

Index

a

abiotic depletion 521
 2-acetamido-2-deoxy-d-glucopyranose
 residue 493
 acetylation 307
 acetylation treatment 142–143
 acidification 521
 acrylated epoxydized soy bean oil (AESO)
 228–229
 acrylonitrile butadiene rubber (NBR)
 290
 adhesion prevention 74
 agar 34
 agarose 34–35
 agave fibers 274
 aging 305–306
 agro-forestry products 246–247
 – biological basis 246
 – economic basis 246–247
 aircrafts and ships, green composites in
 533
 albumin 19, 69
 alginate *See* alginic acid
 alginic acid 32–33, 35–36, 70
 aliphatic and aromatic polyesters and their
 copolymers 379, 412
 aliphatic polyesters (APES) 378
 alkali (NaOH) treatment 442
 alkali-treated fiber-reinforced composites
 307
 alkali treatment 138–139
 all-cellulose composites and nanocomposites
 126–128
 alley cropping 247
 amino acids 14, 17
 amorphous cellulose 540
 amylopectin 372
 – chemical structure of 372

amylose 372
 – chemical structure of 372
 Anaerobe Isolation Agar (AIA) plate 531
 Andersen Windows Company 476
 animal hair fibers 241
 anisotropy 335
 aquatic environments pollution of 527
 – increased aquatic BOD 527
 – marine species risk to 528
 – water transportable degradation products
 527–528
 aromatic polyesters 379
 artificial blood vessels 75–76
 artificial corneas 75
 artificial skin 74
 AT composite 445
 AT fabric composite 445
 attenuated total reflectance Fourier
 transform infrared spectroscopy
 (ATR-FTIR) 149, 150
 automatic material-supplying system 191,
 192–193
 automobiles, green composites in 533
 automotive applications 465, 466, 469–471

b

bacterial cellulose (BC) 46, 540
 – and bacterial cellulose-coated
 biofiber-reinforced thermoplastic
 composites 274–277
 bamboo 247. *See also* individual entries
 – microstructure of 318
 bamboo fiber (BF) 243–244, 317, 318
 – composite 317, 323, 325, 327
 – experiments 320
 – – embedded test 322

- bamboo fiber (BF) (*contd.*)
 - fabrication procedure of developed composite using PLA, BF, and MFC 320
 - fracture toughness test 321–322
 - microdrop test 321
 - test specimens, type of 320, 322
 - three-point bending test 321
 - extracted by steam explosion 319
 - matrix 318
 - microfibrillated cellulose (MFC) 319
 - modified 319
 - results and discussion 322
 - bending strength of PLA/BF/MFC composite 322–324
 - crack propagation behavior 325–327
 - fracture toughness of PLA/BF/MFC Composite 325
 - internal state of PLA/BF/MFC composite 322
- bamboo fiber content influence 195–197
- bamboo fiber reinforced thermoplastics (BF RTP) 191, 194–195, 259–260
 - automatically (BF RTP-AT) 192
 - hand made (BF RTPHM) 193
- bamboo-NR composites 294
- basic fibroblast growth factor (bFGF) 502
- bast fiber 242–244
- benzoylation 308
- benzoylation and benzoylation treatments 143
- bioactive glass nanofiber (BGNF) 397
- biobased (hydrodegradable) material 80
- Bioceta 79
- biochar 6
- biocompatible hydroxyapatite/collagen bionanocomposites 397
- biocompatibility 72
- biocomposite 1–3, 29, 133, 240, 465. *See also* natural fibers; wood plastic composite (WPC) processing technology
 - classification 5–8
 - dynamic mechanical properties 161–163
 - engineering and development 3–5
 - impact properties 160–161
 - interfacial properties 153–157
 - mechanical properties 135–159
 - and natural fiber surface treatment 134–137
 - thermal properties 164–166
 - water absorption behavior 166–168
- biocomposites, applications of 467
 - automotive applications 469
 - market and products 471
 - materials 469–470
 - requirements 470
- structural applications 472
- flame retardancy 475
- markets and products 475–476
- materials for structural applications of green composites 473
- mechanical performance 473–474
- requirements 473
- survey of technical applications of natural fiber composites 467
- international trend in biocomposites 468
- biodegradability 2–8, 12, 379, 465
- biodegradability test 530
 - differential scanning calorimetry (DSC) analysis 531–532
 - FTIR-ATR analysis 532
 - mechanical property and weight loss tests after biodegradability 530–531
 - microbial counts in natural and compost soil 531
 - molecular weight after biodegradability 531
 - morphological test 532
 - natural soil burial test and simulated municipal solid waste (MSW) aerobic compost test 530
- biodegradable plastics versus traditional plastics 466–467
- biodegradable polymers
 - basic properties of 496–497
 - matrices 495–498
 - from microorganisms and biotechnology 375
 - polyhydroxyalkanoates (PHAs) 375–376
 - polylactides 376–377
 - from petrochemical products 377
 - aliphatic and aromatic polyesters and their copolymers 379
 - poly(ϵ -caprolactone) (PCL) 377–378
 - polyesteramides 378
 - poly(glycolic acid) (PGA) 380
 - poly(vinyl acetate) (PVAc) 380
 - poly(vinyl alcohol) (PVA) 380
- biodegradable resins, mechanical properties of 433
- biodegradation
 - of cellulose 539
 - effect of soy protein modification on its 455
 - of poly(hydroxy butyrate-co-valerate) (PHBV) 451–454

