Subject Index

A

Abrasion resistance, coated sunglasses, 305, 309f Absorbance spectra leuco crystal violet (LCV) assay for TiO₂ pigment, 356f methyl viologen (MV) assay with TiO₂ pigment, 355f photoreactivity comparison of TiO₂ pigments using, 356f, 357f Acetone process steps for hybrid dispersion, 93 synthesis of polyurethanepolyhedral oligomeric silsesquioxane (PU-POSS), 92-93 See also Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrids Acrylate-based coatings. See Organoclays in UV-curable coatings Acrylate-surface modified boehmite, experiments, 79-80 Acrylic acid, covalent bond between boehmite and, 79f Acrylic coating curing time and softening temperature, 321, 322f residual indentation, 317, 319f softening point, 317, 320f softening temperature vs. time, 322t, 323t Acrylic polyol crosslinked with diisocyanate, thermal analysis, 316 Acrylic-polyurethane (AU) coatings photo-degraded, 321, 326 softening temperature comparison, 324f, 325f

thermal analysis, 316 Adhesion augmented, with non-chromate materials, 146 nanometer-thick scratch resistant coatings, 300, 302-303, 305 pressure-sensitive adhesives (PSA), 305, 310-311 Aerospace coating. See Military aircraft coatings Alignment proposed mechanism of onedimensional, of nanoparticles, 118, 121 See also One-dimensional alignment of nanoparticles in coatings Alkyl-polyglycosides (APG) APG film deposition on mica, 296, 297f APG film deposition on mica from air-water interface, 300, 302f atomic force microscopy (AFM) of paper with cellulose and APG coating, 294f, 295f magnified view of cellulose fiber, 297f molecular modeling for structure, 300, 303f, 304f molecular self-assembly and ordering, 293, 296, 300 orientation on mica surface, 300, 301f paper additive, 293 self-assembled APG on cellulose fibers, 298f Alumina nanoparticles dynamic mechanical analysis of polyurethanes (PU) with, 222-223, 224t

polyurethane automotive coating, 211 predispersed, in study, 110t, 214t scratch comparisons with silica nanoparticles in PU coatings, 248-249, 251, 252f scratch dimensions for PU containing, 241t, 248t scratch testing for polyurethane coatings with, 237, 240, 241, 243-244 thermo-gravimetric analysis of dispersions, 215f See also One-dimensional alignment of nanoparticles in coatings; Polyurethane coatings; Scratch behavior of polyurethane coating Aluminum-based alloys amorphous systems, 130 corrosion characterization, 131, 133 open circuit potential of Al-Co-Ce system, 133, 134f repassivation potential of Al-Co-Ce system, 133, 134f scanning electron microscopy (SEM) images of Al-13Co-26Ce coatings and coating fatigue properties, 133, 138f See also Military aircraft coatings Alumunum/copper alloys, corrosion inhibiting boehmite nanoparticles, 81-82 Amorphous systems, aluminum-based alloys, 130-131 Angular frequency, dependence of viscosity on, by Carreau-Yasuda model, 94-95 Antifogging, multilayer coated glass, 374f Antimicrobial surfaces biocidal activity of silver, 196 dual-action, 196, 197f

gram-negative and gram-positive bacteria, 196 multifunctional coatings, 196, 197f on-site precipitation method for synthesis of dual action material, 197f quaternary ammonium groups, 196, 197, 198f, 199f silver nanoparticles, 196, 198f, 199f survival ratio of E. coli in liquid film with and without TiO₂ thin film, 195f titanium dioxide nanoparticles destroying bacteria, 194-195 Appearance polymeric coatings, 329 See also Surface topography Arrhenius expression, temperature dependence of shift factor, 102 Aspect ratio, nanoparticles, 68-69 Aspirate pipette ink-jet nano-plotter, 166-167 printing E. coli pRB28 using nanoplotter, 176-177 Assemblies, controlled formation of colloidal particle, 109 ASTM-B117 (salt fog testing), corrosion inhibiting boehmite nanoparticles, 82, 84f Atomic force microscopy (AFM) acrylate films with organoclay, 262-263, 266f alkyl-polyglycosides (APG) as coating on paper, 293, 294f, 295f cellulose fibers, 297f epoxy coating images after outdoor exposure, 332-333, 334f, 335f, 336f, 338f, 339f films containing nanoparticles, 217-218 method, 216 polyelectrolyte multilayers, 204f, 205

pressure-sensitive adhesives, 310, 312f root mean square (RMS) roughness vs. exposure time for epoxy coatings, 341f self-assembled APG on cellulose fibers, 298f surface topography method, 329, 332 thermal analysis of polymers, 313-314, 315f See also Surface topography Attraction, between nanoparticles, 66-67 Augmented adhesion, non-chromate materials, 146 Automotive coatings chemically crosslinked, 311, 313 cross-sectional view of commercial, 317, 318f optical clarity, 211 polyurethane coating preparations, 212-213 scratch resistance, 211-212 See also Polyurethane coatings

B

Bacteria, titanium dioxide nanoparticles destroying, 194-195 Bioclean[™], self-cleaning surface, 192 Bioelectronic devices, microbial inks for, 160-163 Bioluminescence E. coli pRB28 in latex micro-wells, 173, 175f reactivity of E. coli latex dot arrays, 179, 182f response of ink-jet printed patches, 171, 172f response of latex micro-wells with ink using reservoir dispense deposition, 171-173, 176

Bioluminescence, mercury-inducible effect of ink drying on, 169-171 reactivity of E. coli pRB28, 163, 183, 1841 See also Reactive adhesive microbial inks Biosensors, integrated circuits, 160 Body, nanoparticle, 70-71 Boehmite nanoparticles acrylate-surface modified, 79-80 carboxylate surface modified, 79 catalyst support, 78 commercial form of boehmite, 78 comparing chromated and nanoparticle inhibited epoxy primers, 82, 84f corrosion inhibiting, for Al/Cu alloys, 81-82 corrosion inhibiting, for cold-rolled steel, 82-83, 85 covalent bond between boehmite and acrylic acid, 79f crystal structure, 77f economic and chemical aspects, 76-78 production, 77-78 release of corrosion inhibitor from, surface, 81f salt fog testing with commercial formula, anthranilic acid nanoparticle + Zn phosphate, and no corrosion inhibitor, 85f smart delivery system for corrosion inhibitors, 78-81 surface-modified, 75-76 Buffer pH. See Titanium dioxide nanostructures

С

Capillary hydrodynamic fractionation (CHDF) particle size analysis, 381 separation mechanism, 382f Capillary zone electrophoresis, particle size analysis, 379-380 Carbon nanotubes, scientific interest, 374 Carboxylate surface modification, boehmite nanoparticles, 79 Carreau-Yasuda model, dependence of viscosity on angular frequency, 94-95 Catalyst support, boehmite, 78 Cellulose fibers alkyl-polyglycosides (APG) on, 296, 298f atomic force microscopy (AFM), 297f paper industry, 293 Ceramic tiles, titanium dioxide coating, 193 Characterization. See Nanostructured material characterization Char yield, acrylate films with organoclay, 263, 269t Chemical warfare (CW) agents adsorption and decomposition with nanoparticles, 201 degradation of organophosphosphorus compounds, 201 hydrolysis of Paraoxon by polyelectrolyte-nanoparticle surfaces, 205-206 incorporation of MgO nanoparticles into polymers, 201-202 mechanism of degradation, 201 reaction of MgO nanoparticles with VX, 201, 202 structures of Sarin, Tabun, Soman and VX, 200f Chloride anions, triggering release of corrosion inhibiting anions, 74 Chromate conversion coatings aerospace industry, 127 chromate-based inhibitive pigments in primer, 127-128

corrosion inhibiting system, 72-73 model of storage and release of $CrO_4^2, 72f$ Cladding, nano-engineered, on military aircraft, 129-133 Clay platelets attempting to encapsulate facemodified, 28-29 covalent modification, 29, 30f covalent modification of, 26-27 encapsulation of covalently edgemodified, 29-32 encapsulation of dualfunctionalized, 32-34 face modification of, 25f, 26 Laponite RD (LRD) and Cloisite Na⁺, 26 modification scheme, 25f See also Encapsulation inside latex particles Clays dispersion into polymers, 256 exchanging with corrosion inhibiting ions, 73-74 See also Organoclays in UVcurable coatings Clear coatings. See Polyurethane coatings Cloisite Na⁺ (MMT) clay, 26 See also Encapsulation inside latex particles Coated sunglasses, abrasion resistance, 305, 309f Coating performance, instrumented indentation, 302-303 Coatings characterizing nanoparticles in, 389, 391 chromate conversion, 72-73 nanoparticles in, 374-375 operating by pH triggered release, 73 polymer nanocomposite, 65 service life, 329

