 189
 - B 487: 152
 - B 537: 183, 188
 - B 538: 185, 187, 189
 - B 578: 7, 96, 98, 100, 104, 105, 107
 - B 583: 196, 198, 202
 - B 627: 187, 189
 - B 636: 20
 - B 680: 185, 187, 161
 - B 765: 194, 197
 - D 1005: 239
 - D 1141: 248
 - D 2244: 161–162
 - D 3359: 239
 - D 3755: 159
 - E 3: 100
 - E 8: 12
 - E 92: 97
 - E 177: 97
 - E 178: 105
 - E 308: 162
 - E 345: 12, 77
 - E 384: 96–98, 100
 - E 578: 7, 96, 98
 - E 796: 13, 67, 68, 90
 - G 3: 189
 - G 5: 189, 215
 - G 33: 188
 - G 43: 185
 - G 50: 188
 - G 59: 188
 - G 61: 169
 - G 71: 188
 - G 76: 155
 - G 82: 188
 - G 84: 188
 - G 85: 185
 - G 87: 185, 187
 - G 91: 188
 - for corrosion of metallic and inorganic coatings, 185 (table)
 - for electrochemical corrosion tests, 189 (table)
 - precision/accuracy of, 96–97
 - for testing atmosphere exposure, 188 (table)
- Atmosphere**
- ASTM Standards, 188 (table)
 - industrial, 181
 - marine, and corrosion of coated steel panels, 212–234, 217, 219, 227 (tables), 236–237, 246–264, 267–268
 - rural, 268
- Autocatalytic nickel coatings** *See Nickel, autocatalytic*
- B**
- Beryllium**
- ring shear test data, 326 (table)
 - zinc immersion surface preparation, 327
- Biaxial stretchability**
- copper/gold, 54–65
- Bibliography**
- adhesion of films and coatings, 343–362
- Boride coatings** tribological applications, 299 (table)
- Bulge tests,**
- hydraulic, 22–31
 - ASTM Committee B-8 standard development, 8
 - mechanical, 28–46
 - copper films, 44–50, 52–65
 - gold films, 52–65
- C**
- Carbide coatings** tribological applications, 295, 299 (table)
- CASS (Copper-Accelerated-Acetic Acid Salt Spray) test**
- ASTM Standard B 368: 185, 187

- use with anodized aluminum, 187
 use with nickel-chromium coatings, 187
- Ceramic coatings
 tribological applications, 298–299, 307 (table)
- Cermet coatings, 298
- Chemical stripping, metals, 169 (table)
- Chloride and corrosion, 180 (table), 214
- Chromate conversion coatings
 Alodine 1000/1200 processes, 143–146
- Chromaticity test
 anodized aluminum, 161–163
 ASTM Standards
 D 2244: 161–162
 E 308: 162
- Chromating, electrochemical effect on copper-nickel-chromium coatings, 265–271
- Chromium coatings
 copper-nickel-chromium alloy, 265–271
 electroplated, 185, 187, 189, 298
 microhardness of, 107–109
- Coatings *See also* Alloys; specific coating components
 bibliography on adhesion of, 342–362
 composition analysis, 167–176
 corrosion tests, 177–191
 electroless, 46–48, 167–176, 298
 electroplated *See also* Alloys; specific metals
 ductility tests on, 19–95
 microhardness, 96–110
 porosity tests on, 193–210
 friction, 289–319
 hard wear resistant, 298–307
 inorganic, 129–149, 177–191
 physical property measurements, 6–7, 11–18, 19–31, 52–65
- soft lubricant, 294–298, 294 (table), 305
 surface application techniques, 293 (table), 302–305
- testing of, in general *See* Testing, coatings
 tribological applications, 289–319 307 (table)
- Color fastness
 anodized aluminum, 161–166
 testing of,
 Fade-Ometer, 165
 Weather-Ometer, 165
- Color matching *See* Chromaticity
- Computer programs
 for biaxial stretchability tests, GNATS, 61
 corrosion software, PARC Soft CORR–332, 215
 use in tension-testing thin foils, 13
- Conductivity *See also* Electrochemical tests
 anodized aluminum, 160
 Duffek test, 160
- Contact potential difference (CPD) and metal surface quality, 331–341
- Contamination
 aluminum surfaces, 324–327, 333–341
- Copper coatings
 biaxial stretchability, 54–65
 copper-nickel-chromium coatings, 265–271
 ductility, 32–52, 54, 58–59, 66–95
 electroless, 46–49, 88–90
 microstructure of, 47–48
 electroplated, 47–50, 54, 58–59, 66–95, 103–104, 265–271
 microhardness, 106, 109
 microstructure of, 46–47
 foil,
 ductility, 66–95

