

## Index

### **a**

absorption rate, of BC-based biomaterials 388  
 acetylated BC/ESO 255  
 acetylation-modified cellulose nanocrystals (ACNCs) 166  
 acetyl-CoA 87  
 acid half-esters 24  
 acid hydrolysis  
     cellulose pretreatments 27–31  
     extraction of cellulose nanocrystals 21–27  
 aerogels 65, 71, 72, 433, 442–458  
 agar 100  
 agitation fermentative cultivation, BC granules 94, 95  
 alkali treatment 63  
 alkynylated cellulose nanocrystals (ACNCs) 232  
 $\alpha$ -D-guluronate (G) 99  
 3-aminopropyl trimethoxysilane (APMS) grafting procedure 387  
 aminosilanes 126  
 ammonium persulfate (APS) 3, 185, 293  
 anisotropic gel phase 42, 317  
 anisotropic nanocomposite foams, thermal transport properties of 437  
 antimicrobial diffusion films (ADFs) 336–338  
 antimicrobial nanomaterials 382  
     inorganic antimicrobial agents 385  
     medical composite material 388

### organic antibacterial agents

386–388

aqueous counter collision (ACC) 61

artificial blood vessels 81, 371–373

atomic force microscopy (AFM) 26, 64, 139

atomic layer deposition (ALD) 409, 441, 454

AU cellulose films, oxygen permeabilities 70, 71

*A. xylinum* 88

### **b**

bacterial cellulose 252  
 BC/ICPs nanocomposites 185  
 $MnO_2$  nanocomposites 409  
 bacterial cellulose (BC) 117–118, 174, 350  
 additives  
     carboxymethyl cellulose (CMC) 97  
     lignosulfonate 100  
     organic acids 97, 98  
     sodium alginate 99  
     alcohols 99  
     SSGO 99–100  
     vitamin C 97  
 biocompatibility 92, 372  
 biodegradability 92–93  
 biomimetic mineralization pathways 370  
 biosynthesis  
     biochemical pathway 85–87  
     biochemistry 83–84

- bacterial cellulose (BC) (*contd.*)  
     molecular regulation 87–88  
     chemical structure and properties 89  
     for dental root canal treatment 388  
     macrostructure control and orientation 91  
     microbial genera 81  
     nanofibrillar patch fabrication 364  
     physiological features 89–90  
     porosity and materials 91–92  
     production  
         by cell-free system 86  
         static fermentative cultivation 93  
     ribbons-like structures 82  
     self-assembly and crystallization 90  
     shaking fermentative cultivation, pellets 94  
     for skin tissue repair 368–370  
     strategies  
         agricultural and industrial wastes 103–104  
         food wastes 104–105  
         fruit juices 101  
         sugarcane molasses 101–103  
     ultrafine thin fibrous structure 90–91  
     for wound dressing 368
- bacterial cellulose nanofibers/graphene oxide (BC-RGO) film 363
- bacterial cellulose nanofibril aerogels 442, 443
- bacterial cellulose scaffolds 364
- bacterial nanocellulose (BNC) 1, 4, 328, 425
- ball-milling 27, 54, 59, 65, 74, 124
- BC/chitosan nanocomposite 184
- BC/polyacrylamide (PAAm) gels 373
- BC/starch nanocomposites 183
- BC-templated-CoFe<sub>2</sub>Co<sub>4</sub> nanotubes 453
- $\beta$ -1,4-glucan chains 4, 81–84, 87, 88, 90
- $\beta$ -(1,4) glycoside linkage 1
- $\beta$ -1,4-glycosidic bonds 30
- $\beta$ -glycosyltransferase 87
- bending properties, of CNF-based thermoset resin nanocomposites 255
- Beycostat NA (BNA) 119
- biocompatible BC tubes 372
- biological macromolecules, immobilization and recognition of 355–360
- biomass-based thermosetting nanocomposite 170
- bio-nanocomposites 164, 165, 172, 337
- birefringence 22, 39, 41, 43, 278, 282, 286, 293, 305, 306
- bone tissue regeneration 370–371
- bromine-based flame retardants 424
- 2-bromoisobutyryl bromide (BriB) 135
- C**
- carboxylate nanocellulose 7, 8
- carboxymethylated BC (CM-BC) 97
- carboxymethylation 4, 43, 64, 68, 118, 124
- carboxymethyl cellulose (CMC) 97
- carboxymethyl cellulose/ZnCdS fluorescent quantum dot nanoconjugates 360
- casting method 168, 170, 178, 179, 182, 281–282, 337
- cell imaging 360–361
- cell scaffolds 361–366
- cellulose aerogel 433  
     stress-strain curves 453  
     XRD results 447
- cellulose aerogel membranes (CAMs) 72
- cellulose fibers 2, 3, 21, 22, 24, 25, 27, 28, 31, 32, 53, 54, 58, 61–63, 83, 89, 115–117, 122–124, 201, 239, 252, 255, 433
- cellulose nanocrystal-graft-polycaprolactone (CNC-g-PCL) nanoparticles 166, 167
- cellulose nanocrystalline/glycerol composites<sup>1</sup> 280
- cellulose nanocrystalline/polyethylene glycol composites 279