surface design, 65-66

- See also Military aircraft coatings; One-dimensional alignment of nanoparticles in coatings; Organoclays in UV-curable coatings; Polyurethane coatings; Reactive nanoparticles in coatings; Titanium dioxidecontaining films
- Coatings industry film formation by electrochemical cross-linking, 53 smart coatings, 51-52
- Coating thickness, latex ink rheology, 168
- Cold-rolled steel, corrosion inhibiting boehmite nanoparticles, 82–83, 85
- Cold spray, kinetic metallization, 133
- Colloidal particle assemblies,
- controlled formation, 109
- Colloid vibration potential (CVP), 378 Color-on-demand functionality, paint flake system, 148, 150
- Conjugated polymer network thin films
 - applications, 52
 - chemical structure of electrochemically cross-linkable polyfluorene precursor polymer, 56f
 - coating film formation by electrochemical cross-linking, 53
 - electrochemical nanolithography (ECN), 58, 59f
 - electrochemical surface plasmon microscopy (EC-SPM) set-up, 57f
 - electro-polymerization of precursor homopolymers/copolymers, 55f

future applications, 60

grafting of carbazole-modified polyfluorenes on electrode surfaces, 57

micro-contact printed patterns of grafted polyfluorene on Au, 58f nanopatterning process by ECN method, 58, 59f patterning by microcontact printing, 56 polymer light emitting diode (PLED) devices, 52, 54, 60 precursor polymer approach, 52-53 precursor polymers, 54, 56 smart coatings, 51-52 synthesis of precursor homopolymers/copolymers, 55f variable turn-on voltage on electrochemical doping of crosslinked PVK thin films, 59f Copper redeposition inhibitor performance for lanthanum chloride and sodium metasilicate, 142f, 143f method, 139 Corrosion characterization, aluminumbased alloys, 131, 133 Corrosion inhibitors boehmite nanoparticles as smart delivery system, 78-81 core-shell cerium/silica particles with loading of, 141, 145f effectiveness of organic, 80 inhibitor performance for lanthanum chloride and sodium metasilicate, 142f, 143f nanoporous silica as encapsulating material, 140 packaging and delivery of, 140-141 rapid identification of nonchromate, 135, 139-140 summary of efficiencies for materials and combinations at pH 7, 144f surfactant-directed assembly of nanoporous particles, 140-141

Corrosion protective coatings chromate conversion coatings, 72-73 coatings by pH triggered release, 73 hybrid sol-gels, 74-75 hydrotalcites and montmorillonite, 73-74 supported polyelectrolyte layers, 75 surface-modified boehmite nanoparticles, 75-76 See also Boehmite nanoparticles Coulter counting, particle size analysis technique, 376-377 Covalent modification clay platelets, 25f, 26-27 See also Clay platelets Critical volume fraction, Krieger-Dougherty equation, 96, 97f Crosslinked coatings, automotive, 311, 313 Cryogenic field emission scanning electron microscopy, nanopores, 168 Crystal growth theory, oriented attachment, 121 Crystal phase, titanium dioxide pigments, 355t Crystal structure, boehmite, 77f

D

Decomposition behavior, acrylate films with organoclay, 263, 269f Deposition devices, piezoelectric, 165–167 Design factors boehmite nanoparticles, 76–77 nanoparticles, 68–69 Differential scanning calorimetry (DSC) acrylate films with organoclay, 262, 265f

polyurethane coatings with nanoparticles, 215 polyurethanes with alumina and silica nanoparticles, 222-223 Diffusion coefficient, Stokes-Einstein relation, 353 Direct current (DC) polarization inhibitor performance for lanthanum chloride and sodium metasilicate, 142f, 143f rapid identification, 139 Disk centrifugation (DC), particle size analysis, 380-381 Dispersions base polyurethane (PU), synthesis, 40,41 organoclays in polymeric matrix, 260, 261f See also Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrid dispersions Drawdown method, coating application, 111, 112f Drop deposition method, coating application, 110-111 Drop on demand (DOD), ink-jet printing, 161-162 Dry coating thickness, latex ink rheology, 168 Dynamic light scattering (DLS) hydrodynamic diameter values for pigment in leuco crystal violet (LCV) assay by buffer and pigment loading, 368t hydrodynamic diameter values for pigment in methyl viologen (MV) assay by buffer and pigment loading, 366t hydrodynamic diameter values for pigment in MV assay by pH, 364t method for measurements, 352-353 normalized autocorrelation functions vs. lag time for LCV assay, 367f

normalized autocorrelation functions vs. lag time for MV assay, 366f

normalized correlation functions for monodisperse and polydisperse particle suspensions, 362f

particle cluster size, 359, 361

- particles in MV assay using phosphate buffer at pH 4.4 and 6.0, 362, 363*f*, 364
- pigment cluster size for MV assay and buffer composition, 364, 365f

See also Titanium dioxide nanostructures

Dynamic mechanical analysis (DMA) polyurethanes with alumina and silica nanoparticles, 222–223 test parameters for scans, 215,

216t Dynamic shear moduli, master curves for polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS), 98-99, 101f

E

Edge modification clay platelets, 25f, 26 covalent, of clays, 26-27 encapsulation of covalently edgemodified clays, 29-32 See also Encapsulation inside latex particles Einstein-Batchelor equation, zero shear viscosity, 96-97 Elasticity, acrylate films with organoclay, 262 Elastic modulus instrumented indentation, 306f, 307f normalized, for latex coatings, 281, 283-284, 286-288

surface, of nanocomposite polyurethanes, 235, 236f See also Nanocomposite latex coatings Electrical applications, conjugated polymer network films, 52 Electroacoustic measurements, particle size analysis technique, 378-379 Electrochemical nanolithography (ECN), nanopatterning process by, 58, 59f Electrochemical surface plasmon microscopy (EC-SPM) conjugated polymers on patterned conducting surface by, 56, 57f set-up, 57f Electronic sonic amplitude (ESA), 378 Electropolymerization. See Precursor polymer approach Electrozone sensing, particle size analysis technique, 376-377 Elongation at break, acrylate films with organoclay, 262, 264f Emulsion polymerization attempting encapsulation of facemodified clay platelets, 28-29 encapsulation of clay inside latex particles, 27 encapsulation of covalently edgemodified clay, 29-32 presence of clays, 25 recipes for, in presence of modified clays, 31t starved-feed, in presence of dualfunctional clay, 32-34 surfactant-free, starved-feed, 29 Encapsulation inside latex particles attempts using face-modified clay platelets, 28-29 characteristics of clay-encapsulated latex particles, 31t characterization methods, 27 chemical structure of hydrophilic quaternary ammonium with

polymerizable group (PEO- V^+), 34f covalent clay modification, 29, 30f covalently edge-modified clay platelets, 29-32 covalent modification of clay platelets, 26-27 cryo-TEM (cryo-transmission electron microscopy) of poly(methyl methacrylate) (PMMA) latexes with modified clay platelets, 28f cryo-TEM micrograph of Laponite RD (LRD-Si) platelets in water, 30f cryo-TEM of PMMA latexes with clays LRD-Ti and montmorillonite-Ti (MMT-Ti), 32f dual-functionalized clay platelets, 32-34 emulsion polymerization, 27 environmental scanning electron microscopy (ESEM) of MMT-Ti-encapsulated PMMA particles, 32, 33f experimental, 26-27 face modification of clay platelets, 26 hydrophobic cation hexadecyltrimethylammonium bromide (CTAB) for dual functionalization, 33-34 materials, 26 modification scheme of clay platelets, 25f $PEO-V^+$ in cationic exchange with covalently modified clays, 32-33 recipes for emulsion polymerizations, 31t thermogravimetric analysis of unmodified and silane-modified clays, 30f