- Copper coatings, foil (*continued*)

 fatigue behavior vs cyclic life, 79–82

 oxygen-free high-conductivity (OFHC), 58–59

 printed wire application, 67, 89
- Corrosion *See also* Corrosion stations; Corrosion tests

 aluminum/zinc/aluminum-zinc coatings, on steel, 246–264

 anodized aluminum, 160–161

 ASTM Standard B538:187

 atmospheric, 178–181, 181 (table), 188–189, 235–245, 265–271

 ASTM Standard B537: 183

 and chloride level, 180(table), 214

 industrial, 181

 marine, 211–234, 246–264

 rural, 268

 copper-nickel-chromium coatings

 on steel, 265–271

 galvanic, 181–182

 phosphate coatings, 272–288

 and physical properties of plated surfaces, 31

 and porosity of coatings, 195–210

 road salt, 180

 salt spray, 179, 180, 257–260

 ASTM Standards B117/B287/B368/G85: 185

 sulfur dioxide, 180, 195–196

 thermal spray coatings on steel, 211–234

 wrought iron, 213–214

 zinc silicate coatings on steel, 235–245
- Corrosion stations, 181(table), 236–237 *See also* Atmosphere, industrial, marine, rural; Environments, polluted
- Corrosion tests

 accelerated, 178, 185–191

 ASTM Standard B117: 186, 187

 ASTM Standards, 185, 187, 188 (tables)

 electrochemical, 189–190

 ASTM Standards, 189 (table)

 software, 215

D

- Density *See* Area density
- Diamond pyramidal hardness test, 97
- Dielectric properties

 aluminum,

 anodized, 158–161

 deoxidized, 333–341

 oxidized, 329–341

 ASTM Standard D 3755:159
- Diffusion welding, 324–326
- Ductility

 electroplated/aged copper, 32–51, 54, 58–59, 83 (illus)

 electroplated/aged gold, 55, 57

 tests,

 ASTM Standard E796: 67

 new methods, 19–31, 34–46, 54–65

 review, 33–34

 thin foils, 12–13, 32–95
- Duffek test for conductivity, 160
- Durability *See also* Corrosion

 copper-nickel-chromium coatings

 on steel, 265–271

 zinc silicate coatings on steel, 235–245

E

- ECD *See* Electrostatic charge decay
- Elasticity, gold coatings, 61–63
- Elcometer adhesion tester, 333
- Electrochemical chromating, 265–266

- Electrochemical tests,
 aluminum coatings, 252–257
 aluminum-zinc coatings, 226–233,
 227 (table), 252–257
 ASTM Standards, 189 (table)
 phosphate coatings, 273–283
 for surface contamination, 333
 STEP test, 189
 zinc coatings, 252–257
- Electrodeposits** *See also* Chromium
 coatings, electroplated; Copper coatings, electroplated;
 Gold coatings, electroplated;
 Nickel coatings, electroplated
 thin metal foils, 11–18
- Electroformed copper** *See* Copper, coatings, electroplated
- Electroformed gold** *See* Gold, coatings, electroplated
- Electroless plating** nickel coatings, 112–115, 298
- Electron microscopy**
 aluminum/zinc/aluminum-zinc coatings, 249–252
 contamination, aluminum panels, 333–334, 340–341
 copper, microstructure of, 46–49
- Electron probe microanalysis (EPMA)**
 aluminum/zinc/aluminum-zinc coatings, 249, 252, 257
- Electron spectroscopy for chemical analysis(ESCA)**, 333
- Electroplated coatings** *See also* Alloys; specific metals
 corrosion tests, 177–191
 ASTM Standards, 187, 188, 189 (tables)
 ductility tests on, 19–31
 porosity tests on, 193–210
 thin metal foils, 11–18
- Electrostatic charge decay (ECD)**, 329–341
- equipment, 331
 procedure, 331–332, 336 (table)
- Environment, polluted** *See also* Industrial atmosphere
 corrosive effects, 237, 267
- Epoxy topcoat** for zinc silicate coatings, 237
- F**
- Fade-Ometer**, 165
- Fatigue tests** for measuring ductility, 34, 66–95, 91 (table)
- Films** *See also* Thin films bibliography on adhesion, 343–362
- Finite analysis** biaxial stretchability, aged/plated gold, 61–62
- Flame spray coatings**, 211–234
- Fluoride coatings** tribological application, 297–298
- Friction**
 coating materials, 289–319
 and surface treatments, 289–319
 tests on coatings for tribological application, 316–318
- G**
- German Industrial Standard (DIN) 53151:239**
- GNATS** nonlinear, elastic-plastic finite-element analysis code, 61–62
- Gold coatings** electroplated, biaxial stretchability, 52–64
 porosity testing, 194, 203, 204 (tables)
 tribological applications, 296
- Grain structure vs ductility in copper foil**, 77
- Graphite coatings** tribological application, 295–297, 307 (table)