- of polylactic acid 536
- of polyvinyl alcohol (PVA) 534–536
- of starch-based green composites 458–460
- biofiber-inspired thermoplastic composites 259–271
- biofiber-reinforced natural rubber composites 289
 - applications 312
 - cure characteristics 293–294
 - dielectric properties 304–305
 - diffusion and swelling properties 302–304
 - fiber–matrix adhesion, approaches to improve 307
 - benzoylation 308
 - bonding agents 309–311
 - coupling agents 308–309
 - mercerization 307
 - mechanical properties 294
 - fiber length, effect of 294–295
 - fiber loading, effect of 296–300
 - fiber orientation, effect of 295–296
 - physical properties of 298
 - processing 292
 - rheological and aging characteristics 305–306
 - viscoelastic properties 300–301
- biofiber-reinforced thermoplastics composites applications 277–278
- biofiber-reinforced thermoset composites 213
 - biosynthetic thermoset composites 229–231
 - lignin-based composites 225–226
 - protein-based composites 226–227
 - tannin-based composites 227–228
 - triglyceride-based composites 228–229
 - end-of-life-treatment 231
 - chemical recycling 232–233
 - energy recovery 233
 - pyrolysis 232
 - recycling as composite fillers 231
 - fabrication techniques 217
 - compression molding 219
 - filament winding 219
 - hand layup 218
 - pultrusion 219
 - resin transfer molding (RTM) 220
 - natural fibers 215–217
 - resins 213–214
 - biosynthetic thermosets 215
 - synthetic thermosets 214–215
 - synthetic thermoset composites 225
 - epoxy-based composites 222–223
 - phenolic resin-based composites 224
 - polyester-based composites 220–222
 - vinyl ester-based composites 223–224
- biofibers 109–110, 133, 239–240, 290–291
 - advantages 248–249
 - all-cellulose composites and nanocomposites 126–128
 - application as reinforcement 254
 - biofiber-inspired thermoplastic composites 259–271
 - composite boards 255–259
 - bacterial cellulose and bacterial cellulose-coated biofiber-reinforced thermoplastic composites 274–277
 - biofiber-reinforced thermoplastics composites applications 277
 - cellulose microfibrils and macrofibrils mechanical and thermal properties 121–126
 - classification of 291
 - disadvantages 249–250
 - graft copolymerization 250–252
 - graft copolymers reinforced thermoplastic composites 271–274
 - natural plant fibers
 - crystal structure 114–117
 - microstructures 110–114
 - properties 117–121
 - sources 242–243
 - surface modifications, using bacterial cellulose 254, 256
 - types 241
 - annual biofibers 241–244
 - perennial biofibers (wood fibers) 245–247
- biomass-derived materials 2–6
- biomaterials 72
- biomedical polymer composites and applications 483
 - biocompatibility issues 485–487
 - natural matrix based polymer composites 488
 - chitin and chitosan as matrices 489–490
 - hyaluronic acid composites 491–493
 - mammal protein-based biocomposites 490–491
 - other natural polymer matrices 493–494
 - silk biocomposites 488–489
 - polymer-nanosystems and nanocomposites in medicine 504–506

- biomedical polymer composites and applications (*contd.*)
 - smart polymers and biocomposites 502–504
 - synthetic polymer matrix biomedical composites 494
 - biodegradable polymer matrices 495–498
 - synthetic polymer composites 499–502
- biomedical polymers 65–70
- biomimetic mineralization 501
- bionanocomposites 361, 362
 - characterization 382
 - elongated particle 363
 - layered particle-reinforced 363
 - matrices for 370
 - aliphatic and aromatic polyesters and their copolymers 379
 - poly(ϵ -caprolactone) (PCL) 377–378
 - polyesteramides 378
 - poly(glycolic acid) (PGA) 380
 - polyhydroxyalkanoates (PHAs) 375–376
 - polylactides 376–377
 - polysaccharides 370–372
 - poly(vinyl acetate) (PVAc) 380
 - poly(vinyl alcohol) (PVA) 380
 - proteins 373–375
 - starch 372–373
 - from microorganisms and biotechnology 399
 - polyhydroxyalkanoates 399–403
 - polylactides 404–406
 - mixing 380–381
 - particulate 363
 - from petrochemical products 406
 - aliphatic and aromatic polyesters and their copolymers 412–416
 - poly(ϵ -caprolactone) (PCL) 406–411
 - polyesteramides 411–412
 - poly(glycolic acid) (PGA) 418–419
 - polysaccharide 383
 - chitin 387–388
 - chitosan 388–391
 - starch 383–387
 - poly(vinyl acetate) (PVAc) 417–418
 - poly(vinyl alcohol) (PVA) 416–417
 - processing 381–382
 - protein 391
 - collagen 396–398
 - gelatin 395–396
 - gluten 399
 - silk fibroin 399
 - soy protein isolate 392–395
 - zein 399
 - reinforcements used in 364
 - cellulose 365–368
 - chitin and chitosan 368–369
 - nanoclays 365
- Biophan 79
- bioplastics 11, 82
 - current research areas 82–83
- biopol 80
- biopolymers 11–12, 370
 - applications 72
 - agricultural applications 76–77
 - medical 72–76
 - packaging 77–80
 - biomedical polymers 65–70
 - blends 71
 - classification 13
 - composite material 71
 - current research areas 82–83
 - exceptional properties 65
 - natural biopolymers 13–14
 - low molecular weight biopolymers 39–42
 - microbial-synthesized biopolymers 42–46
 - natural poly(amino acids) 46–50
 - nucleic acids 50–54
 - polysaccharides 27–39
 - proteins 14–27
 - need 64
 - nonbiodegradable biopolymers 80–82
 - nonbiodegradable polymers and conversion to biodegradable polymers 82
 - partially biodegradable packaging materials 80
 - synthetic biopolymers 54–64
- biorubber. *See* poly(glycerol sebacic acid) (PGS)
- biosynthetic thermosets 215, 229–231
 - lignin-based composites 225–226
 - protein-based composites 226–227
 - tannin-based composites 227–228
 - triglyceride-based composites 228–229
- Biotechnology Process Engineering Centre (BPEC) pathway 81
- bis(3-triethoxysilylpropyl) tetrasulfide (TESPT) 309
- bis-phenyl glycidyl dimethacrylate (Bis-GMA) 501
- Bocell™ fibers 127
- bonding agents 309
- bone fixation devices 73
- braid architecture 350

