

Index

- A**
Abrasion resistance testing 279–282
addition polymerization 21
additives 29, 38
adhesion *See also* adhesion enhancement.
 bonding to boundary layer 19
 coatings 36
 in composites 50
 degradation 44
 determination of 10
 effect of delamination on 123
 effect of sputtering on 230
 failure 19, 205–207
 interlaminar 57
 interlayer 34, 44
 measurements of 203–204
 metal–polymer interfaces 224–230
 particle 152
 polyethylene to organic resins 56
 polyimide films 175
 polymer–polymer interface 222
 polymer surfaces 18, 19
 polyolefins 174
 reduction in molding 55
 reinforcement–matrix interface 32
 role of surface tension 124
 theoretical analysis 200–202
 thermodynamic work of 152
 unmodified surfaces 228
 urethane coatings to substrate 38
 work of 150
adhesion enhancement
 bond rearrangement 185
 in composites 51
 by interface mixing 183
 ion-beam techniques 180–186
 ion-induced 179–180
 in organic fibers 56–57
 polyolefins 174
 promoter layers 191–192
 by silane agents 38
 by surface roughening 122–123
 by surface treatments 173–177
adhesion theory of friction 266
adhesive bond breakage 266
adhesive bonding of laminates 52
adhesive coating 26
adhesive promoters
 as difunctional compounds 32
 organofunctional silanes 177
 polyimide film applications 174–175
 promoter layers 180
 as surface treatment 175–177
adhesive wear 269
adsorption 157–162
AES *See* Auger electron spectroscopy.
AFM *See* atomic force microscopy.
agglomeration 10
aggregates 48
air–water interface in I–B films 32
amphiphilic compounds 32
anionic polymerization 23
Archard wear equation 292
ASTM laboratory friction/wear tests 277–284
atomic force microscopy (AFM)
 film roughness 42
 imaging of methyl groups 114
 inversion wall 114
 physical principles 113
 polymer surfaces 111, 114
 substrate surface 122
ATR *See* attenuated total reflection.
ATR-FTIR *See* attenuated total reflection FTIR.
ATR-IR *See* attenuated total reflection IR.
attenuated total reflection (ATR) 126
attenuated total reflection FTIR
 (ATR-FTIR) 177
attenuated total reflection IR (ATR-IR) 178
attractive forces 151

Auger electron spectroscopy (AES)
adhesion failure 205
catalyst systems study 172
junction locus failure 229
surface contaminants 182
autoclave 34, 53, 54

Beam-induced damage 68
binding energies 69, 179, 226
biocomparability of surfaces 124–125
birefringence 32
blends 8–10, 224
block copolymers 9, 109, 110, 114
blow molding 36
bonding
breakage in VDP polyimide 46
chemical 11
composites 50
coupling agents 175–176
dissimilar polymers-glass 176
electrovalent 126
interracial bonding energy 240
intermolecular forces 289
laminates 52
metal-polymer 226
organic polymers to ceramics 175
organic polymers to minerals 175
silane interpenetration 176
strength in composites 52
bonding enhancement *See* adhesion
enhancement.
boundary layer 19
bulk molding composites 33
bulk regions 20

Calendering 37
CARS *See* coherent anti-stoke Raman
scattering.
catalysts 24–25, 172
cathodoluminescence 104
cationic polymerization 23
chain
branching 14, 22, 25
configuration 12–14
conformation 2, 14–15, 20
entanglement 12, 17, 222
flexibility 2
initiator fragment in 22
labeling of polymers 246

orientation 16, 123, 124
propagation 22
stress 12
tangled 12
transfer agents 21
chain characteristics 2, 12–14
CK-edge transitions 79
coatings
abrasion resistance 279
deposition of 36–37
dielectric 41
planar 36
polymers as thermosets 26
polystyrene, wear of 273
polyurethanes 37–40
tribological 265
coefficient of friction 263, 271, 283, 284
coherent anti-stoke Raman scattering
(CARS) 131
cohesive energy 271
cohesive failure of material 266, 268–269
commercial polymers 30
composites
cooling, effects of 53
fabrication considerations 50, 52–55
fillers used in fabrication 50
impact resistance 52
interlaminar shear strength 52
matrix 51
mechanical properties 50
porosity 54
processing 32–34
reactions in PI films 223
voids 53–54
compression molding 36
concentration profiling techniques 252–259
condensation energies 227–228
conformations, chain 2, 14–15
contact angles
flat solids and films 154–156
grafting evaluation 177
hysteresis 156
particulate materials and fibers 156–157
study of film surfaces 161–162
contaminants *See* impurities.
cooling effects 16, 17
coordination polymerization 24–25
copolymer composition 3
corrosion 44