H

Hardness *See also* Microhardness
anodic oxide coatings on aluminum, 154–155

ASTM Standards

- B 578: 96, 98
- E 92: 97
- E 384: 96–98, 100
- G 76:155

chromium, 96–110

copper, 103–106, 107
numbers,

Knoop (HK), 97–98, 104, 106–108

Vickers (HV), 98, 104, 106–108
plated coatings, 96–110
tests for,

abrasive blast, 155, 156–157

Diamond pyramidal, 97

groove, 155

scratch, 155–156

Vickers, 97–98

Hydrogen gas bubbles, relationship to ductility, 48–49

I**Impedance**

phosphate coatings, 280–283
zinc silicate coatings, 239–241

Inductively coupled plasma (ICP)
analysis of coatings, 168,
170–176

Industrial atmosphere, 181 *See also*
Environment, polluted

Inorganic coatings, 129–149, 177–191

International Standards Organization (ISO) Metallic Coatings, 268

IPC Specifications on Copper Foil for Printed Wire Applications (ANSI/IPC-CF-150), 67, 89 (table)

IPC Test Method on Flexural Fatigue and Ductility, 68, 69

Iron corrosion of, 213–214

L

Lead sulfide coatings, 297

Lubrication, 289–319

M

Magnesium, zinc-magnesium coatings, 213–234

Manganese coatings, 216–219

Manson-Coffin plot (strain range vs fatigue life), 75

copper foil specimens, 76, 80, 81

Marine atmosphere *See* Atmosphere, marine

Mass per unit area metal coatings, 124–125

Mechanical property measurements
electroplated copper/gold, 52–65
technical overview, 5–6
thin metal foils, 11–18

Metallic foil/coatings *See* Thin foils

Metallographic test specimen preparation

ASTM Standard E 3: 100

Metallography

aluminum/zinc/aluminum-zinc coated steel, 224–226, 249–252

Metals *See also* Alloys; Aluminum; Beryllium; Cermets; Chromium; Copper; Gold; Lead sulfide; Manganese Nickel; Powder coatings; Silver; Steel; and Zinc

adhesion tests for coatings, 320–328, 322 (table)

thin inorganic coatings on, 129–149

use as tribological coatings, 298, 299, 300, 307 (tables)