- braiding 354–355
- braiding yarns (BYs) 349
- butadiene rubber 290
- butyl rubber (IIR) 290
- C**
- Cadillac 471
- capillary rheometer 203–206
- carbohydrate-based vaccines 69
- carbon footprint 432
- carbon nanotubes (CNT) 365, 410, 518
- carrageenan 36, 38
- casein 24–27
- κ -casein 25–26
- caseinogen 26
- cellulose 27–28, 365–368, 540
 - biodegradation of 539
 - chemical structure of 367
- cellulose-based packaging materials 79
- cellulose fiber-reinforced starch
 - bio-composites 539–541
- cellulose fibers, life cycle analysis of 556–558
- cellulose microfibrils and macrofibrils
 - mechanical and thermal properties 121–126
- cellulose nanocrystals 364
- cellulose nanofiber-reinforced “green”
 - composites 446–447
- cellulose nanofibers (CNFs) 388
- cellulose nanofibrils 364
- cellulose nanopaper 125
- cellulose nanowhiskers (CNWs) 368, 405
- chemical recycling 232–233
- chemical treatment methods, for natural fibers
 - acetylation treatment 142–143
 - alkali treatment 138–139
 - benzoylation and benzylation treatments 143
 - MAPP treatment 143–144
 - peroxide treatment 144–145
 - silane treatment 139–142
- Chevrolet 471
- chickpea 374
- chitin 31–32, 69, 368–369
 - chemical structure of 368
 - and chitosan as matrices 489–490
- α -chitin 369
- chitin bionanocomposites 387
- chitosan 30–31, 66–67, 368–369
 - schematic representation of 390
- chitosan bionanocomposites 388
- chitosan (CS)/hydroxyapatite (HA)
 - bionanocomposites 391
- chitosan/vermiculite (VMT)
 - bionanocomposites 389
- chloroprene rubber 290
- chondroitin sulfate 41, 70
- chymosin 26
- cis*-1,4 polyisoprene 289
- clays 365
 - minerals 365
- coir 49
- coir fiber–NR composites 296
- cold hibernated elastic memory (CHEM) 503
- collagen 15–18, 67–68, 374, 396–398
- collagen matrices 490
- commingled yarns 347
- comminution 231
- compatibilizer 202–203
- composite boards 255–259
- composite material 71, 518
- composites 289
 - of biomass 465
- composting 526
 - test method 530
- compression molding 219
- cone rheometer 206
- continuous natural fiber-reinforced
 - thermoplastic composites, intermediate materials for 345–348
- controlled release, of agricultural chemicals 77
- core yarns (CYs) 349
- cornstarch-based resin (CPR) 339
- corn zein/MMT bionanocomposites 399
- corona treatment 146
- cosine braiding yarn centerline 350
- coupling agents 308
- crack propagation
 - behavior 325
 - propagation process 327
- crystalline cellulose 540
- crystalline transition rate 443
- curdlan 44–45
- cure time 293
- curing 293, 294
- cutan 36–38
- cutin 38–39
- cyanophycin 47–48
- cyclical form materials 179
- d**
- α -d-(1,4)-bonds 372
- α -d-(1,4)-glycoside bonds 372