- cellulose nanocrystalline/silica composites 280
- cellulose nanocrystals (CNC) 1 21, 115, 315
- amino acid and DNA 142–144
  - aminosilanes 126
  - anisotropic phases 39
  - characteristics 458
  - chiral nematic phase 41
  - colloidal properties 315–324
  - cotton linter-derivate 3
  - esterification of 124
  - fabrication of 32
  - from fiber cell walls 439
  - fluorescent and dye molecules on 139–142
  - gold (Au) nanoparticle 440
  - $H_2SO_4$ -hydrolyzed 36
  - hydrolysis, cellulose fibers 2
  - ecotoxicology 350
  - geometrical characteristics 206
  - iridescent films 320
  - inorganic nanoparticle templated synthesis 438, 440
  - isotropic phase 39
  - from lignocellulosic biomass 439
  - mesoporous silica (Si) nanoparticles 441
  - non-flocculated dispersion 119
  - organ distribution and bone tropism 361
  - percolation network formation, factors affecting 208–211
  - platinum (Pt) nanoparticle synthesis 440
  - preparation of, acid hydrolysis 21, 22
  - freeze-drying technology 23
  - HBr hydrolysis 25
  - microcrystalline cellulose (MCC) 24
  - sulfuric acid 22, 23
  - pretreatments of cellulose, before acid hydrolysis 27–31
  - self-assemble structure of 277–281
  - self-cross-linking 144–145
  - silver (Ag) nanoparticle 438, 439
  - silylation of 125–126
  - structure and properties
  - cellulose nanocrystal suspension 39–45
  - physical properties 32–39
  - sulfonation of 121–122
  - CNC-templated nanostructured films 464
  - TEMPO-mediated oxidation
  - mechanism of 122
  - TEMPO-oxidized CNC (TOCNC) 3
  - theranostic field 361
  - ureidopyrimidinone (UPy) motifs 324
  - vertical-assembly film 291
- cellulose nanofibril (CNF) 1, 4, 21, 53, 117, 251
- aqueous counter collision (ACC) 61
  - bottom-up process 252
  - characteristics of 252–253
  - chemical bleaching 54
  - cryocrushing 62
  - from different sources 55–57
  - drying 253
  - features and properties
  - crystallization of 65
  - morphology of 64
  - processing and products 65–73
  - from fiber cell walls 439
  - as fillers, challenges of 252
  - fluorescence correlation spectroscopy (FCS) 360
  - food packaging applications 267, 269
  - grafting in water 387
  - from holocellulose 336
  - industrialization 269
  - mechanical disintegration
  - aqueous counter collision (ACC) 61
  - ball-milling 59, 60
  - cryocrushing 62
  - grinding 58
  - homogenization 54–58