Energy-dispersive x-ray (EDX), polysulfone-MgO, 202, 203f Energy-dispersive x-ray spectroscopy (EDS) aligned particles in coating with alumina D, 114, 116f coating with alumina C, 114, 117f, 118, 119f 1-D arrangements in control coating system, 118, 120f elemental analysis of coatings with aligned nanoparticles, 114, 118 spray applied coating with silica A nanoparticles, 114, 115f Epoxy coatings atomic force microscopy (AFM) images, 334f, 335f, 336f, 338f, 339f correlation between roughness and gloss retention, 340, 345f gloss retention and surface roughness, 340, 343, 345-346 gloss retention vs. exposure time, 340, 344f gloss retention vs. root mean square (RMS) roughness, 343, 345, 346f laser scanning confocal microscopy (LSCM) images, 338f outdoor ultraviolet (UV) exposure, 330-331 RMS roughness vs. scan sizes, 342f scaling factor vs. exposure time, 340, 343*f* surface roughness and scaling factor, 337, 340 surface topography characterization after outdoor exposure, 332-333, 337 See also Surface topography Escherichia coli bacterial growth and viability, 164 bioluminescence in ink-jet printed patches, micro-wells, and dot arrays, 171-179

bioluminescence kinetics of nanoplotter printed dot arrays of, 179, 182f bioluminescence reactivity of, latex dot arrays, 179, 182f glycerol and sucrose effect on inkjet printed, bioluminescence, 184t ink-jet nano-plotter, 166-167 ink-jet printing, 182 limitation of model E. coli system, 184-185 nano-plotter printing of, without adhesive latex, 177 printing, using nano-plotter for aspirate pipette deposition, 176-177 single cell deposition, 160-161 structure of, latex ink dot arrays using nano-plotter, 178 survival ratio of E. coli in liquid film with and without TiO₂ thin film, 195*f* toxicity of acrylate/vinyl acetate latex emulsions to, 169 See also Reactive adhesive microbial inks Exposure. See Outdoor exposure

F

Face modification attempting to encapsulate facemodified clays, 28–29 clay platelets, 25*f*, 26 *See also* Clay platelets
Far Field Optical Microscopy, particle size analysis technique, 376
Field effect transistor (FET), film applications, 52
Field-flow fractionation (FFF) minimum diameter by sedimentation FFF (SdFFF), 385*f*

particle size analysis, 381 SdFFF of pigments, 383-386 separation mechanism, 382f Fillers. See Scratch behavior of polyurethane coating Films coatings with nanoparticles, 217 polyurethane dispersions, 41-43 steps for hybrid dispersions by, 40-41, 42 See also Conjugated polymer network thin films; Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrid dispersions; Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrids; Titanium dioxide-containing films Fluorometric detection of Al³⁺ chemical assay method, 139 inhibitor performance for lanthanum chloride and sodium metasilicate, 142f, 143f Fractionation methods capillary hydrodynamic fractionation (CHDF), 381, 382f capillary zone electrophoresis, 379-380 commercially available particle size analysis, 375t comparison, 379t disk centrifugation (DC), 380-381 field-flow fractionation (FFF), 381, 382f particle electrophoresis, 379 sedimentation methods, 380-381 sieving (SIV), 379 size exclusion chromatography (SEC), 380 See also Particle size determination Functional groups, nanoparticle surface, 80-81

G

Gel content, UV-radiation exposure for clay-free and nanocomposites, 261*f*, 262 Gels, viable cell immobilization, 160 Glass forming region (GFR) modeling to predict, 131, 132f predicting, of alloy system, 130, 131f Glass transition temperature (Tg) acrylate films with organoclay, 262, 265f impact of filler in latex coating on, 280-281, 282t nanocomposite polyurethanes with nano-alumina and nano-silica, 236, 238f polyurethanes with alumina and silica nanoparticles, 222-223 polyurethane Tg values vs. drying time, 224, 227f Gloss acrylate films with organoclay, 267, 270t, 271 coatings with nanoparticles, 216, 217t correlation to roughness for epoxy coatings, 340, 345f retention and surface roughness of epoxy coatings, 340, 343, 345-346 retention of polyurethane coatings with alumina nanoparticles, 221t retention vs. exposure time of epoxy coatings, 340, 344f retention vs. root mean square (RMS) roughness for epoxy coatings, 345, 346f scratch resistance by, retention, 218, 220f, 221 studying surface topography, 329-330, 332 See also Surface topography

Gold nanoparticles, scientific interest, 374–375

H

Hardness instrumented indentation, 306f, 307f pendulum, of nanocomposite polyurethanes, 236, 238f surface, of nanocomposite polyurethanes, 235, 236f Hazard protection chemical and biological hazards, 200 chemical degradation of organophosphorus compounds, 201 MgO nanoparticle incorporation into polymers, 201-202, 203f reactivity of polyelectrolyte films with MgO against Paraoxon, 205-206 See also Chemical warfare (CW) agents; Reactive nanoparticles in coatings Head, nanoparticle, 70, 71f Hexadecyltrimethylammonium bromide (CTAB), hydrophobic cation for dual functionalization of clays, 33-34 **HVOF** coating scanning electron microscopy image of powders vs., 133, 137f thermal spray method, 133 x-ray diffraction of aluminumbased powders vs. coatings, 133, 136f Hybrid dispersions. See Polyurethanepolyhedral oligomeric silsesquioxane (PU-POSS) hybrid

dispersions

Hybrid films. See Polyurethanepolyhedral oligomeric silsesquioxane (PU-POSS) hybrids Hybrid sol-gels, applications, 74-75 Hydrogen peroxide assay with leucocrystal violet (LCV) method, 351-352 See also Titanium dioxide nanostructures Hydrophilic quaternary ammonium with polymerizable group $(PEO-V^{\dagger})$ chemical structure, 34f dual functionalization of clays, 32-33 Hydrotalcite, exchanging with corrosion inhibiting ions, 73-74 Hydrotect[™] coatings, self-cleaning applications, 193, 194f Hydroxide anions, triggering release of corrosion inhibiting anions, 74

I

Imaging nanoparticles in coatings, 389, 391 particle size analysis technique, 375-376 Indentation. See Instrumented indentation (IIT) Ink-jet inks adaptation of latex biocatalytic coating formulations as microbial, 162-163 aspirate pipette deposition, 166-167 bioluminescence response of inkjet printed patches, 171, 172f bioluminescence response of latex micro-wells, 171-173, 176 characteristics of polymer and solvent-dye based, 161-162 ink-jet deposition, 157 ink-jet nano-plotter, 166-167

ink-jet office printers, 165-166 reactivity of, 157-158 reservoir dispense deposition, 165-166 See also Reactive adhesive microbial inks Instrumented indentation (IIT) abrasion resistance of coated sunglasses, 305, 309f analysis of nanocomposite latex coatings, 278-279 dynamic mechanical analysis and tensile testing vs., 275-276 mechanical behavior of small length scales, 306f, 307f method modification, 303, 305 residual indentation of acrylic clearcoat, 317, 319f residual stresses on coating performance, 302-303 surface stress analysis, 303, 308f testing method, 277-278 Integrated circuits, micro-biosensors, 160 Interphase, nanoparticles, 67-68 Intrinsically conducting polymers (ICPs) behavior, 52 See also Conjugated polymer network thin films Isopropyl alcohol test conversion to acetone for TiO₂ samples, 354, 357, 358f method, 352 See also Titanium dioxide nanostructures

K

Kinetic metallization, cold spray, 133 Kluyveromyces fragilis bacterial growth and viability, 164 ink-jet nano-plotter, 166-167 ink-jet printed, micro colony array, 183*f*ink-jet printing, 182
ink-jet surface patterning with living microbes, 179, 182
See also Reactive adhesive microbial inks
Krieger-Dougherty equation, critical volume fraction, 96, 97*f*

L

Langmuir-Blodgett (LB) films, atomic force microscopy (AFM), 293, 296 Laponite RD (LRD) clay, 26 See also Encapsulation inside latex particles Laser scanning confocal microscopy (LSCM) characterizing scratch morphology, 233, 235 comparing images of scratch profiles of unfilled polyurethane (PU) and PU containing nanoalumina and nano-silica, 251f epoxy coating images after outdoor exposure, 333, 337, 338f, 339f image of scratch profile of unfilled PU, 239f images of progressive scratch (Pscratch) profiles for nanocomposite coating with nano-silica, 250f images of set of P-scratch (nanoalumina) systems, 247f P-scratch profile of unfilled coating and coating with nano-alumina, 240f, 244f root mean square (RMS) roughness vs. exposure time for epoxy coatings, 341f

surface topography method, 329, 331-332 See also Scratch behavior of polyurethane coating; Surface topography Latex biocatalytic coating formulations, adaptation as microbial ink-jet inks, 162-163 Latex coatings appearance of, with pigment dispersions, 280-281 commercial coatings, 275 properties of particles in, 277t See also Nanocomposite latex coatings Latex ink formulations determining ink toxicity to microorganisms, 167-168 determining rheology and dry coating thickness, 168 ink-jet office printers, 165-166 monodispersed acrylate/vinyl acetate copolymer, 167, 168t reactive microbial inks, 158-159 Latex particles. See Encapsulation inside latex particles Lecyar model, composition dependence of zero shear viscosity, 97--98 Leuco-crystal violet (LCV), hydrogen peroxide assay with absorbance spectrum for LCV assay with TiO₂ pigment, 354, 356f absorbance with acetone buffer at pH 4.4 and 5.8, 359, 361f dynamic light scattering (DLS), 366-368 photoreactivity comparison from, with TiO₂ pigments, 354, 357f photoreactivity response, 370 pigment cluster size vs. photoreactivity, 371f See also Titanium dioxide nanostructures