cross-linking 14
cross-sectional transmission electron microscopy (XTEM) 182, 231, 232
crystal lattice 15
crystalline characteristics 2, 15, 16
crystallinity 53, 273
crystal nucleation 20
cyclic organic compounds 25
cycloimidization 77

Defects, chain 2
defect structures of TLCPs 96–97, 101
deformation
 AFM applications 113
 load-induced 265
 role of adhesion in 267
 semicrystalline material 16
 stress-related 268
 surface 18
 tangential forces 266
degradation of polymer 2
delamination, skin–core 123
deposition 32, 42, 47
diblock copolymers 101, 102, 109, 110, 114, 255
DIC *See* differential interference contrast microscopy.
dielectric constant
 metals in EM wave techniques 132
 polyimides 174, 232
 surface probe applications 134
dielectric films 127, 128
dielectric layers, polyimide films 41
differential interference contrast microscopy (DIC) 94, 96, 97
differential scanning calorimetry (DSC) 53
diffuse reflectance infrared spectroscopy (DRIFT) 51
diffusion 44, 247
diffusion coefficient 244, 248
diffusion distance measuring 247–252
disinclination defects in TLCPs 101
domain
 crystalline 16
 irradiation-induced 44
 surface 18
 transcrystalline 20
dopants in catalyst systems 173
Drago constants 158

DRIFT *See* diffuse reflectance infrared spectroscopy.
DSC *See* differential scanning calorimetry.
DTMA *See* dynamic mechanical thermal analysis.
dynamic mechanical thermal analysis (DMTA) 221

EDS *See* electron dispersive spectroscopy.
EDX *See* energy-dispersive X-ray.
EELS *See* electron energy-loss spectroscopy.
elastomeric materials 14
electron beam damage 100, 106, 107
electron dispersive spectroscopy (EDS) 248
electron energy-loss spectroscopy (EELS) 172
ellipsometry 162, 229
energy-dispersive X-ray (EDX) 232
energy sites 80, 158
enthalpy of absorption 158, 160
entropic intermixing at phase boundary 9
environmental SEM (ESEM) 104–106
epitaxy 108
epoxies 40
equivalence in polymerization 26
ERIR *See* external reflectance infrared spectroscopy.
ESCA *See* X-ray photoelectron spectroscopy.
ESEM *See* environmental SEM.
etching of surfaces 172
external reflectance infrared (ERIR) spectroscopy 223
extrusion process 34–35

Fabrication 29, 31–36
fatigue 290
fibers 32, 33, 51, 56–57
fiber spinning 35
Fickian diffusion equation 222
filament winding technique 34
fillers in composite fabrication 50, 51
film-forming processes 31–32
films
 degradation 233, 234
 growth by VDP 75
 highly ordered 126
 polyimide film development 40–47
 preparation for wave-guiding 128
 refractive index 130