- decorative purposes, green composites in 534
 - decotication 244
 - dextran 43–44
 - d-glucopyranose 372
 - die hard impregnation 185–186
 - 1,6-diisocyanatohexane 491
 - dipeptide 13
 - direct extrusion molding machine 208
 - DNA 47, 50–52
 - double-walled carbon nanotubes (DWCNTs) 518
 - drug delivery systems (DDS) 74–75, 503
 - dynamic contact angle measurement 151, 156
 - dynamic mechanical analysis (DMA) 300
- e**
- E-glass fibers 501
 - elastic modulus 117–120
 - elastin 18–19
 - elastomers 292
 - electron beam treatment 147
 - electrospinning 491
 - elongated particle bionanocomposites 363
 - end-of-life-treatment, of NFR thermostat composites 231
 - chemical recycling 232–233
 - energy recovery 233
 - pyrolysis 232
 - recycling as composite fillers 231
 - energy recovery 233
 - enhancer 317, 326, 328
 - environmentally degradable plastics (EDPs) 536
 - environment pollution 523
 - epoxy-based composites 222–223
 - ethylene propylene diene rubber 307
 - exfoliated nanocomposites 363
 - extracellular matrix (ECM) 490
 - extrusion machine 203–204
 - extrusion molding 207–208
- f**
- fabrication techniques 217
 - compression molding 219
 - filament winding 219
 - hand layup 218
 - pultrusion 219
 - resin transfer molding (RTM) 220
 - feedstock recycling. *See* chemical recycling
 - fiber/soy protein interfacial properties 435–437
 - fiberboards 258–259
 - fiber length, effect of 294–295
 - fiber loading, effect of 296–300
 - fiber–matrix adhesion 307, 310
 - benzoylation 308
 - bonding agents 309–311
 - coupling agents 308–309
 - mercerization 307
 - fiber orientation angle 338, 340
 - fiber orientation, effect of 295–296
 - fiber reinforced composites 499–501
 - fiber-reinforced green composites 447
 - fibers 331–333, 335. *See also* individual entries
 - fibrillation 150
 - fibrin 19–20, 70
 - fibrinolysis 20
 - fibroins 50
 - fibronectin 20
 - filament winding 219
 - fill ratio 353
 - film-stacking method 346
 - flax 240, 242–243
 - flax fiber-reinforced thermoplastics 261–264
 - flocculated/phase-separated nanocomposites 363
 - forest farming 247
 - forest plant products 246
 - fracture toughness test 321–322
 - fringed micelle structure 112
 - furan resin 229–231
- g**
- gelatin 22–23, 374, 395–396
 - gel permeation chromatography (GPC) 531
 - glass fiber-reinforced composite (FRC) substructure 501
 - glass fiber-reinforced plastics (GFRPs) 515
 - glass fiber-reinforced polymers 500
 - glass fibers 467
 - gliadin 21
 - global warming 521
 - glutelin 21–22
 - gluten 21–22, 399
 - glutenins 22
 - graft copolymerization, biofibers 250–252
 - graft copolymers reinforced thermoplastic composites, biofibers 271–274
 - grasses 244
 - green body 6
 - green chemistry 6

- green composite 4, 6, 8, 517
 - advantages of, over traditional composites 532
 - application and end-uses 532
 - aircrafts and ships 533
 - automobiles 533
 - decorative purposes 534
 - mobile phones 533–534
 - uses 534
 - biodegradability test 530
 - differential scanning calorimetry (DSC) analysis 531–532
 - FTIR-ATR analysis 532
 - mechanical property and weight loss tests after biodegradability 530–531
 - microbial counts in natural and compost soil 531
 - molecular weight after biodegradability 531
 - morphological test 532
 - natural soil burial test and simulated municipal solid waste (MSW) aerobic compost test 530
 - cellulose fiber-reinforced starch biocomposites 539–541
 - cellulose fibers, life cycle analysis of 556–558
 - cellulose, biodegradation of 539
 - comparison 548–551
 - disadvantages of 532
 - environmental aspects of 518–520
 - environmental impacts of 520–521
 - green principles assessment results 548
 - impact categories, choice of 521
 - abiotic depletion 521
 - acidification 521
 - global warming 521
 - life cycle assessment (LCA) 541
 - decision matrix 545–546
 - green design metrics 543–545
 - methods 542–543
 - results 546
 - life cycle inventory analysis of 551
 - fiber composites 551–552
 - life cycle analysis of polylactide (PLA) 552–555
 - natural fibers 552
 - poly(hydroxybutyrate), life cycle analysis of 556
 - polylactic acid, biodegradation of 536
 - and its composites 537–538
 - polylactide, environmental impact of 522
 - polyvinyl alcohol (PVA)
 - biodegradation of 534–536
 - environmental effect of 523–525
 - potential negative environmental impacts 526
 - aquatic environments, pollution of 527–528
 - litter 528–529
 - potential positive environmental impacts 526
 - composting 526
 - energy use 526
 - landfill degradation 526
 - “green” composites, applications of 465
 - applications of biocomposites 467
 - automotive applications 469–472
 - structural applications 472–476
 - survey of technical applications of natural fiber composites 467–468
 - biodegradable plastics versus traditional plastics 466–467
 - “green” composites, fully biodegradable 431, 451
 - biodegradation of PHBV 451–454
 - biodegradation of starch-based green composites 458–460
 - effect of soy protein modification on its biodegradation 455
 - soy protein-based green composites 434
 - fiber/soy protein interfacial properties 435–437
 - Phytigel® addition of, effect 437–438
 - stearic acid modification effect of 439–441
 - starch-based green composites 441
 - biodegradation of 458–460
 - cellulose nanofiber-reinforced “green” composites 446–447
 - evaluation of mechanical properties of green composites 447–450
 - fiber treatments 442
 - “green” composites, future scope 476
 - choice of materials and processing methods 477–478
 - green principles assessment results 548
 - guar gum 39–40
 - gum copal 41–42
 - gum damar 42
- h**
- hand layup 218
 - heat deflection temperature (HDT) 165–166