Light scattering dynamic, (DLS) measurements, 352-353 nanoparticles in coatings, 389, 391 particle size analysis technique, 377-378 pigments, 373-374 See also Titanium dioxide nanostructures Limiting oxygen index (LOI), acrylate films with organoclay, 263, 269t Local thermal analysis (LTA) polymeric coatings, 314, 316 softening temperature comparison, 321, 324f. 325f

M

Magnesium oxide nanoparticles, incorporation into polymers, 201-202 Mechanical behavior, instrumented indentation, 306f, 307f Mechanical properties particles in coatings, 275 surface, 233 surface, of nanocomposite polyurethanes, 235-236 See also Scratch behavior of polyurethane coating Mechanisms one-dimensional alignment of nanoparticles in coating, 118, 121 TiO₂-containing surfaces, 191–192 Mercury-inducible bioluminescence determination of reactivity after ink-jet printing, 164-165 effect of drying temperature and relative humidity on, reactivity in latex ink formulations "macrodots", 170t effect of ink drying on, 169-171

reactivity of E. coli pRB28, 163, 183. 184t See also Reactive adhesive microbial inks Metal and metal oxide nanoparticles, immobilization in polymers, 189 Metal oxide nanoparticles, incorporation or immobilization on surfaces, 202, 205 Methyl methacrylate (MMA) emulsion polymerization, 27 See also Encapsulation inside latex particles Methyl viologen (MV) assay absorbance for KHP buffer at pH 6.0 and two TiO₂ loadings, 358-359, 360f absorbance for phosphate and potassium hydrogen phosphate (KHP) buffers at pH 6.0, 358, 360f absorbance for phosphate buffer using pH 4.4 and 6.0, 358, 359f absorbance spectrum for MV assay with TiO₂ pigment, 354, 355f dynamic light scattering (DLS), 364, 365f, 366f method, 351 photoreactivity comparison of TiO₂ pigments by, 354, 356f photoreactivity response, 369-370 pigment cluster size vs. photoreactivity, 369f See also Titanium dioxide nanostructures Mica surface. See Alkylpolyglycosides (APG) Microbe enzymes, reactive microbial inks, 158-159 Microbial inks development, 157-158 See also Reactive adhesive microbial inks Micro-biosensors, microbial inks for, 160 - 163

416

tensile testing, 278 Tg for films with inorganic pigments at 2.5% PVC, 282t zinc oxide and titanium dioxide particles, 276-277 Nanocomposites considering final outcome, 69 interphase region, 67, 68f polymer coatings, 65 preparation, 65 Nano-engineered cladding, military aircraft, 129-133 Nanoparticles alumina and silica in polyurethane coatings, 233 applications in coatings, 211 attraction between, 66-67 body, 70-71 characterization in coatings, 389, 391 coating processes, 374-375 components, 69-71 degree of dispersion in polyurethane coatings, 216-218 economic and chemical aspects of boehmite, 76-78 functional groups on surface, 80-81 head, 70 interphase, 67-68 photoactive, 275 surface effects, 66-71 surface-modified boehmite nanoparticles, 75-76 tail, 71 technical design factors, 68-69 understanding surface properties of, 65-66 well-dispersed, coatings, 65 See also Boehmite nanoparticles; One-dimensional alignment of nanoparticles in coatings; Polyurethane coatings; Reactive nanoparticles in coatings;

Scratch behavior of polyurethane coating; Surface modified nanoparticles Nanoparticle Tracking Analysis (NTA), particle size analysis technique, 376 Nano-plotter aspirate pipette deposition, 166-167 bioluminescence kinetics of, dot arrays of E. coli pRB28, 182f E. coli pRB28 latex ink dots using piezoelectric, 180f, 181f printing E. coli pRB28 using, for aspirate pipette deposition, 176-177 printing of E. coli without adhesive latex, 177 structure of E. coli latex ink dot arrays using, 178 Nanoporous particles, surfactantdirected assembly, 140-141 Nanoporous silica, encapsulating material for corrosion inhibitors, 140 Nanostructured adhesives. See Reactive adhesive microbial inks Nanostructured conjugated networks. See Conjugated polymer network thin films Nanostructured hybrid dispersions. See Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrid dispersions Nanostructured material characterization abrasion resistance of coated sunglasses, 305, 309f acrylic curing time and softening temperature, 321, 322f acrylic film thermal softening, 317, 320f acrylic softening temperature vs. time, 322t, 323t

- adhesion of nanometer-thick scratch resistant coatings, 300, 302–303, 305
- AFM (atomic force microscopy) probing thermal properties, 311, 313-314
- AFM of paper with cellulose acetate and APG coating, 293, 294*f*, 295*f*
- alkylpolyglycosides (APG) molecular self-assembly and ordering, 293, 296, 300
- analytical problems, 293
- analytical tools, 293
- APG films on mica sheets from airwater interface, 300, 302f
- APG monolayer film on mica surface, 296, 299*f*
- calibrating thermal probes with polycaprolactone and polyethylene, 315f
- cellulose fiber by AFM showing height and phase images, 296, 297f
- cellulose with APG as adhesion promoter, 293, 294*f*, 295*f*
- comparing thickness of bilayer of minimized APG, 300, 304f
- cross-sectional view of commercial automotive coating, 317, 318f
- dynamic mechanical analysis (DMA) for viscoelastic behavior, 310, 311f
- instrumented indentation for mechanical behavior, 302–303, 306f, 307f
- local thermal analysis (LTA), 314, 316f
- measuring thermal properties at nanoscale, 311, 313–314, 316– 317, 321
- molecular modeling for APG molecule, 300, 303f

orientation of APG away from mica surface, 300, 301f

phase imaging (AFM) of styreneisoprene-styrene (SIS), 310, 312f photo-degraded acrylicpolyurethane (AU) coatings, 321, 326 pressure-sensitive adhesives, 305, 310-311 resin aromaticity and PSA performance, 310, 312t, 313f self-assembled APG on cellulose fibers, 296, 298f softening temperature comparison of UV-exposed and filled AU coatings, 324f, 325f styrenic block copolymers (SBCs) in PSA industry, 305, 310 surface stress analysis by indentation of planar surface, 303, 305, 308f surface stress analysis of problem lenses by indentation, 305, 309f topview images of acrylic coating after LTA testing, 317, 319f See also Thermal analysis Nanostructures. See Titanium dioxide nanostructures Near Field Optical Microscopy, particle size analysis technique, 376 Non-fractionation methods electrozone sensing, 376-377 imaging, 375-376 light scattering, 377-378 particle size analysis, 375t, 375-379

ultrasonic or electroacoustic measurements, 378–379 See also Particle size determination

0

Office printers, reservoir dispense deposition, 165–166

One-dimensional alignment of nanoparticles in coatings AFM (atomic force microscopy) height image of polyurethane (PU) coating with alumina C nanoparticles, 111f AFM height image and line profile of alumina C arrangements by spray application, 112f AFM height images of coatings with alumina D and C nanoparticles, 112f application by drawdown method, 111 application by drop deposition method, 110-111 application by spray method, 112-113 dispersed nanoparticles in study, 110t EDS (energy dispersive x-ray spectroscopy) analysis of coating with Al and Si elements, 116f EDS analysis of 1-D arrangements in control coating, 120f EDS analysis of coating with alumina C, 117f, 119f EDS analysis of coating with silica A nanoparticles, 115f electron micrographs of silica A arrangements by spray application, 113f experimental, 109-110 heat from electron beam of SEM evaporated large deposits on coating surface, 118f literature, 109 optical microscope image of micrometer-scale arrangements by spray application, 114f optical microscopy image of, by 100x magnification, 113f