- M**
- Microcracks in plated surfaces, 29
- Microhardness**
- chromium, electroplated, 107–109
 - copper, electroplated, 106, 109
 - electroplated coatings, 96–110
 - ASTM Standard B 578: 7
 - equipment for testing, 100
 - nickel, 298 (table)
 - standards/tests, 98–102
 - ASTM Standard B 578: 7, 96, 98, 100, 104, 105, 107
 - ASTM Standard E 384, 96–97
 - ASTM Standard E 578: 7, 96, 98
 - wear-resistant coating materials, 298, 299 (tables)
- Microporous chromium coatings**, 265–271
- Microstructure**, copper, 46–48
- Molybdenum disulfide coatings tribological application**, 295, 307 (table)
- N**
- Nickel coatings**
- autocatalytic (electroless), analysis of chemical composition, 168–175, 173, 175 (tables)
 - hydraulic bulge test, 23–28
 - internal stress measurement, 114–121
 - microhardness, 298 (table)
 - ductility measurements, 30
 - electroplated,
 - copper-nickel-chromium coatings, 265–271
 - corrosion, 181 (table), 182, 189
 - microhardness, 298 (table)
 - tension-testing of, 15–17, 16 (table)
 - Wood's nickel strike, 325 (table), 327
- Nitric acid and corrosion of metallic coatings**, 195–196
- deoxidation of aluminum, 333
- gas-exposure porosity test, 196–197, 205–208
- Nitride coatings tribological applications**, 299 (table)
- Nomarski interference lighting**, 29
- Nondestructive tests for surface contamination**, 329–341
- Nonuniformity of coating materials, effect on stress/strain**, 60–63
- O**
- OFHC copper** *See Copper, oxygen-free high conductivity*
- Optical microscopy**, 249–252
- Oxidation**
- aluminum alloys, 135–139, 333
 - hard coatings, 300 (table)
- Oxide coatings tribological application**, 296, 299 (table), 301
- Oxide coatings on aluminum**
- anodic, 130, 139–143, 146–166, 187, 188
 - ASTM Standard B 137: 151
 - corrosion of,
 - ASTM Standard B538: 187
 - hydrated, 137–139
 - natural, 135–137, 333–342
- P**
- PARC Soft CORR-332**
- corrosion software, 215
- Phosphate coatings test methods for**, 272–288
- Phosphophyllite/hopeite ratio**, 284
- Phosphoric acid anodizing, aluminum**, 146–148
- Phosphorus coatings**, 11–18, 16 (table)
- stress 116–121

- Physical property measurements, coatings, 11–18, 19–31, 52–65
technical overview, 5–7
- Plastic coatings
tribological applications, 294–295, 294, 307 (tables)
- Plastic strain electroless/electrolyte copper, 32–33
- Plated metal films *See* Electroplated coatings
- Plating, electro- *See* Electroplated coatings
- Plating, electroless *See* Electroless plating
- Polyimide, 294 (table)
- Polytetrafluoroethylene (PTFE)
in chromium-nickel coatings, 298
testing of coatings on, 247, 252–257
- Pores
in electroplated coatings, 194–210
in gold specimens, 204 (table)
- Porosity
aluminum/zinc/aluminum-zinc coatings, 249
metallic coatings, 193–210, 249
ASTM Standard B 765:197
phosphate coatings, 278–280, 283–286
screening for tribological applications, 311
- Potentiodynamic polarization thermal sprayed coatings, 229–234
- Potentiometry
phosphate coatings, 273–277
- Powder coatings
alloys, 212 (table), 212–234
mixed, 212 (table), 216–224
multi-metal, 215–234
single element, 212 (table), 216–219
- Primers (coatings) on aluminum, 333–334
- PTFE-polyphenylene sulfide coatings, 294 (table)
- PTFE-polyamide-imide coatings, 294 (table)
- Q**
- Quality control tests
ASTM Standards, 187 (table)
- R**
- Resin binder coatings, 295
- Ring shear test
adhesion, nickel coatings, 320–328, 325, 326 (tables)
applications, 324–327
- Rubber, chlorinated as topcoat, 237
- Rural environment *See* Atmosphere, rural
- S**
- Salt spray, 179, 180, 217 (tables)
257–260
- Scanning transmission electronic microscopy (STEM) *See* Electronic microscopy
- Sealing of coatings
anodized aluminum, 160–161
ASTM Standard B 680: 161
topcoats, 236, 237 (table)
- Seawater immersion, 214, 260–261
ASTM Standard D 1141: 258
- Silver coatings
electroplated adhesion of, 324–327, 326 (table)
physical-vapor-deposited microhardness of, 298 (table)
tribological applications, 296
- Spiral contractometer
ASTM Standard B 636: 20