- helical yarn geometry 333
 - helically twisted yarn 334
 - hemicellulose 49, 111, 112, 240
 - hemp fiber 243
 - hemp fiber-reinforced thermoplastics 269–271
 - Henschel type mixer 204–205
 - 1,1,1,3,3,3-hexafluoro-2-propanol 491
 - hexitol nucleic acids (HNAs) 54
 - high-amylose corn starch (HACS) 78
 - high density polyethylene (HDPE) 500, 526
 - human fetal osteoblast (hFOB) cells 391
 - human osteoblast (HOB) cell 491
 - hyaluronic acid (HA) 32, 70
 - composites 491–493
 - hybrid composite 297
 - hydroxyapatite (HAp) 6, 397, 483
 - chitosan (HAp/CTS) 391
 - collagen bionanocomposite bone scaffold 397
 - hyperbranched polyesteramide (HBP) 412
- i**
- injection molding 208–209
 - in situ* polymerization 381
 - intercalated nanocomposites 363
 - interfacial adhesion 134–135, 138
 - in bamboo polymer *see* Bamboo fiber (BF)
 - interfacial shear strength (IFSS) 155
 - interfacial shear stress (IFSS) 435, 436
 - interlaminar shear strength (ILSS) 156–157
 - interpenetrating polymer networks (IPNs) 501
 - isodimensional particle 364
 - isora fiber–NR composites 294, 304
 - Izod impact strength 196
- j**
- jute 49, 240–241, 243
 - jute fiber reinforced-thermoplastics 266–269
 - jute/polylactic acid composites, braid-trusion of 349
 - braid geometry 349–353
 - experiments 353
 - braiding 354–355
 - pultrusion 355–356
 - yarns 353–354
 - results and discussion 356–358
- k**
- kenaf–NR composites 297
 - keratin 241
 - Kyoto protocol 432
- l**
- lactic acid 376
 - lactic acid, stereoisomers of 376
 - layered particle-reinforced bionanocomposites 363
 - layered polymer nanocomposite (LPN) 363
 - life cycle assessment (LCA) 432, 541
 - decision matrix 545–546
 - green design metrics 543–545
 - methods 542–543
 - results 546
 - life cycle impact assessment (LCIA) 542
 - life cycle inventory analysis of green composites 551
 - fiber composites 551–552
 - life cycle analysis of polylactide (PLA) 552–555
 - natural fibers 552
 - lignin 49, 111–112, 240
 - lignin-based composites 225–226
 - lithium chloride (LiCl) 405
 - littering 528
 - appropriate disposal environments, determination of 528–529
 - built environment, role of 529
 - locked nucleic acid (LNA) 54
 - low density polyethylene (LDPE) 526
 - low molecular weight biopolymers 39–42
 - lumen 111, 218
 - Lyocell™ fibers 127
 - lysine-based diisocyanate (LDI) 168
- m**
- maleic anhydride polypropylene (MAPP) 264
 - mammal protein-based biocomposites 490–491
 - mangium 245
 - man-made cellulose fibers 556
 - life cycle of 558
 - MAPP treatment 143–144
 - maximum crimp angle 350
 - maximum torque 293
 - mechanical testing 317, 320, 328
 - medium-density fiberboards (MDFBs) 258
 - melt indexer 205
 - mercerization 115, 138, 307
 - acetylation of fibers 300
 - mercerized fiber-reinforced composites 302

- micelles 24
- microbial cellulose (MC) 540
- microbial-synthesized biopolymers 42–46
- microbond test, schematic of 435
- microbraided yarn (MBY) 348
 - application, to textile 349
 - schematic drawing and photograph of 348
 - types of 348
- microcrystalline cellulose (MCC) 297, 405
- microdrop test 321
- microfibril angle 121–122
- microfibrillated cellulose (MFC) 317, 319, 323, 326, 364
 - appearance of 319
 - bending strength with respect to 324
- microfibrils 111–114
- microorganisms and biotechnology,
 - biodegradable polymers from 375
 - polyhydroxyalkanoates (PHAs) 375
 - polylactides 376
- microwave radiation (MWR) 250–252
- middle-end yarns (MEYs) 349
- migration 338
- mobile phones, green composites in 533–534
- modified soy protein isolate (MSPI) system 440
- monolignols 225
- montmorillonite (MMT) 366, 384, 405
- mulches (agricultural) 76
- multiwalled carbon nanotubes (MWCNTs) 383
- multiwalled nanotubes (MWNTs) 485
- n**
- N,N-dimethylacetamide (DMAc) 405
- N-(3-dimethylaminopropyl)-
 - N'-ethylcarbodiimide (EDC) 396
- N-hydroxysuccinimide (NHS) 396
- nanoclays 365
- nanocomposites 504–506
- nanofiber 112–114, 124–125
- nano-hydroxyapatite (n-HA) 412
- nanowhiskers 364
- natural biopolymers 13–14
 - low molecular weight biopolymers 39–42
 - microbial-synthesized biopolymers 42–46
 - natural poly(amino acids) 46–50
 - nucleic acids 50–54
 - polysaccharides 27–39
 - proteins 14–27
- natural fiber-reinforced thermoplastic
 - composite processing technology 179–180
 - PLA resin 181
 - thermoplastic resin
 - – pellet manufacturing technology 183–197
 - – pellet production technology 181–183
- natural fibers 2–4, 133–134, 215–217, 291, 292, 307, 312, 465, 467–471, 477, 552. *See also* biocomposites
 - chemical changes 149–150
 - mechanical changes 151
 - morphological and structural changes 150–151
 - surface treatment methods 137–138
 - – chemical treatment methods 138–145
 - – physical treatment methods 145–149
- natural matrix based polymer composites 488
 - chitin and chitosan as matrices 489–490
 - hyaluronic acid composites 491–493
 - mammal protein-based biocomposites 490–491
 - other natural polymer matrices 493–494
 - silk biocomposites 488–489
- natural nucleic acids 50–51
- natural plant fibers
 - crystal structure 114–117
 - microstructures 110–114
 - properties 117–121
- natural poly(amino acids) 46–50
- natural rubber (NR) 289–290
 - structure of 290
 - typical analysis of 290
- NiTinol 502
- nonbiodegradable polymers 80–82
 - conversion to biodegradable polymers 82
- nonwood fibers 241–242
- nonwood natural fiber–plastic composites 468
- nucleic acids 50–54
- number- and weight-average fiber lengths 295
- Nutrient Agar (NA) plate 531
- o**
- oil palm wood flour (OPWF)/NR composites 293
- oligopeptides 14
- optimal screw configuration and bamboo
 - fiber diameter influence 193–195
- organically modified layered silicate (OMLS) 404