proposed mechanism of alignment, 118, 121 scanning electron microscopy (SEM) elemental analysis, 114, 118 Open circuit potential, Al-Co-Ce system, 133, 134f **Optical clarity** coating property, 211 coatings with nanoparticles, 217 Ordered monolayers, monodisperse polystyrene spheres, 147-148, 149f Ordering, alkyl-polyglycosides (APG), 293, 296, 300 Organic corrosion inhibitors, effectiveness, 80 Organic π -conjugated polymers behavior, 52 See also Conjugated polymer network thin films Organoclays in UV-curable coatings abrasion resistance, 267, 271 advantages, 256-258 applications for UV-curing process, 256 atomic force microscopy (AFM), 262–263, 266f characterization methods, 259-260 char yield, 263, 269t decomposition behavior, 263, 269f differential scanning calorimetry (DSC) of acrylate with and without organoclay, 262, 265f elasticity, 262 experimental, 258-260 gel content vs. UV-radiation time curves for clay-free and nanocomposite/organoclay samples, 261f glass transition temperature (Tg) of acrylates vs. organoclay content, 262, 265f gloss of acrylate films by organoclay content, 267, 270t gloss retention after steel-wool scratch test, 261f

limiting oxygen index (LOI), 263, 269t polymeric nanocomposites, 256 polymerization progress, 261f, 262 preparation of coating, 259 preparation of organoclay, 258-259 scanning electron microscopy (SEM), 262-263, 266f SEM images of clay-free and nanocomposite surfaces after steel-wool scratch test, 267, 270f tensile properties of acrylate films vs. organoclay content, 262, 264f thermal stability, 263, 269f transmission electron microscopy (TEM), 263, 267f, 268f x-ray diffraction profile of clay and organoclay, 260f x-ray diffraction profile of nanocomposite films with organoclay, 261f Organophosphorous compounds, chemical degradation, 201 Oriented attachment, crystal growth theory, 121 Original equipment manufacturer (OEM) cladding, 129-133 limitations of OEM coating system, 128 military aerospace coating, 127 Outdoor exposure epoxy coating surface topography, 332-333, 337 ultraviolet (UV) testing of epoxy coatings, 330-331 See also Surface topography

P

Packing arrangement, boehmite, 77 Paraoxon, hydrolysis by polyelectrolyte-nanoparticle surfaces, 205–206 Particle electrophoresis, particle size analysis, 379 Particle size commercial analysis techniques, 375t dynamic light scattering for particle cluster size, 359, 361 measurement method, 39 mechanical properties of latex coatings, 288-289 nanoparticle size analysis, 375 polyurethane/polyhedral oligomeric silsesquioxanes (PU/POSS) dispersions, 43t titanium dioxide pigments, 355t See also Particle size determination; Titanium dioxide nanostructures Particle size determination capillary hydrodynamic fractionation (CHDF), 381, 382f capillary zone electrophoresis, 379-380 commercially available techniques, 375t disk centrifugation (DCF), 380-381 electroacoustic measurements, 378-379 electrozone sensing, 376-377 experimental conditions, 385-386 FFF (field-flow fractionation), 381, 382f FFF analysis by scanning electron microscopy (SEM), 386 fractionation methods, 379-383 imaging, 375–376 light scattering, 377-378 light scattering behavior, 373-374 multiangle light scattering (MLS), 377-378 nanoparticles in coatings, 389, 391 nanoparticle size analysis, 375 non-fractionation methods, 375-379 particle electrophoresis, 379

420

photon correlation spectroscopy (PCS), 377 poly(methyl methacrylate) (PMMA) beads and aggregates, 386, 387f SdFFF (sedimentation FFF) characterization of pigments, 383-386 SdFFF fractogram and size distribution of iron oxides and TiO₂, 388, 390f SdFFF fractogram and size distribution of titanium dioxide, 388f sedimentation methods, 380-381 shape of nanoparticles, 389 sieving (SIV), 379 size and distribution, 373-374 size distribution curves for TiO₂ nanoparticles, 383f size exclusion chromatography (SEC), 380 ultrasonic measurements, 378-379 Patterning, microcontact printing, 56, 58f Peroxotitanium sol, creation of selfcleaning coatings, 193-194 pH. See Titanium dioxide nanostructures Photon correlation spectroscopy (PCS), particle size analysis technique, 377-378 Photoreactivity. See Titanium dioxide nanostructures pH trigger release, coatings operating by, 73 Physical properties, polyurethanepolyhedral oligomeric silsesquioxane (PU-POSS) films, 43, 44*t* Piezoelectric deposition devices aspirate pipette, 166-167 ink-jet nano-plotter, 166-167 ink-jet office printers, 165-166 reservoir dispense, 165-166

types, 165t Pigments scattering light, 373-374 See also Titanium dioxide nanostructures Pigment volume concentration (PVC). See Nanocomposite latex coatings Pilkington ActivTM, self-cleaning surface, 192-193 Platelets. See Encapsulation inside latex particles Polyacrylic acid, metal oxide nanoparticles on surface of multilayer films, 205 Poly(allylamine hydrochloride) (PAH), metal oxide nanoparticles on surface of multilayer films, 205 Polycaprolactone, calibration of nanothermal probes, 315f Polyelectrolyte multilayer films atomic force microscopy (AFM), 204f hydrolysis of Paraoxon on, 205-206 metal oxide nanoparticles on surface, 205 Polyethylene, calibration of nanothermal probes, 315f Polyfluorenes grafting carbazole-modified, on electrode surfaces, 57 See also Conjugated network polymer thin films Polyhedral oligomeric silsesquioxane (POSS) compatibility with polymeric materials, 37 enhancing physical properties, 90 functionalities for polymerization, 90 See also Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrid dispersions;

Polyurethane-polyhedral

oligomeric silsesquioxane (PU-POSS) hybrids Polymer based ink-jet inks, characteristics, 161-162 Polymeric coatings appearance and service life, 329 See also Surface topography Polymerization progress, nanocomposite films with organoclay, 261f, 262 Polymer light emitting diode, film applications, 52, 54, 60 Polymers, metal and metal oxide nanoparticles in, 189 Poly(methyl methacrylate) (PMMA) characteristics of clay-encapsulated latex particles, 31t composites with metal fillers, 189 emulsion polymerization, 27 environmental scanning electron microscopy (ESEM) of clayencapsulated PMMA latex, 33f scanning electron microscopy (SEM), 386, 387f sedimentation field-flow fractionation (SdFFF), 386, 387f See also Encapsulation inside latex particles Polystyrene spheres, ordered monolayers of monodisperse, 147-148, 149f Polysulfone (PSU) energy dispersive x-ray (EDX) of PSU-MgO, 202, 203f incorporation of MgO nanoparticles into, 201-202 SEM micrographs of PSU-MgO, 202, 203f Polyurethane-acrylate coatings advantages of, with nanoparticles, 257-258 See also Organoclays in UVcurable coatings

Polyurethane coatings alumina and silica nanoparticles, 211 applications, 211 atomic force microscopy (AFM), 217-218 control-H formulation, 214t, 214-215 control-L formulation, 213t, 213-214 degree of dispersion of nanoparticles, 216-218 differential scanning calorimetry (DSC) and dynamic mechanical analysis (DMA), 215 DMA scores of control and alumina D coatings, 223f experimental, 212-216 film clarity, 217 formulation solvent effects, 224, 226f, 227f glass transition temperature (Tg) of coatings with control-H, 222f gloss values before scratching, 216, 217t optical clarity, 211 percent gloss retention of control-H and control-H plus nanoparticles, 222f predispersed nanoparticles in study, 214*t* preparations, 212-213 scanning electron microscopy (SEM), 218, 219*f*, 220*f* scratch resistance by percentage gloss retained, 220f scratch resistance mechanisms, 225, 229, 229f scratch resistance of control-H by gloss retention, 221t scratch resistance of solvent-free coatings, 225, 228f scratch resistance results, 218, 221 scratch resistance testing, 213-215