- films *continued*
 - sheets 31, 34, 37
 - solvent absorption into 44
 - spin cast 42
 - strain in 234
 - stress effects in 234
 - surface modification 44
 - film study techniques
 - contact angles 161–162
 - grazing incidence X-ray scattering 139–145
 - reflectivity 136–139
 - second-order nonlinearity surface probe 134–135
 - surface EM-wave 131–134
 - wave-guiding 127–130
 - flame retardance 38–39
 - flammability of polyurethane coatings 38
 - flexibility of chain 2
 - flexural moduli of RIM polyurethanes 56
 - fluoropolymer films 32
 - flux ratio control 80
 - foam 31, 38, 39
 - force transducer 286, 290
 - forward recoil spectroscopy (FRS and FRES) 44, 250–252
 - Fourier transform infrared (FTIR) analysis
 - acidic group detection 39, 40
 - chemical composition 70
 - imidization reaction monitor 45
 - mold release agents 55
 - storage modulus 221
 - Fourier transform infrared (FTIR) spectroscopy
 - band relationships 39
 - etching mechanisms 191
 - hydroxyl identification 190
 - irradiation effects on polymers 49
 - L–B film chain orientation 126
 - plasma effects 190
 - polyimide spectra 77
 - polymer surfaces 164–165
 - principles of operation 164–165
 - resolution of XPS results 190
 - ring bond breaking 44
 - structure segregation 80
 - fracture energy 238, 239, 240, 245
 - free energy 19, 152, 153, 155, 156, 158
 - free radical polymerization 22
 - FRES *See* forward recoil spectroscopy.
 - Fresnel equation 256, 257
 - Fresnel's law 133, 134, 137
 - friction
 - cause of 265–267
 - force 282, 283, 288, 292, 293
 - loss tangent correlation 273
 - measurements overview 274–276
 - plowing theory 266
 - tests for 282–284
 - friction-induced oscillations 267–268
 - FRS *See* forward recoil spectroscopy.
 - FTIR *See* Fourier transform infrared analysis and Fourier transform infrared spectroscopy.
- G**as chromatography-mass spectroscopy (GC-MS) 55
- GC-MS *See* gas chromatography-mass spectroscopy.
 - GIXS *See* grazing incidence X-ray scattering.
 - glass transition 17
 - goniometer 154
 - graft copolymers 9, 109, 110, 114
 - grazing incidence X-ray scattering (GIXS) 42, 127, 139–145
 - group-transfer polymerization 23
- H**igh resolution electron energy-loss spectroscopy (HREELS) 71, 202
- high resolution SEM (HRSEM) 100–101
 - homopolymer composition 3
 - HREELS *See* high resolution electron energy-loss spectroscopy.
 - HRSEM *See* high resolution SIM.
- I**GC *See* inverse gas chromatography.
- immiscibility 8, 9
 - impregnated rovings 34
 - impurities
 - in Kapton-H films 42
 - in polyimides 83–86
 - infrared (IR) studies 232
 - initiator fragment 22
 - injection molding 35
 - ink adhesion on polyolefins 174
 - Instron Tester 56
 - insulation, thermal 38

- interdiffusion in PI/PI films 222, 223
- interface
 - acid–base interactions 153, 158
 - adhesion 123, 152
 - air–water in L–B films 32
 - amphiphilic compounds 32
 - bonding energy 240
 - buried 259–260
 - chain orientation 124
 - composition characterization 83
 - copolymer location in 245
 - corrosion 44, 230
 - failure 205
 - fiber–polymer, voids in 53–54
 - film–substrate adhesion 34–35
 - fracture 234–240
 - healing 200
 - immiscible polymer 253, 256
 - interdiffusion 200
 - locking 122
 - metal–polymer 108, 201–202, 224–230
 - mixing 180
 - PI–metal 232, 233
 - polymer–air 110
 - polymer–metal 108, 230–234
 - polymer–polymer 222–224, 244–246
 - polymer–sodium chloride 110
 - reinforcement–matrix 32
 - shear stress 238–239, 271
 - silicon–polyimide 45
 - stress failure testing 208
 - substrate 222
 - toughness 238
 - transmission of load 265
 - width 252–253
- intermixing, entropic 9
- interpenetration at PI–PI interface 222
- interphase regions in blends 9
- inverse gas chromatography (ICG) 162–164
- ion bombardment 182–183, 185, 186
- ion-induced adhesion technique 182–187
- ion scattering spectroscopy (ISS) 190, 206
- infrared microdensitometry 248
- IR studies *See* infrared studies.
- isomerism 13
- ISS *See* ion scattering spectroscopy.
- Kapton-H films 42, 44
- Kaufman guns 180–181
- Kevlar 51
- kinetic coefficient of friction 283
- Lamellae growth 101
- Langmuir–Blodgett (L–B) films
 - applications 47–48, 125
 - electrical properties 48–49
 - formation 32, 47
 - structural aspects 125–126
 - synthesis 125, 126
- Langmuir equation 160
- Langmuir model 160–161
- laser-induced fluorescence (LIF) 190
- laser interferometry 45
- lattice characteristics 15, 185
- layers *See* coatings.
- L–B films *See* Langmuir–Blodgett films.
- LCP *See* liquid crystalline polymers.
- LEED *See* low-energy electron diffraction.
- Lewis acid–base forces 151–154
- LIF *See* laser-induced fluorescence.
- liquid crystalline polymers (LCPs) 17, 20
- London–Van der Waals forces 151
- loss tangent 273
- low-energy electron diffraction (LEED) 172
- low voltage HRSEM (LVHRSEM) 101–103
- LVHRSEM *See* low voltage HRSEM.
- Magnetic resonance spectroscopy (MRS) 48
- matrix
 - crystalline 16
 - materials 32
 - mobility within 19, 221
 - plasticizing of 19
 - polymer chains 11
- melting 15, 16
- microdomains 95, 98, 101, 109
- microfibrils 16
- microspheres 31
- microtomy 94
- microwave discharge 188
- migration of material to surface 19
- MIR *See* multiple internal reflection.
- miscibility 9
- modified optical schlieren technique (MOST) 248
- molding 35–36, 55–56
- mold release agents 35