- organically modified montmorillonite (OMMT) 384
 - organically modified synthetic fluorine mica (OSFM) 415
 - orthotropic theory, yarn modulus based on 335–338
- P**
- paracasein 26
 - parallel gap 352
 - partially biodegradable packaging materials 80
 - particleboards 256–258
 - particulate bionanocomposites 363
 - PBT (polybutylene terephthalate) 379
 - pectin 33–34, 240
 - pellet manufacturing technology 183
 - of continuous natural fiber-reinforced thermoplastic resin composite material 183–189
 - of distributed type natural fiber-reinforced thermoplastic resin composites 189–197
 - pentosans 216
 - peptide bond 373
 - peptide nucleic acid (PNA) 53–54
 - peptide synthesis 374
 - perennial biofibers (wood fibers) 245
 - agro-forestry products 246–247
 - forest plant products 246
 - tree plantation products 245
 - peroxide treatment 144–145
 - peroxide treatment of biofibers 308
 - PET (polyethylene terephthalate) 379
 - petrochemical products, biodegradable polymers from 377
 - aliphatic and aromatic polyesters and their copolymers 379
 - poly(ϵ -caprolactone) (PCL) 377–378
 - polyesteramides 378
 - poly(glycolic acid) (PGA) 380
 - poly(vinyl acetate) (PVAc) 380
 - poly(vinyl alcohol) (PVA) 380
 - petrochemical products, bionanocomposites using biodegradable polymers from 406
 - aliphatic and aromatic polyesters and their copolymers 412–416
 - poly(ϵ -caprolactone) (PCL) 406–411
 - polyesteramides 411–412
 - petroleum-derived materials 2, 6
 - petroleum hydrocarbons 529
 - γ -PGA 47
 - phase-separated nanocomposites 363
 - phenolic resin-based composites 224
 - physical treatment methods, for natural fibers 145
 - corona treatment 146
 - electron beam treatment 147
 - plasma treatment 145–146
 - ultrasonic treatment 148–149
 - ultraviolet treatment 147–148
 - Phytigel® 437–438
 - pineapple leaf fiber (PALF)-filled NR composites 293, 296
 - SEM photomicrographs of fracture surfaces of 308
 - pitch length 349
 - plait 350
 - plant fiber 432, 442
 - plasma treatment 145–146
 - pluronic 503
 - poly(2-hydroxyethyl methacrylate) (PHEMA) 68
 - poly(3-hydroxybutyrate) (PHB) 494
 - poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) 401, 505
 - poly(3-mercaptopropionate) (poly(3MP)) 81–82
 - poly(anhydrides) (PA) 60, 70
 - poly(butylene succinate) (PBS) 412, 413
 - poly(d-lactide) (d-PLA) 536
 - poly(dl-lactide) (dl-PLA) 536
 - (PDLLA)/HAp biomaterials 503
 - poly(ester amides) (PEAs) 63–64
 - poly(ether ether ketone) (PEEK) 499
 - poly(ethylene 2,6-naphthalate) (PEN) 518
 - poly(ethylene terephthalate) (PET) fibers 505
 - poly(glycerol sebacic acid) (PGS) 58–59
 - poly(glycolic acid) (PGA) 55, 380, 418–419
 - chemical structure of 380
 - poly(hydroxyalkanoates) (PHAs) 63, 433
 - poly(hydroxybutyrate) (PHB) 375, 403, 451, 522
 - copolymers 401
 - life cycle analysis of 556, 557
 - poly(hydroxybutyrate-co-hydroxyoctanoate) (PHBO) 375
 - poly(hydroxybutyrate-cohydroxyvalerates) (PHBV) 375, 376
 - poly(hydroxy butyrate-co-valerate) (PHBV) 433
 - biodegradation of 451–454
 - poly(lactic acid) (PLA) 55–56, 67, 149, 155–156, 158–160, 162–163, 165–166, 168, 179–180, 188–189, 197, 376