- cellulose nanofibril (CNF) (*contd.*)  
other methods 63  
refining 62  
steam explosion 61  
twin-screw extrusion 62–63  
ultrasonication 59–60  
morphology 252  
nanocomposites 267–269  
nanostructure of 54  
optical and barrier properties of 267–269  
pretreatment 63, 64  
random plane orientation 253  
sedimentation test 68  
TEMPO-mediated oxidation 123  
tensile strength 253  
top-down process 252  
water vapor transmission rate 267  
Young's modulus 253
- cellulose nanowhisker (CNW) 1, 157, 158, 166, 169–171, 201
- cellulose-negative (Cel<sup>-</sup>) mutants 94
- cellulose raw material 10, 22
- cellulose sulfate 24
- cellulose synthase 84–87
- cellulose xerogel 450
- chemically cross-linked CNC aerogels 234, 236, 237
- chitin nanocrystals 41, 387
- chitosan (CH) 183
- chitosan-nanocellulose biocomposites 338
- chlorhexidine digluconate (CHX) 328
- chlorine dioxide 54
- cholesteric liquid crystals 11, 39, 41, 278, 286, 288, 323, 324
- cholesteric structure  
of CNC films 284–286  
and crosslinking structure in gel 286–288
- cholesteric TiO<sub>2</sub> films 290
- circular dichroism spectra, of CNC films 299
- Cladophora* 32, 406, 407
- clay nanopaper nanocomposites 426
- CNC/silver nanowires (AgNWs)  
composite films 304
- CNF/PA nanocomposites 185
- CNF/thermoplastic starch  
nanocomposites 182
- cobalt ferrite nanoparticles 443, 444, 446
- composite aerogels 435  
stress–strain curves 453  
XRD results 447
- contact angle (CA)  
of carboxymethyl cellulose films 333  
*vs.* lignin content, of MFC films 335
- copper-mediated LRP 134
- Cr(III)-hydrolyzed nanocellulose 30
- cryocrushing 54, 62, 73, 117
- crystal thickness 28

**d**

- Daphnia magna* 354
- DC cellulose hydrogels 65, 68
- deep eutectic solvents (DES) 63
- defibrillation, of cellulose fibers 58
- degradation, of glycosidic linkages 30
- depolymerization of cellulose 30
- deprotonation process 30
- diguanylate cyclase (DGC) 85, 88
- diguanylic cyclase 87
- disk diffusion method 385
- dimethylsulfoxide (DMSO) 41, 59
- dispersive surface energy ( $\gamma^d$ ) 38
- distinctive rheological properties 43
- DNA immobilization 360
- dodecenyl succinic anhydride-modified CNC (DCNC) 170
- (2-dodecen-1-yl) succinic anhydride-CNC-PU  
nanocomposites 225
- double-cross-linked (DC) cellulose hydrogels 65
- drug carrier systems 376, 377
- drug delivery system 81, 328, 349, 375, 381
- bacterial nanocellulose (BNC) 328