molecular orientation after spin-casting 42
molecular packing 221
molecular packing coefficient 219
molecular weight
 determinations in VDP films 45
 distribution in polymer 11–12
 polymer 26
 polymer systems 247
 reaction mixture 26
MOST *See* modified optical schlieren
 technique.
MRS *See* magnetic resonance spectroscopy.
Mullin's softening effect 10, 11
multiple internal reflection (MIR) 191
mutual diffusion coefficient, PM blends 247

Nanofabrication 113

near edge X-ray absorption fine structure
 (NEXAFS) 70, 78, 79, 83
neutron reflectivity (NR) 136, 256–259
NEXAFS *See* near edge X-ray absorption fine
 structure.
NIR-FT-Raman 56
NMR imaging 205
NR *See* neutron reflectivity.
NRA *See* nuclear reaction analysis.
nuclear reaction analysis (NRA) 250, 253
nucleation, crystal 20

OM *See* optical microscopy.

optical constant of organic film 128
optical microscopy (OM)
 adhesion failure 205–206
 depth profiling 98
 liquid crystal defects 96
 surface morphology 95
 techniques and applications 94–98
optical properties of thin films 127–136
organic reinforcement fibers 51, 52, 56
oscillations, friction-induced 267–268

PAA curing 232

parallel chains 114
particle adhesion 152
PAS *See* positron annihilation spectroscopy.
peel strength 175, 184, 200–205, 229
Peltier stage 105
phase boundary and entropic intermixing 9

phase separation 9, 80
piezoelectric crystal in AFM 113
piezoelectric drive in STM 111
planer coatings 36
plasma gas chemistries 188–190
plasma modification of surfaces 187–190
plasma pollution 188, 189
plasticizers, effect on chain mobility 19
plastic part molding 35–36
plowing theory of friction 266
PMDA-ODA films 41–42
PMMA block 96
polarized infrared spectroscopy 32
poly(etheretherketone) (PEEK) 52
polyimide films 40–46, 174–175
polyimide L-B films *See* Langmuir–Blodgett films.
polyimides 174–175, 218–222, 224
polymer blends 8–10, 224
polymer chains 218–219, 222
polymer dynamics, theory of 247
polymerization catalysts 24–25
polymerization initiators 22–24
polymer–metal interfaces 230–234
polyolefins 24, 174
polypyrrole films 47–48
polytetrafluoroethylene (PTFE) 173–174
polyurethanes 37–40
positron annihilation spectroscopy (PAS) 54
precursor
 concentration 188
 divalent salts 126
 monovalent 126
 polyamic ethyl ester 232
 polyamide acid 45
 polymer solutions 230–231
 stoichiometry 45
processing techniques 29–37
PTFE 173–174
pulsed 33–34

RAMAN spectroscopy 71

RBS *See* Rutherford backscattering spectroscopy.
reaction injection molding 35–36
reactive centers for chain polymerizations 23
reflectivity in EM wave application 133
refractive index of thin films 130
reinforced plastics 33
reinforcement fiber drawing 56–57
reinforcement fibers 32, 33, 51, 56–57