SEM image of control-H film with alumina D nanoparticles, 229f test parameters for DMA scans, 216t Tg values of control-H coatings and coatings with nanoparticles, 224t thermal properties, 222-223 thermogravimetric analysis (TGA) of nanoparticle dispersions, 215f thermo-mechanical analysis, 215 thermo-mechanical properties of solvent-free coatings, 225, 227f, 228f understanding mechanisms of scratch resistance improvements, 211-212 See also One-dimensional alignment of nanoparticles in coatings; Scratch behavior of polyurethane coating; Scratch resistance Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrid dispersions base polyurethane (PU) dispersion synthesis, 40, 41 coating system of waterborne polyurethane dispersions (PUD), 37-38 compatibility of POSS with polymeric materials, 37 experimental, 38-41 film preparation, 43 materials, 38-39 measurement methods, 39-40 particle size and viscosity of PU/POSS dispersions, 43t physical properties of films, 43, 44t preparation of PU-POSS hybrid dispersion, 38 prepolymer process for PU dispersion preparation, 41-43 representative hybrid dispersion preparation (PU10), 40-41

shear frequency dependence of storage modulus of nanocomposite films, 46f steps for hybrid dispersion by prepolymer mixing, 42 steps for synthesis of pure PUD dispersion and chain extension, 41 storage modulus of nanocomposite films, 44, 45f surface behavior, 43-44 tan delta of nanocomposite films, 44-45, 46f thermogravimetric analysis (TGA) for nanocomposite films of, 47 viscoelastic and thermogravimetric measurements, 45, 47 waterborne hybrid dispersions, 37-38,48 weight fraction dependence of complex viscosity for nanocomposite films, 47f wide-angle x-ray diffraction (WAXD) patterns of amino-POSS-PU's, 44f Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrids acetone process, 91 acetone process synthesis of, 92-93 Arrhenius expression, 102 behavior of, nanocomposites by prepolymer process, 98, 99f complex viscosity vs. angular frequency for PU/POSS nanocomposites by acetone process, 94, 95f complex viscosity vs. angular frequency for PU/POSS nanocomposites by prepolymer process, 95f, 95-96 composition dependence of zero shear viscosity of composite without unreacted dispersed phase, 97-98

critical volume fraction using Krieger–Dougherty equation, 96 deviation of Williams-Landel-Ferry (WLF) equation at high temperature, 99, 101 dimethylol propionic acid (DMPA) for prepolymer process, 96 Einstein-Batchelor equation, 96-97 enhancement of physical properties, 90, 91 experimental, 92-94 functionalities on POSS for polymerization, 90 Lecyar model, 97–98 master curves of dynamic shear moduli, G' and G", 98-99, 101f measurement methods, 93-94 microphase separation temperature (T_{MPS}), 102, 104 POSS stratifying at surfaces of polymers, 90-91 prepolymer (NMP) process, 91 prepolymer process synthesis of, 41-43 shift factor vs temperature for, by acetone and prepolymer processes, 102, 103f small-angle x-ray scattering (SAXS) measurements, 101 steps for hybrid dispersion by acetone process, 93 temperature dependence of shift factor, 102, 103f temperature dependence of storage modulus of, by acetone and prepolymer process, 102, 105f volume fraction dependence of complex viscosity of, by acetone process, 96-97, 97f wide-angle x-ray diffraction (WAXD) of, by acetone and prepolymer processes, 98, 100f WLF expression, 102

Polyvinylcarbazole (PVK) nanopatterning process by electrochemical nanolithography (ECN), 58, 59f variable turn-on voltage based on electrochemical doping, 59f Poly(vinyl chloride (PVC) incorporation of MgO nanoparticles into, 201-202 SiO₂ nanocomposites, 189 Poly(vinylidene fluoride-cohexafluoropropylene), incorporation of MgO nanoparticles into, 201-202 Precursor polymer approach conjugated polymers, 52–53 cross-linking by electropolymerization, 54, 56 electropolymerization of homopolymers/copolymers, 55f schematic, 53fsynthesis of precursor homopolymers/copolymers, 55f vinyl monomers with electropolymerizable sidegroups, 54 See also Conjugated polymer network thin films Predictive modeling, nanoparticles, 69 Prepolymer process synthesis of polyurethanepolyhedral oligomeric silsesquioxanes (PU-POSS), 41 - 43See also Polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) hybrids Pressure-sensitive adhesives (PSAs) atomic force microscopy (AFM) imaging, 310, 312f characteristic properties, 305 dynamic mechanical analysis (DMA), 311f resin aromaticity and PSA performance, 310, 312t

storage modulus and tan delta vs. temperature for PSA formulations, 310-311, 313f styrenic block copolymers (SBCs), 305, 310 tackifier chemistry, 310 viscoelastic behavior, 310, 311f Primer, functional, for corrosion protection, 128 Profilometry E. coli pRB28 latex ink dots using piezoelectric nano-plotter, 180f, 181f images of micro-well printed using Canon 1080A printer, 173, 174f methods for micro-wells and dot arrays, 168 monitoring microbial dot array printing, 184 Progressive-load scratch initial and residual penetration depths from, for alumina nanoparticle/polyurethane systems, 242f, 245f laser scanning confocal microscopy (LSCM) images of, profiles, 240f, 244f, 250f, 251f penetration curves for unfilled polyurethane (PU), 239f testing, 234-235, 237 See also Scratch behavior of polyurethane coating Proposed mechanism, onedimensional alignment of nanoparticles in coating, 118, 121 Pulsed thermal spray (PTS) method, 133 x-ray diffraction of Al-18Co-9Ce feedstock and coatings, 133, 136f

Q

Quaternary ammonium groups antimicrobial coatings, 196, 197f dual-functional antibacterial coating with, and silver, 197, 198*f*, 199*f*

R

Reactive adhesive microbial inks adaptation of latex biocatalytic coating formulations, 162-163 altered in vivo gene expression, 159 aqueous latex formulations, 158 aspirate pipette deposition, 166-167 bacterial growth and determination of viability, 164 bioluminescence kinetics, 172f, 175f, 182f bioluminescence reactivity of Escherichia coli latex dot arrays, 179, 182f bioluminescence response of inkjet printed patches, 171, 172f bioluminescence response of latex micro-wells with nanoporous latex ink using reservoir dispense deposition, 171-173, 176 characteristics of polymer and solvent-dye based ink-jet inks, 161-162 characteristics of solvent-dye based ink-jet inks, 162t determination of latex ink rheology and dry coating thickness, 168 determination of latex ink toxicity to microorganisms, 167-168 development of microbial inks, 157-158 drying temperature and relative humidity on E. coli bioluminescence reactivity, 170t E. coli and K. fragilis, 182 formulation approaches, 158-159

future monitoring, 184 glycerol and sucrose effects on inkjet printed E. coli bioluminescence, 184t ink drying and mercury-inducible E. coli bioluminescence reactivity, 169-171 ink-jet deposition development, 157 ink-jet deposition devices, 182-183 ink-jet nano-plotter, 166-167 ink-jet office printers, 165-166 ink-jet printed K. fragilis micro colony array, 183f ink-jet surface patterning using living microbes, 179, 182 ink reactivity, 157-158 latex ink formulations, 167, 168t limitation of model E. coli system, 184-185 manipulating microbes' enzyme content, 158-159 manually deposited "macrodots", 169-171 materials and methods, 164–168 mercury-inducible bioluminescence reactivity of E. coli pRB28, 163f, 183, 184t micro-biosensors and bioelectronic devices, 160-163 microscopic and profilometer imaging, 183-184 microscopy, image analysis and profilometry methods, 168 nano-plotter printing of E. coli without adhesive latex, 177 nanoporous coating technology, 158 piezoelectric deposition devices, 165-167 printing E. coli pRB28 using nanoplotter for aspirate pipette deposition, 176–177 profilometer images of latex ink dots, 178, 180f, 181f

profilometer images of latex microwell, 173, 174f rate and maximum reactivity, 159 reactivity after ink-jet printing by bioluminescence, 164-165 reservoir dispense deposition, 165-166 structure of E. coli latex ink dot arrays using nano-plotter, 178, 179t toxicity of acrylate/vinyl acetate latex emulsions to E. coli pRB28 and yeast, 169 Reactive nanoparticles in coatings antimicrobial surfaces, 194-197, 200 biocidal activity of silver, 196 chemical warfare (CW) agents, 200-201 dual-action antimicrobial coatings, 196, 197f hazard protection, 200-202, 205-206 hydrolysis of Paraoxon by polyelectrolyte-nanoparticle surfaces, 205-206 killing gram-negative and grampositive bacteria, 196 mechanism of degradation of chemical agents, 201, 202 metal oxide nanoparticle incorporation/immobilization on surfaces, 202, 204f, 205 MgO nanoparticle incorporation into polymers, 201-202, 203f on-side precipitation method for dual-action antibacterial composite, 197f photocatalytic activity of titanium dioxide, 189-194 quaternary ammonium groups, 196, 197, 198f, 199f release-killing and contact-killing capabilities, 197 self-cleaning surfaces, 189-194

silver nanoparticles as antimicrobial agents, 196 two-level coating, 200 See also Titanium dioxidecontaining films Repassivation potential, Al-Co-Ce system, 133, 134f Reservoir dispense deposition bioluminescence response of latex micro-wells with ink using, 171-173, 176 ink-jet office printers, 165-166 piezoelectric device, 165t **Rheological properties** Arrhenius equation, 102 Carreau-Yasuda model, 94-95 composition dependence of zero shear viscosity, 97-98 Einstein-Batchelor equation, 96-97 Krieger-Dougherty equation, 96 latex ink rheology, 168 Lecyar model, 97-98 master curves of dynamic shear moduli, 98-99, 101f microphase separation temperature, 102, 104, 105f shear frequency dependence of complex viscosity and elastic modulus for PU/POSS nanocomposites, 94, 95f temperature dependence of shift factor, 102, 103f volume fraction dependence of complex viscosity of PU/POSS nanocomposites, 96, 97f, 98, 99f wide-angle x-ray diffraction (WAXD) patterns of amino-POSS PU, 98, 100f Williams-Landel-Ferry (WLF) equation, 99, 101, 102 See also Polyurethane-polyhedral oligomeric silsesquioxane (PU-