- forms of 375  
 MFC coated paper for 328–329  
 drug release studies 376
- e**  
 elastic aerogel magnets 444  
 electric double layer capacitors (EDLCs) 404  
 electrochemical capacitors 404  
 electrodes, LIBs 399  
 electrolytes, LIBs 403  
 electronically conducting polymers (ECPs) 406  
 Entner Doudorouff (ED) 87  
 enzyme and protein immobilization 355, 356  
 epichlorohydrin (ECH) 67, 141, 185, 213  
 (2,3-epoxypropyl)trimethylammonium chloride (EPTMAC) 220  
 epoxy resin nanocomposites 169, 184  
 esterification reaction, CNC-polymer matrix 124, 237  
 Eucommia ulmoides gum (EUG) 162  
 evaporation-induced self-assembly (EISA) method 277, 284  
 expanded polystyrene (EPS) 433, 437
- f**  
 FeSO<sub>4</sub>/CoCl<sub>2</sub> salts 443  
 fibrillated cellulose-filled nanocomposites  
   natural polymer-based 182–184  
   polyester-based nanocomposites 178–180  
   polyolefin-based 172–176  
   polyurethane-based 180–182  
   rubber-based 176–178  
   waterborne polyurethane-based 180–182  
 field emission scanning electron microscopy (FE-SEM) 64, 119  
 fingerprint texture structure 41  
 fireproofing treatments 423  
 fire resistance
- of clay nanopaper nanocomposites 426  
 nanoparticles for 425  
 FITC-labeled nanocrystals 142  
 flame retardant additives 424  
   halogenated 424  
   mineral 425  
   nanoparticles 425  
   nitrogen based 424–425  
   phosphorus-based 424  
   silicon-based 424  
 flour-rich waste (FRW) 104  
 fluorescence correlation spectroscopy (FCS) 360  
 fluorescent molecule-modified CNC (fCNC) 12  
 fossil fuels 397  
 Fourier transform infrared spectroscopy (FTIR) 168  
 freeze-cast nanocomposite foams 436  
 freeze-dried BC 453, 454  
 freeze-drying technology 23, 71  
 fuel cells 411–413, 415
- g**  
 gamma-aminopropyltriethoxysilane (APS) 340  
 gaseous acid 27  
*G. hansenii* 85, 100, 102  
 global packaging market revenues 324  
 glucokinase 85  
 glucose-6-phosphate (G6P) 85  
 glucosidic bonds 23  
 glycerol plasticized starch based composites 210  
 grafting from approach 131  
   end modification reaction 139  
   living radical polymerization (LRP) 134–137  
   ring opening polymerization (ROP) 132–134  
 grafting onto method 126  
 graphene/CNC modified epoxy composites 169  
 guided bone regeneration (GBR) 370

***h***

halogenated flame retardants 424  
 Halpin–Kardos model 203, 205, 207,  
 208, 213, 214  
 HBr hydrolysis 25  
 HCl-catalyzed hydrolysis 42  
 Hestrin and Schramm (HS) medium  
 97  
 high-pressure homogenization 2, 4,  
 58, 63, 64, 252  
 high-pressure homogenizer 58, 339  
 Huisgen cycloaddition click chemistry  
 232–233  
 human keratinocytes (HaCaT) 92  
 human marrow mesenchymal stem cells  
 (hMSCs) 363, 364  
 hydrobromic acid 25  
 hydrogel scaffolds 364  
 hydroxyl (OH) groups 2

***i***

inorganic antimicrobial agents 382,  
 385  
 inorganic hollow nanotube aerogels,  
 synthesis of 454–458  
 in situ polymerization 11, 157, 160,  
 161, 164, 165, 167, 174, 176, 185,  
 405, 406, 408  
 interfacial behaviors, CNC-polymer  
 matrix 211  
 chemical coupling 237–242  
 CNC-poly (vinyl alcohol)  
 nanocomposites 211, 212  
 EO-EPI/PVA/CNC nanocomposites  
 214  
 esterification reaction 237  
 functional groups effect 211–225  
 Huisgen cycloaddition click chemistry  
 232–233  
 Schiff's base reaction 233–237  
 segmental entanglement mediated  
 with grafted chains 225–229  
 surface modification method 211  
 thiol-ene coupling process 230–232  
 inter-molecular hydrogen bonding 53,  
 89, 97, 161, 222