- natural fiber-reinforced resin composite material 181
 - packaging materials 78–79
 - poly(lactic-co-glycolic acid) (PLGA) 377
 - poly(lactide-co-glycolide) (PLGA) 56–57, 503
 - poly(l-lactide) (l-PLA) 536
 - poly(methyl methacrylate) (PMMA) 483
 - poly(N-isopropylacrylamide) (pNiPAAm) 503
 - poly(orthoesters) (POEs) 60–61
 - poly(*p*-dioxanone) (PDO) 57
 - poly(phosphazene) 61–62
 - poly(propylene fumarate) (PPF) 59–60
 - poly(thioesters) (PTE) 80–82
 - poly(trimethylene carbonate) 495–498
 - poly(trimethylene carbonate) (PTMC) 58
 - poly(vinyl acetate) (PVAc) 380, 417–418
 - chemical structure of 380
 - poly(vinyl alcohol) (PVA) 62, 380, 416–417, 524
 - biodegradation of 534
 - – in aqueous environments 536
 - – composting conditions 535
 - – in soil environment 535
 - chemical structure of 380
 - environmental effect of 523–525
 - poly(β -hydroxyoctanoate) (PHO) 403
 - poly(ϵ -caprolactone) (PCL) 377, 406, 490
 - poly(ϵ -lysine) 48
 - polyaromatic ether ketones 499
 - polyaryl ether ketones (PAEKs) 499
 - polybutylene adipate/terephthalate (PBAT) 379
 - polycaprolactone (PCL) 57, 68
 - polycaprolactone planting containers 77
 - polycarbonate–polyurethane (PCU) matrix 506
 - polycardanol 164
 - polyester-based composites 220–222
 - polyesteramides (PEAs) 378, 411
 - polyesters 378, 386, 409
 - polyethylene (PE) 109, 517
 - polyglutamic acid 47
 - polyhydroxyalkanoates 375, 399–403
 - polyhydroxybutyrate (PHB) 375, 403, 522
 - copolymers 401
 - life cycle of 557
 - polyhydroxyhexanoate (PHH) 375
 - polylactic acid (PLA)/bamboo fiber (BF)/microfibrillated cellulose (MFC) composite 320, 323
 - bending strength of 322–324
 - fabrication procedure of developed composite using 320
 - fracture toughness of 325
 - internal state of 322–323
 - stress–strain curves of 324
 - polylactic acid, biodegradation of 536
 - and its composites 537–538
 - polylactide (PLA) 376, 404–406, 522
 - biocompatibility of 555
 - chemical structure of 552
 - environmental impact of 522
 - life cycle 552–555
 - polymer/bioactive glass nanocomposite systems 505
 - polymerization-filling technique (PFT) 410
 - polymer-nanosystems and nanocomposites in medicine 504–506
 - polymethylene adipate/terephthalate (PTMAT) 379
 - polynucleotides 11, 14, 50
 - polypeptides 14
 - polypropylene (PP) 517
 - polysaccharide bionanocomposites 383
 - chitin 387–388
 - chitosan 388–391
 - starch 383–387
 - polysaccharides 27–34, 370–373
 - from marine sources 34–39
 - proteins 373–375
 - starch 372–373
 - poly- β -hydroxybutyrate (PHB) 58
 - pop-corn 494
 - powder-impregnated yarns 346, 347
 - power cosine rule 333
 - preimpregnated tape 345, 346
 - protein-based composites 226–227
 - protein bionanocomposites 391
 - collagen 396–398
 - gelatin 395–396
 - gluten 399
 - silk fibroin 399
 - soy protein isolate 392–395
 - zein 399
 - protein bodies 23
 - proteins 14–27, 369, 373–375
 - pullulan 42
 - packaging materials 79
 - pultrusion 219, 355–356
 - pyrolysis 232
- r**
- γ -radiation 307
 - ramie 240–241, 243, 331, 332, 338

- ramie fiber-reinforced thermoplastics 260–261
- ramie twisted yarn, migration in 338
- recycling, as composite fillers 231
- residual fibers 244
- resin injection molding (RIM). *See* resin transfer molding (RTM)
- resin transfer molding (RTM) 220
- resorcinol–hexa–silica bonding system 301
- rice husk ash (RHA)-filled NR composites 294
- RNA 14, 50–51, 53
- roller materials 191–193
- room temperature vulcanizing (RTV) silicone 505
- rosin 40–41
- rubber composite 289–312