POSS) hybrids

Root mean square (RMS) roughness equation, 331 See also Surface topography

S

Salt fog test, corrosion inhibiting boehmite nanoparticles, 82, 84f Scanning electron microscopy (SEM) acrylate films with organoclay, 262–263, 266f coatings with nanoparticles, 218, 219f, 220f elemental analysis of coatings with aligned nanoparticles, 114, 118 heat from electron beam of, evaporated large deposits on coating surface, 118f images of scratched acrylate films with and without organoclay, 267, 270f poly(methyl methacrylate) (PMMA), 386, 387f polysulfone-MgO, 202, 203f powders vs. resulting HVOF coating, 133, 137f Scanning Mobility Particle Sizer spectrometry, particle size analysis technique, 376 Scanning probe microscopes, surface topography, 329 Scattered light dynamic fluctuations of, from particles, 352-353 See also Titanium dioxide nanostructures Scratch behavior of polyurethane coating alumina (Filler A and B) and silica (Filler C) nanoparticles, 233-234 comparing Filler A, B, and C systems, 248-249, 251

- constant load scratch width for unfilled coating and coatings with Filler A, B, and C, 252f
- dividing scratch profiles, 253
- experimental, 233–235
- Filler A system, 237, 240
- Filler B system, 241, 243–244
- Filler C system, 248
- full scratch width, peak-to-peak scratch width vs. scratch force of unfilled and Filler B systems, 246f
- glass transition temperature and pendulum hardness vs. particle concentration for coatings with Filler A, B, and C, 238f
- initial and residual penetration depth from progressive scratch (P-scratch) profiles of Filler A systems, 242f
- initial and residual penetration depth from P-scratch profiles of Filler B systems, 245f
- laser scanning confocal microscope (LSCM) method, 235
- LSCM images of profiles from Pscratch of unfilled coating and coatings with Filler A, B, and C, 251f
- LSCM images of progressive scratch profiles and residual scratch depth for unfilled and Filler C coatings, 250f
- LSCM images of P-scratch profiles from progressive load-scratch on unfilled and coating with Filler B, 244*f*
- LSCM images of P-scratch profiles on unfilled and coating with Filler A, 240f
- LSCM images of P-scratch with Filler B systems, 247f
- LSCM images of scratch, 239f
- mechanical measurements, 234

peak-to-peak scratch width, full scratch depth, and ratio for Filler A system, 241t peak-to-peak scratch width, full scratch depth, and ratio for Filler B system, 248t penetration curves from P-scratch on unfilled PU, 239f percentage of recovery from Pscratch test, 252f progressive-load scratch testing, 237, 239f scratch morphology characterization, 234-235 scratch profiles of 1 and 2.5 wt% Filler A systems, 243f scratch testing, 234-235 surface elastic modulus and hardness vs. nanoparticle concentration of coatings with Filler A, B, and C, 236f surface mechanical measurements, 235-236 Scratch resistance acrylate films with organoclay, 267, 270t, 271 adhesion of nanometer-thick, coatings, 300, 302-303, 305 gloss retention of polyurethane coatings with alumina nanoparticles, 221t gloss values of coatings before scratching, 217t mechanisms, 225, 229 percentage gloss retention after scratch test, 220f results for coatings with nanoparticles, 218, 221 solvent-free coatings, 225, 228f testing, 213-215 understanding mechanisms, 211-212 See also Polyurethane coatings; Scratch behavior of polyurethane coating

Sedimentation field-flow fractionation (SdFFF) experimental, 385-386 fractogram of poly(methyl methacrylate) and aggregates, 386, 387*f* iron oxides, 390f minimum diameter by SdFFF, 385f nanoparticle shape, 389, 390f pigments, 383-386 retention ratio, 384 titanium dioxide nanoparticles, 386, 388f, 390f See also Field-flow fractionation (FFF) Sedimentation methods, particle size analysis, 380-381 Self-assembly, alkyl-polyglycosides (APG), 293, 296, 300 Self-cleaning surfaces aircraft coating, 146 commercial products, 192-193 generation of super-hydrophilic surface, 191 Hydrotect[™] by TOTO Ltd., 193 irradiation of TiO2 with UV light, 190f mechanisms for TiO₂-containing surfaces, 191-192 peroxotitanium sol, 193-194 photoactive TiO₂ coatings for development of, 192-193 photocatalytic activity of titanium dioxide, 189-190 Pilkington Activ[™], 192–193 Tower of Earth in Nagoya City Pavilion, 193, 194f Self-repair methods, aircraft coatings, 146-148 Sensing methods, aircraft coatings, 146-148 Service life, polymeric coatings, 329 Shift factor, temperature dependence, 102, 103f Sieving, particle size analysis, 379

Silica nanoparticles dynamic mechanical analysis of polyurethanes with, 223, 224t incorporation into UV-cured polymers, 257 polyurethane automotive coating, 211 predispersed nanoparticles in study, 214t scratch comparisons with alumina nanoparticles in PU coatings, 248-249, 251, 252f scratch testing for polyurethane coatings with, 248 thermo-gravimetric analysis of dispersions, 215f thin film coatings, 374 See also One-dimensional alignment of nanoparticles in coatings; Polyurethane coatings; Scratch behavior of polyurethane coating Silver nanoparticles antimicrobial agents, 196 dual-functional antibacterial coating with quaternary ammonium salts and, 197, 198f, 199f Size analysis of particles. See Particle size; Particle size determination Size exclusion chromatography (SEC), particle size analysis, 380 Smart coatings coatings industry, 51-52 corrosion inhibiting system, 72-73 See also Conjugated polymer network thin films Smart delivery system, boehmite nanoparticles as, for corrosion inhibitors, 78-81 Solar panels, nanocrystals, 374 Sol-gels, hybrid, 74-75 Solvent-dye based ink-jet inks, characteristics, 161-162

Solvent effects, formulation and nanoparticle dispersion media, 224, 226f Solvent-free coatings polyurethanes with nanoparticles, 225, 227f, 228f scratch resistance, 225, 228f Spectrophotometric assays. See Titanium dioxide nanostructures Spray method coating application, 112-113 electron micrographs of silica A arrangements by, 113f optical microscope image of micrometer-scale arrangement, 114f optical microscopy image of 1-D alignments, 113f Stimulated Emission Depletion microscopy, particle size analysis technique, 376 Stokes-Einstein relation, diffusion coefficient, 353 Storage modulus dynamic mechanical analyzer (DMA), 39 polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) nanocomposite films, 44, 45f Strategies for modification, nanoparticle surface, 69, 70f Stress analysis instrumented indentation, 303, 308f problem lenses by indentation, 305, 309f Styrenic block copolymers atomic force microscopy (AFM) imaging of styrene-isoprenestyrene (SIS) resin, 310, 312f pressure-sensitive adhesives, 305, 310 storage modulus and tan delta vs. temperature for adhesive formulations, 310-311, 313f

viscoelastic behavior of SIS-based formulation, 311f SunClean[™], self-cleaning surface, 192 Sunglasses, abrasion resistance of coated, 305, 309f Surface behavior amino-polyhedral oligomeric silsesquioxane (amino-POSS)/polyurethane films, 43--44 mechanical properties, 233 See also Scratch behavior of polyurethane coating Surface design, nanocomposite coatings, 65-66 Surface modified nanoparticles aspect ratio, 68-69 body, 70-71 boehmite, 75-76 boehmite nanoparticles as smart delivery system, 78-81 chromate conversion coatings, 72-73 coatings operating by pH triggered release, 73 components, 69-71 considering final outcome for nanocomposite, 69 economic and chemical aspects of boehmite nanoparticles, 76-78 head, 70 hybrid sol-gels, 74–75 hydrotalcite and related materials, 73-74 improving mechanical and barrier properties, 66 interphase, 67-68 morphologies, 68 nanocomposite interphase region, 68f predictive modeling research, 69 protective coatings, 72 range of modification strategies, 69,70f

schematic of parts, 71f supported polyelectrolyte layers, 75 surface effects of nanoparticles, 66-71 tail, 71 technical design factors, 68-69 See also Boehmite nanoparticles Surface roughness correlation to gloss retention for epoxy coatings, 340, 345f epoxy coatings, 337, 340 gloss retention and, for epoxy coatings, 340, 343, 345-346 gloss retention vs. for epoxy coatings, 345, 346f Surface stress instrumented indentation, 303, 308f problem lenses by indentation, 305, 309f Surface topography AFM (atomic force microscopy) method, 332 AFM images of March Group epoxy coating after outdoor exposure, 334f, 335f characterization with AFM and LSCM, 332-333, 337 correlation between roughness and gloss retention for September Group, 340, 345f 3-D AFM images of March Group epoxy coating after outdoor exposure, 336f equation for root mean square (RMS) surface roughness (Sq), 331 experimental, 330-332