intramolecular hydrogen bonds 28, 53,  
 82

intrinsically conductive polymers (ICPs)  
 185

inverted sample tubes 44

ionic liquid (IL) 27, 28, 405

iridescent CNC films

fracture surface across 322

poly (vinyl alcohol) incorporation  
 324

reflection wavelength 321

static solution casting 320

vacuum-assisted self-assembly  
 technique 321

iridescent color control  
 of CNC composite materials  
 300–302

of CNC films 298–300

isocyanation 128

isophorone diisocyanate (IPDI)  
 monomer 239

***k***

*K. sucrofermentans* 104

***l***

Langmuir–Schaeffer technique 120

lignocellulosic nanofibers (LCNF)  
 morphology 252, 253

polymer nanocomposites 253

lignosulfonate 100

1,4-linked β-d-mannuronate (M) 99

liquid crystal phase transition 43

liquid crystal structure, of CNCs 277,  
 284, 294, 324

lithium ion batteries (LIBs) 72, 398

nanocellulose-based binders  
 403–404

nanocellulose-based electrodes  
 398–400

nanocellulose-based electrolytes  
 403

nanocellulose-based separators  
 401–403

$\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{CNT}/\text{NFC}$  hybrid film 400

- living radical polymerization (LRP) 134–137
- luminescent CNF 354
- m**
- magnetic composite aerogels, synthesis of 442–454
- maleic anhydride (MAH) grafted poly(lactic acid)/CNC bio-nanocomposite scaffolds 366
- mean-field theory 202–204
- mechanical properties BC/PP nanocomposite 176  
CNF/chitosan films 330, 332  
of CNC/CMC and mCNC/CMC films 221  
of CNC composite films 295–298  
of CNC/PCL nanocomposite films 225  
of CNC/PEG composite films 297  
of CNC/poly(2-hydroxyethyl methacrylate) composite films 298  
of CNC self-assemble films 295  
of CNF/polyester nanocomposites 179  
of CNF/thermoset resin nanocomposites 255  
for cross-linked mCNC/PBD composites 231  
EO-EPI/CNC and EO-EPI/PVA/CNC nanocomposite films 214  
of PVA films, CNC-reinforced 240  
of thermoplastic polymers/CNF nanocomposites 255–257
- semicrystalline PHO based composites 209
- of waterborne polymer nanocomposites 257–258
- melamine, thermal decomposition of 424
- melamine-ureaformaldehyde (MUF)/CNC composites 303
- melt-compounding method 159
- melt extrusion process 256–257
- polyethylene/CNF nanocomposites 259
- mesoporous cholesteric phenol-formaldehyde resin 288
- metal inorganic salts 27, 28
- methyl cellulose (MC) nanofibrous mats 359
- methyl silylation effect 173
- microbial strains 1, 4, 82, 89, 91, 94, 100, 105
- microcrystalline cellulose (MCC) 1, 24, 221, 361
- microcrystalline cellulose-graft-poly (*p*-dioxanone) (MCC-graft-PPDO) nanomicelles 361
- microfibrillated cellulose (MFC) 53, 251, 326
- antimicrobial diffusion films 336–338
- coated paper for delivery system 328–329
- film, chemical composition effect on 334–336
- microfluidization processes 63
- micro-supercapacitor (MSC) 72
- mineral flame retardants 425
- mineral wool 433
- Mn(III)-hydrolyzed nanocellulose 30
- modified CNCs (mCNCs) composites 220
- monocomponent endoglucanase enzyme 64
- morphology-tailored BC/PPy hybrid composites 406
- n**
- nanocellulose 1
- chemical modification amidation 8  
esterification 6, 7  
etherification 8  
other chemical methods 8–9  
oxidation 7, 8  
physical interaction 9
- ECP composite electrodes 407