- resin processing 36
- ring-opening polymerization 25
- Rutherford backscattering spectroscopy (RBS)
 - adhesion failure 205–206
 - interface studies 250
 - Kapton-H film analysis 44
 - semiconductor analysis 250
 - solvent absorption rate 44
- SAM** *See* scanning acoustic microscopy.
- SAXS *See* small-angle X-ray scattering.
- scanning acoustic microscopy (SAM) 206, 229
- scanning electron microscopy (SEM)
 - adhesion failure 206
 - catalyst systems study 172
 - interfaces 100
 - principles of operation 98–100
 - sample preparation 100
 - substrate surfaces 122
 - surface effects of ion beam 183
 - surface scanning 249
 - surface structure 98
- scanning probe microscopy (SPM) 111–116
- scanning transmission electron microscope (STEM) 232
- scanning tunneling microscopy (STM) 46, 111–113
- schlieren texture 96
- secondary mass ion spectrometry (SIMS)
 - adhesion 206, 230
 - depth profiling 254–255
 - film surface analysis 42
 - grafting evaluation 178
 - junction failure 229
 - lateral composition maps 72
 - molecular information 72
 - morphology of thin films 96
 - plasma treatment 190
 - PS-DPS system investigation 253
 - SMMA diblocks 96
- second-order nonlinearity surface probe 134–136
- seeding 172
- SEM *See* scanning electron microscopy.
- semiconductor mold compounds 55
- semicrystalline material 16, 20
- semipermeable membranes 53
- separation membranes 20
- SERS *See* surface-enhanced Raman scattering.
- shaping of polymer parts 35–36
- shear strength, composite interlaminar 52, 57
- SIMS *See* secondary ion mass spectrometry.
- skin formation 123–124
- skiving 32
- small-angle X-ray scattering (SAXS) 126
- SMMA diblock copolymers 95, 96
- solution casting 32
- solvent effects on conformational rearrangements 2
- spectroscopic phase-modulated ellipsometry (SPME) 127
- spherulitic bulk crystalline structures 16
- spin cast films 42
- spin coating 36, 42
- SPM *See* scanning probe microscopy.
- SPME *See* spectroscopic phase-modulated ellipsometry.
- STEM *See* scanning transmission electron microscope.
- step reaction polymerization 25–26
- stereoisomerism 13
- stereoregular linear chain polymers 24
- STM *See* scanning tunneling microscopy.
- storage modulus 221
- stress
 - interracial fracture related 238, 271
 - interlayer 235
 - load contact area 266
 - measurements 235
 - multilayer structures 216
 - role in materials failure 268–269
 - silicon–polyimide interface 45
 - stress/failure strength ratio 271
 - substrate–film stress 43
 - thermal–related 43, 234
- stretch deformation fracture test 238
- substrate
 - bulk phase 18
 - cleaning by ion beam 180
 - conductive 113
 - effects of ion irradiation 182
 - glass, in wave-guiding 127
 - gold, film thickness on 96
 - grafting to 178
 - hardening 180
 - heat dissipation in 185
 - ion bombardment damage 186–187
 - metal-coated 113
 - photografting of 177
 - plasma-treated 189