- gloss, 329-330
- gloss measurement method, 332
- gloss retention and surface roughness, 340, 343, 345-346
- gloss retention vs. exposure time for four groups, 340, 344*f*
- gloss retention vs. RMS roughness for four groups, 343, 345, 346f

- laser scanning confocal microscopy (LSCM) method, 331-332
- LSCM and AFM images of July Group epoxy coating after outdoor exposure, 338f, 339f
- method for outdoor UV exposure, 330-331
- RMS roughness (LSCM) vs. exposure time for four groups, 341f
- RMS roughness vs. exposure time (LSCM and AFM), 341f
- RMS roughness vs. scan sizes, 342f
- scaling factor vs. exposure time for March and September Groups, 340, 343f
- service life of polymeric coatings, 329
- surface roughness and scaling factor, 337, 340
- techniques for measurement, 329
- Surface treatment, titanium dioxide pigments, 355t
- Synergistic combinations, corrosion inhibitors, 135

Т

Tackifier chemistry, pressure-sensitive adhesives, 310 Tail, nanoparticle, 71 Tan delta dynamic mechanical analyzer (DMA), 39 polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) nanocomposite films, 44-45, 46f Tensile properties, acrylate films with organoclay, 262, 264f Tensile strength, acrylate films with organoclay, 262, 264f Thermal analysis (TA) acrylic coating, 317, 319f

atomic force microscopy (AFM), 313-314, 315f calibration of AFM probes, 315f contact mode and nano-TA probes, 314, 316f curing time and softening temperature of acrylic coatings, 321, 322f local thermal analysis (LTA), 314, 316 softening point for acrylic film, 317, 320f softening temperature comparison, 324f, 325f softening temperature vs. time for acrylic coatings, 322t, 323t Thermal spray methods cladding, 129-130 HVOF as promising process, 133 Thermal stability, acrylate films with organoclay, 263, 269f Thermogravimetric analysis (TGA) acrylate films with organoclay, 263, 269f measurement method, 39-40 polyurethane formulations with nanoparticles, 224, 226f polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) nanocomposite films, 47, 48f Thermo-mechanical analysis, polyurethane coatings with nanoparticles, 215, 216t Thin film coatings, silica nanoparticles, 374 Tissue engineers, ink-jet deposition, 157 Titanium dioxide comparing moduli vs. pigment volume concentration, 285f normalized moduli for latex coating with, 283t normalized moduli vs. PVC for t wo, fillers, 286f

particles in coatings, 276-277 size distribution curves for nanoparticles, 381, 383f See also Nanocomposite latex coatings Titanium dioxide-containing films antimicrobial surfaces, 194-197. 200 applications, 193 destroying bacteria, 194-195 development of "self-cleaning" windows, 192-193 Hydrotect[™] coatings by TOTO, 193 mechanisms for self-cleaning, 191-192 particle size, 192 peroxotitanium sol, 193-194 photocatalytic activity of TiO₂, 189-190 pigments in paint industry, 191 self-cleaning by generation of super-hydrophilic surface, 191 Tower of Earth in Nagoya City Pavilion, 193, 194f See also Reactive nanoparticles in coatings Titanium dioxide nanostructures absorbance spectrum for leuco crystal violet (LCV) assay for peroxide with pigment A, 356f absorbance spectrum for methyl viologen (MV) assay with pigment A, 355f buffer composition and cluster size for MV assays, 364, 365f characteristics of pigments A-H, 355t cluster size and photoreactivity response, 368 commercial materials, 350 diffusion coefficient D, 353 distribution of decay rates, 353 DLS data for LCV assays, 366-368

- DLS for MV assay using phosphate buffer at pH 6.0 and 4.4, 362, 363*f*, 364
- dynamic fluctuations of scattered light from particles, 352-353
- dynamic light scattering (DLS) and particle cluster size, 359, 361
- experimental, 351-353
- hydrogen peroxide assay with LCV method, 351-352
- isopropyl alcohol conversion for series of pigments, 354, 357, 358f
- isopropyl alcohol test, 352
- LCV assay absorbance with acetone buffer at pH 4.4 and 5.8, 359, 361*f*
- LCV assay and photoreactivity response, 370, 371f
- light scattering measurements, 352-353
- measured hydrodynamic diameter values for LCV in acetate buffer vs. pH and pigment loading, 368t
- measured hydrodynamic diameter values for MV assay at pH 6.0 for phosphate and KHP buffers vs. pigment loading, 364, 366t
- measured hydrodynamic diameter values for MV assay in phosphate buffer vs. pH, 364t
- MV assay, 351
- MV assay absorbance using phosphate buffer and potassium hydrogen phosphate (KHP) buffer at pH 6.0, 358, 360f
- MV assay absorbance with KHP buffer at pH 6.0 at two pigment loadings, 358–359, 360f
- MV assay and photoreactivity response, 369-370
- MV assay for phosphate buffer using pH 4.4 and 6.0, 357-358, 359f

normalized autocorrelation functions for monodisperse and polydisperse particle suspensions, 362*f*

- pH of buffer and pigment loading in LCV assay, 367f
- photoreactivity comparison based on peroxide concentration, 357f
- photoreactivity comparison of pigments using MV, 356f
- photoreactivity using altered conditions, 357-359, 361-368
- photoreactivity using standard experimental conditions, 354, 357
- pigment cluster size vs. photoreactivity for LCV assay, 371f
- pigment cluster size vs. photoreactivity for MV assay, 369f
- pigment loading and MV assay, 364, 366f
- spectrophotometric assays for measuring photoreactivity, 350 uses, 350
- Topography. See Surface topography
- Tower of Earth, Nagoya City Pavilion, 193, 194*f*
- Toxicity, determining latex ink, to microorganisms, 167–168
- Transmission electron microscopy (TEM), acrylate films with organoclay, 263, 267*f*, 268*f*

U

- Ultrasonic measurement, particle size analysis technique, 378-379
- Ultrasonic vibration potential (UVP), 378

Ultrathin films. See Conjugated polymer network thin films Ultraviolet (UV) curing applications, 256 See also Organoclays in UVcurable coatings Ultraviolet radiation. See Surface topography Urethane-acrylate films. See Organoclays in UV-curable coatings

V

Viable cell immobilization, gels, 160 Viscoelastic measurement method, 39 polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS) nanocomposite films, 45, 46f, 47, 47f Viscosity composition dependence of zero shear, by Lecyar model, 97-98 dependence of, on angular frequency by Carreau-Yasuda model, 94-95 measurement, 39 polyurethane/polyhedral oligomeric silsesquioxanes (PU/POSS) dispersions, 43t

W

Water rejection, aircraft coating, 146 Wide-angle x-ray diffraction (WAXD) patterns, polyurethane-polyhedral oligomeric silsesquioxane (PU-POSS), 98, 100*f* Williams-Landel-Ferry (WLF) equation deviation at high temperature, 99 temperature dependence of shift factor, 102

X

X-ray diffraction (XRD) aluminutn-based powders vs. coatings, 133, 136f clay and organoclay, 260f nanocomposite films with organoclay, 261f

Yeast, toxicity of acrylate/vinyl acetate latex emulsions to, 169 Young's modulus acrylate films with organoclay, 262, 264f

polyurethanes with nanoparticles, 225, 228f

Z

Zinc oxide normalized moduli for latex coating with, 283*t* particles in coatings, 276–277