- nanocellulose (*contd.*)  
 nanocellulose-based composite  
     materials 9–12  
 synthesis  
     bacterial nanocellulose (BNC) 4  
     cellulose nanocrystals (CNC) 2–3  
     cellulose nanofibers (CNF) 3–4  
 nanocellulose-based separators  
     401–403  
 nanocellulose/MCNT electrode  
     preparation 399  
 nanocrystalline cellulose (NCC) 2, 28,  
     201, 333, 372, 438  
 nanocrystals, thermal properties of 36  
 nanofibrillated cellulose 53, 69, 251,  
     399, 429  
 nanofibrillated cellulose/MoS<sub>2</sub>/CNT  
     film 400  
 nanofibrillated cellulose-nanozeolite  
     aerogels 434  
 nanogenerators 414–415  
 nanopaper 70, 253, 255, 412, 414,  
     432  
     fire resistant 425–431  
     magnetic 442, 444, 448  
     water-resistant 329–334  
 nanoparticles, for fire resistance 425  
 nanotechnology  
     for fire retardancy 425  
     high-performance thermal insulation  
         materials 434  
 nanotoxicology research 349  
 natural polymer-based nanocomposites  
     171–172, 182–184  
 neat CNC 160, 212, 218, 284–286, 294,  
     295  
 NFC based aerogels 434  
 NFC-based TENG 415  
*N*-hydroxylsuccinimide (NHS) 8  
 niobium (NdFeB) magnets 299  
 nisin 338  
 nitrogen based flame retardants 424  
*N*-methylmorpholine-*N*-oxide  
     (NMMO) 27  
 non-agglomerated colloid suspensions  
     41
- nuclear magnetic resonance (NMR)  
     89, 234  
 nucleus pulposus replacement 371,  
     375
- o**
- O<sub>2</sub> barrier properties, polymers used  
     267  
 oil/water separation, CNC self-assembly  
     305  
 oligonucleotide-modified CNC 144  
 O<sub>2</sub>-permeability, of CNF films 267  
 optical applications  
     of CNC composites films 306–307  
     of CNC films 306  
 optical control, of CNC self-assembly  
     gels 302–303  
 organic antibacterial agents 386  
 oven/air dried CNFs 67–98
- p**
- PAAm/CNC nanocomposites 286, 303  
 packaging industry 164, 324  
 paper coating 326–328  
 PBS/CNC-foamed nanocomposite 164  
 PDMAEMA-grafted CNC aqueous  
     suspensions 135  
 pellicle formation 4  
 pentose phosphate pathway (PPP) 85  
 percolation model 204–208, 214–216  
 percolation network 155, 156, 162,  
     201, 208–211  
 percolation threshold 181, 205, 206,  
     208, 209, 224  
 periodate-bisulfite sulfonation 64  
 periodate–chlorite oxidation 64  
 phosphate buffered saline (PBS) 93  
 phosphodiesterase A (PDEA) 88  
 phosphoglucomutase 85  
 phosphodiesterases (PDE-A and  
     PDE-B) 87  
 phosphoric acid hydrolyzed cotton 26  
 phosphorus-based flame retardants  
     424  
 photonic crystal 284, 290, 304, 464