- S**
- scaffolds 489
- scanning electron microscope (SEM) 223, 532
- scorch time 293
- shape memory polymers (SMPs) 503
- short fiber-reinforced elastomeric composites 292
- silane A1100 [γ -aminopropyltriethoxy silane] 300
- silane A151 [vinyl triethoxy silane] 300
- silane coupling agents 309
- silane F8261 [1,1,2,2-perfluorooctyl triethoxy silane] 300
- silane F8261-treated fibers 300
- silane treatment 139–142
 - oil palm–NR composites 294
- silica 397
- silicon rubber 290
- silk 49–50
- silk biocomposites 488–489
- silk fiber 125–127, 241
- silk fibroin 399
- silk fibroin-reinforced chitin whiskers 399
- silk fibroin scaffolds, cell and tissue applications of 489
- silk sericin 488
- silkworm silk 50
- silver sulfide 401
- silvopasture 247
- single wall carbon nanotubes (SWCNTs) 403
- single walled nanotubes (SWNTs) 485
- sisal 243–244
- sisal–coir hybrid fiber-reinforced NR composites 303, 305
- sisal fiber-reinforced thermoplastics 264–266
- sisal–oil palm hybrid fiber-reinforced NR composites 300
- sisal–oil palm hybrid NR composites 296, 301–304
 - dielectric characteristics of 305
- smart polymers and biocomposites 502–504
- soybeans 434
- soy protein 23–24, 434
- soy protein-based green composites 434
 - fiber/soy protein interfacial properties 435–437
 - Phytigel[®] addition, effect of 437–438
 - stearic acid modification, effect of 439–441
- soy protein concentrate (SPC) resins 518
- soy protein isolates (SPIs) 374, 392–395
- soy protein resins 434
- spider silk 50
- spun yarns 3, 331
- starch 28–29, 372–373, 493–494
- starch-based green composites 441
 - biodegradation of 458–460
 - cellulose nanofiber-reinforced “green” composites 446–447
 - evaluation of mechanical properties of green composites 447–450
 - fiber treatments 442
 - – effect of NaOH treatment of ramie yarns on tensile properties 444–446
 - – NaOH concentration and cellulose, relationship between 442–444
 - – studies on 442
- starch-based packaging materials 78
- starch bionanocomposites 383
- starch nanocrystals (StNs) 387
- steam explosion method 318
- stearic acid modification, effect of 439–441
- strand (rod)-cutting method 183
- straw 242
- structural applications 472–476
- structural isomers 372
- S-twist 186
- styrene butadiene rubber (SBR) 290
- surface crystallinity index (SCI) values 452
- surgical sutures 72–73
- sustainability 432
- sustainable society 2–3
- synthetic biopolymers 54–64
- synthetic nucleic acids (SNA) 51–54
- synthetic polymer composites 499
 - dental applications 500–501

- orthopedic applications 499–500
- other tissue engineering applications 502
- synthetic polymer matrix biomedical composites 494
- biodegradable polymer matrices 495–498
- synthetic polymer composites 499
- – dental applications 500–501
- – orthopedic applications 499–500
- – other tissue engineering applications 502
- synthetic thermosets 214–215, 225
- epoxy-based composites 222–223
- phenolic resin-based composites 224
- polyester-based composites 220–222
- vinyl ester-based composites 223–224

t

- taking over system and pelletizer 186
- tannin-based composites 227–228
- Teed company 476
- tensile strength 120–121
- tensile stress 333
- textile biocomposites, definition of 331
- textile biocomposites, fabrication process for 331
- continuous natural fiber-reinforced thermoplastic composites, intermediate materials for 345
- jute/poly(lactic acid) composites, braid-trusion of 349
- – braid geometry 349
- – experiments 353
- – results and discussion 356
- textile composite 331, 335
- thermal expansion 122
- thermoplastic acetylated starch (TPAS) 384
- thermoplastic resins 4, 137, 142
- “thermoplastic starch” (TPS) 516
- thermosetting resin 137
- third phase 135
- three-dimensional reduced stiffness 341
- three-point bending test 321
- traditional fiber-reinforced composites 500
- traditional plastics, biodegradable plastics versus 466–467
- trans*-1,4-polyisoprene 289
- tree plantation products 245
- treofan 79
- triethylene glycol dimethacrylate (TEGDMA) 501
- triglyceride-based composites 228–229
- tropoelastin 18
- “truly green” composites 516
- twice functionalized organoclay (TFC) 414

- twin-screw extruder 185
- twisted/plied yarn 331
- twisted yarn biocomposites elastic properties of 331
- twisted yarn composite, cylindrical model for 337
- twisted yarn-reinforced composites orthotropic theory for 335
- extension of theory to off-axis loading 341–343
- relation between mechanical properties and twist angle 338–341
- yarn modulus based on orthotropic theory 335–338
- two-dimensional off-axis reduced stiffness 338

u

- ultrahigh molecular weight poly(ethylene oxide) (UHMWPEO) 391, 505
- ultrasonic treatment 148–149
- ultraviolet treatment 147–148
- unsaturated elastomers 306
- unsaturated polyesters (UPs) 214
- UT composite 445

v

- vacuum-assisted resin transfer molding (VaRTM) 220
- vascular endothelial growth factor (VEGF) 502
- vascular grafts 73–74
- vegetable fibers 240
- vinyl ester-based composites 223–224
- volatile organic compounds (VOCs) 218
- vulcanizates, mechanical properties of 295, 297

w

- water-soluble PVA film 523
- whey protein 24
- wind breaks and shelterbelts 247
- wood and nonwood natural fibers 468
- wood ceramics 6
- wood fibers/flour (WF/F) 4–5
- wood–plastic composite (WPC) processing technology 197–198
- compatibilizer 202–203
- compounding process 203
- – evaluation of compounds 205–207
- – extrusion machine 203–204
- – Henschel type mixer 204–205
- future outlook 209
- molding process 207

wood–plastic composite (WPC) processing
 technology (*contd.*)
– – extrusion molding 207–208
– – injection molding 208–209
– plastic 201–202
– woody materials manufacture 198–200
wood–plastic composites (WPC) 4–5, 468,
 475
wood pulp fibers 473
wool 241

x

xanthan 45–46
XCell 494

y

yarn elastic modulus, classical theories of
 332–335
yarn mechanics 3

yarn modulus 332, 333
 – based on orthotropic theory 335–338
yarns 49, 332, 353–354
yarn strain 333
Young's modulus 332, 340–342, 386, 444,
 449
 – on fiber orientation angle 449

z

zein 20–21, 399
zero-dimensional particle 364
zooplankton cuticles 368
Z-twist 186–187