- Stain resistance
 anodized aluminum
 ASTM Standard B 136: 161
- Standards *See* ASTM Standards; German Industrial Standards; International Standards Organization; IPC specifications; IPC test methods
- Steel
 coated with,
 aluminum, 246–264
 copper-nickel-chromium, 265–271
 nickel, 325 (table)
 phosphate, 272–288
 silver, 326
 zinc, 246–264
 zinc silicate, 235–245
 zinc-aluminum, 212–234, 246–264
 electrochemical behavior, 226–233
 electrochemical testing, 252–257
 ring shear test data, 325, 326 (tables)
 surface preparation of, 324–327, 326 (table)
- STEP test, electrochemical test for corrosion resistance, 189
- Stress
 internal
 electrodeposited metals, 6
 nickel, electroless, coatings, 114–121
 nickel-plated metal strips, 113–121, 117, 118, 121 (tables)
 radial and hoop, coatings on steel, 323–324
- Strikes, use of, 324–327
- Sulfur dioxide
 corrosion of metallic coatings, 180 (table), 195–196
- gas exposure porosity test, 196–205
- Surface analysis
 aluminum, 333–341
- Surface treatment, 291–294, 293 (illus), 302–305, 303 (table), 324–327
 aluminum, 326, 333–342
 beryllium, 327
 diffusion processes, 302–304
 steel, 324–327
 surface hardening, 304–305
 tribological applications, 305–307 (table), 310–319
- T**
- Tensile strength
 copper foils, 77, 78 (table)
 plated metal layers, 19–31
- Tension-testing
 machines, 13–15
 metal coatings, 34 (table)
 ASTM Standards E8/E 345: 12, 77, 78 (table)
- Testing, coatings
 accuracy of, 68, 96–97
 ASTM Standard E 177: 97
 direct measurement, 2–3
 future needs, 9
 performance, 2
 precision of, 68, 96–97
 ASTM Standard E 177: 97
 problems in, 1–2
 reasons for, 1
 round robin, 69–79, 82–97, 101–109, 197–205
 technical overview, 4–10
- Thermal spray coatings,
 aluminum/zinc/aluminum-zinc, 246–264
 powder alloys on steel, 212–234

- Thickness, coatings**
- area density, 124–125, 127–128
 - effect on ductility, 46 (illus)
 - gages for, 126–128
 - inorganic coatings on metal, 129–149, 136, 140, 142, 145, 146 (tables)
 - instruments for measuring, 53–54, 123–124, 152–154
 - measurement of, 7, 70, 73, 123–128, 129–149, 151–154
 - methods for measuring,
 - ASTM Standards B 244/B 487: 152–153
 - eddy currents, 153–154
 - optical, 152
 - organic coatings, ASTM Standard D 1005: 239
 - zinc silicate coatings, 237 (table)
- Thin coatings**
- advantages of, 291–294
 - inorganic thickness measurement, 129–149, 142 (table)
- Thin electrodeposits** *See Thin foils*
- Thin foils**
- ductility, 52–95
 - tension testing, 11–18, 32–51, 77
- Thin metal films** *See Thin foils*
- Topcoats**, 236, 237 (table)
- Trace elements in nickel alloy coatings**, 175 (table)
- Transmission electron microscopy (TEM)** *See Electron microscopy*
- Tribology**, 289–319
- screening methodology, for coatings, 310–319
 - for surface treatments, 305–307, 310–319
- Tristimulus color-matching test**, 161
- Tubes, electroplated ductility measurements**, 52
- U–V**
- Uniaxial tension tests, 5–6
 - Vickers hardness test, 97–98
 - ASTM Standard E92: 97
 - HV hardness number, 98, 104, 106–108
 - Voltammetry phosphate coating tests, 277–280
 - Von Mises effective strain, 59–60
- W**
- Wear**, 289–291
 - resistance
 - anodized aluminum, 154–158, 156 (table)
 - tests, tribological applications, 316–318
 - types of, 290
 - Weather-Ometer**, 165
 - Welding**, 324–326
 - Wiring, flexible printed (FPW)**, 67, 89 (table)
 - Wood's nickel strike**, 325 (table), 327
- X–Z**
- X-ray diffraction**
 - aluminum/zinc/aluminum-zinc coatings, 249–252
 - phosphate coatings, 283–286, 285 (table)
 - Zinc coatings**
 - on beryllium, 327
 - immersion process, 326
 - on steel, 246–264
 - Zinc silicate coatings on steel**, 235–245
 - Zinc-aluminum coatings on steel/PTFE**, 213–234, 246–264
 - Zinc-magnesium coatings on steel**, 213–234