- substrate *continued*
 - preparation for film adhesion 35, 36
 - preparation in ion enhancement 183
 - role in X-ray reflectivity 136–139
 - silicon, film thickness on 96
 - single-crystal graphite 113
 - stress 43
 - surface roughness 122–123
 - urethane adhesion to 38
 - UV irradiation of 192
 - surface
 - adsorption of impurities on 19
 - catalytic 24, 25
 - chain conformations in 20
 - charge accumulation 69
 - corrugation 114
 - defects 25
 - density 18
 - domain 18
 - electron flooding 69
 - energies 151, 153
 - forces, measurements of 157
 - free energy 156
 - ion damage to 186
 - migration of material to 19
 - photografting of 177
 - polystyrene 172
 - properties 18
 - reinforcements 51
 - replicas 107
 - role in X-ray reflectivity 136–139
 - roughening 171–172
 - seeding 172
 - skin/core delamination 123
 - substrate roughness 122–123
 - tension 18, 152, 155–157
 - transition behavior 20
 - surface EM-wave thin film techniques 131–134
 - surface energy 152–154
 - surface-enhanced Raman scattering (SERS) 126, 134
 - surface modification
 - characterization 81–83
 - by dry techniques 179–186
 - molecular change 183
 - of organic fibers 56–57
 - by photochemicals 177–178
 - by plasma 187–190
 - of polyimides 174–175
 - of polyolefins 174
 - roughening 171–172
 - of thermoplastic PTFE 173–174
 - by vapor phase photografting 191
 - surface replica preparation 107–108
 - surface roughness role in adhesion 122–123
 - surface structure 18–20
 - surface tension 18, 124, 152, 156, 157
 - synchrotron radiation 68, 140
 - synthesis 20–26
- T**
- Tape automated bonding (TAB) 41
 - TDS *See* thermal desorption spectroscopy.
 - TEM *See* transmission electron microscopy.
 - tensile strength 12
 - thermal characteristics, polyimide film 40
 - thermal desorption spectroscopy (TDS) 172
 - thermal effects 2
 - thermal expansion coefficient 235
 - thermal stability 173
 - thermal stress 43, 234–240
 - thermodynamic measuring techniques
 - adsorption and calorimetry 157–159
 - adsorption isotherms 159–162
 - infrared spectroscopy (FTIR) 164–165
 - inverse gas chromatography 162–164
 - thermodynamics 9, 157
 - thermoplastic polymers 2, 172, 173, 270–271
 - thermoplastic starch 104
 - thermoplastic state 26
 - thermoplastic thin films 31
 - thermoset materials 26, 36, 270–271
 - thermoset molding 55
 - thermosetting polymers 2, 172
 - thermotropic liquid crystalline polymers (TLCP) 96, 101
 - thick film 40–46, 80
 - thin film
 - adhesion 32
 - dielectrics 122
 - formation 22, 31–32
 - molecular orientation 32
 - polyimide 22, 40–46
 - preparation of 107
 - refractive index 130
 - thermoplastic 31
 - thickness 130
 - ultrathin organic 32
 - thin-film characterization tools
 - grazing incidence X-ray scattering 139–145
 - reflectivity 136–139

second-order nonlinearity probe 134–136
surface EM-wave 131–134
wave-guiding 127–130

tie molecules 16

time-of-flight (TOF) 252

TLCP 96, 101

transfer molding 36

transmission electron microscopy (TEM)
adhesion failure 206
applications 110
block copolymer 114
catalyst systems study 173
contrast mechanisms 106–110
grain boundary 110
interface 109, 110
L–B film lateral packing 126
microdomain morphology 110
precipitate identification 80
solvent evaporation 110
thin film morphology 110
triblock copolymers 110

triblock copolymer 110

tribological applications 264–265

Ultramicrotomy 107, 110
ultrathin films 32, 40–47
urethane coatings 37–38

Vapor deposition polymerization (VDP) 45
vapor pressure osmometry (VPO) 48
VDP films 45–46
VPO *See* vapor pressure osmometry.
Vrbanac and Berg equations 159

Wave-guiding 127–130
WAXD *See* wide-angle X-ray diffraction.
wear
abrasive 269, 271
adhesive 269
coefficient 292
consequences of 268–269
friction interdependent 263–264
maps 277
measurement 289–291
mechanics of 265–266
molecular weight effects 271–273
rates 279
stress and 271

wear measurement interpretations 291
wear test design considerations 284–291
wide-angle X-ray diffraction (WAXD) 224

XPS *See* X-ray photoelectron spectroscopy.
X-ray diffraction (XRD) 42, 48, 126
X-ray fluorescence (XRF) 55
X-ray photoelectron spectroscopy (XPS or ESCA)
adhesion studies 175, 205
amine concentration 57
catalyst systems study 173
chemical analysis 68, 225
chemical bonding change 57
depth profiling 182
etching mechanism 191
film surface analysis 42
glass fiber data 51
interface composition 83
interface contaminants 182
interface mechanisms 202
low-energy bombardment 183
metallized surfaces 224
modified surfaces 81, 173
mold release agents 55
molecular packing 221
molecular structure 79
NMP/PAA complexes 220
photografting evaluation 177
plasma treatment 190
polyimide degradation 232
polymer electric states 224
purity of samples 69
reactions in PI films 223
ring bond breaking 44
shake-up intensities 70
surface blends 224
surface modification 185, 190
surface of coupling agent 51
surface oxidation 189
survey spectra 73
VDP film reactivity 45
X-ray reflectivity 136–139
XRD *See* X-ray diffraction.
XRF *See* X-ray fluorescence.
XTEM *See* cross-sectional transmission electron microscopy.

Young's modulus 113