- physical adsorption, of surfactants 119–120
- piezoelectric nanogenerators (PENGs) 415
- pineapple peel medium (PA-BC) 104
- PLA/CNF nanocomposites 256
- plasmonic properties, of CNCs 304
- plastic composite surface (PCS) 95
- polar surface energy ( $\gamma^p$ ) 38
- polyamide (PA) polymers 184, 267
- polyaniline/NFC/graphene nanoplatelet (GNP) electrodes 408
- polyester-based nanocomposites 164–167, 178–180
- Polyethylene/cellulose pulp fiber (PE/CF) nanocomposites cross-sectional morphology 265, 266
- modulus values 264
- optical properties 265, 266
- Polyethylene/CNF nanocomposites fiber size effect and lignin presence 264
- morphologies 260, 262
- optical properties 261, 263
- Young's modulus and tensile strength 259, 261
- Polyethylene/lignocellulosic nanofibers (PE/LCNF) nanocomposites cross-sectional morphology after tensile tests 265
- optical properties 265, 266
- tensile strength 264
- Polyethylenimine-grafted cellulose nanofibril aerogels 381
- Poly(lactic acid) (PLA) 11
- polymer grafting 43, 134, 139, 178, 186
- polymethylsilsesquioxane (PMSQ) aerogels 434
- polymethylsilsesquioxane–cellulose nanofiber (PMSQ–CNF) composite aerogels 435
- Polyolefin-based nanocomposites 156
- fibrillated cellulose-filled 172
- in situ* polymerization 160
- Poly(vinyl alcohol) advantages 161
- processing and modification of CNCs methods 156
- solution mixing method 156, 157, 159, 161
- Polyolefin/CNF nanocomposites 256, 259
- Polypropylene (PP) 10
- nanocellulose reinforced 3D PPy electrodes 405
- nanocellulose composite electrodes 406
- Polypyrrole-Cladophora cellulose composite electrodes 407
- Poly(*S*-co-BuA)-based nanocomposite films 202
- Polystyrene(PS)-grafted CNC 135
- Polystyrene sulfonate sodium (PSSNa)/nanocellulose composite 406
- Polyurethane (PUR) 433
- Polyurethane-based nanocomposites 167
- fibrillated cellulose-filled 180
- Poly(vinyl alcohol)/CNC electrospun fiber mats 212, 213
- CNC-reinforced 239
- Porous CNF/polypyrrole composite 388
- Post-sulfonation modification, of CNC 121
- Pressured extrusion method 400
- protein-based composites 172
- protofibrils 4, 82, 90
- pseudocapacitors 404
- Pyrene fluorophore (Py-CNC) 142
- q**
- Quaternary ammonium-functionalized nanocellulose/graphene oxide solid-state electrolyte 403
- Quasi isotropic composite 203
- r**
- Reactive cellulose nanocrystals (RCNCs) 237
- Refining 62, 63

- reinforcing effect, of cellulose whiskers in poly(*S*-*co*-BuA) matrix 202
- ring-opening polymerization 132–134, 165–167, 184, 361
- rod-like morphology 2, 41
- rod-shaped CNC suspensions 294, 458
- rotating disk reactor 95
- rubber-based nanocomposites 161
- chemical/physical CNC modification 162
- fibrillated cellulose-filled 176
- fillers effect 162
- S**
- Schiff base reaction 7, 233
- self-assembly, of CNCs
- bulk materials of 288
  - casting method 281–282
  - components of 279
  - evaporation-induced self-assembly 284
  - forms of 279–281
  - iridescent color properties 298–302
  - mechanical properties of 295–298
  - modifying surface chemical structure 291–295
  - oil/water separation 305–306
  - optical applications 306–307
  - plasmonic properties 304–305
  - sensor applications 307–309
  - spin-coating method 282
  - structural adjustment 284
  - templates 458–464
  - vacuum assisted self-assembly (VASA) 283–284
- self-cross-linking, of CNC 144–145
- semicrystalline PHO based composites 209
- semicrystalline polymer 53
- sensor applications 307–309
- separator, LIBs 401–403
- shaking fermentative cultivation 94
- silica aerogels 433
- silicon-based flame retardants 424
- silver nanoparticle/bacterial cellulose gel membranes 385
- silver sulfadiazine loaded bacterial cellulose/sodium alginate (BC/SA-AgSD) composite films 385
- silylated CN suspension 43
- silylation, of CNC 126
- simulated body fluid (SBC) 93, 370
- single sugar-linked glucuronic acid-based oligosaccharide (SSGO) 99
- skin repair materials 368
- skin tissue repairing 368–370
- slow water release rate (WRR) 81
- small-diameter replacement vascular graft (SDRVG) 372
- sodium alginate 99, 376, 385, 386
- sodium alginate/CNF antibacterial composites 386
- sodium chlorite 54
- sodium hypochlorite 54
- sodium montmorillonite-cellulose nanofiber (MTM-CNF) hybrid composites
- filtration processing 425
  - fire protection 426, 428
  - fire retardant features 428
  - flammability test 430, 431
  - oxygen transmission rate 429
  - thermal degradation 428
  - thermal oxidation 429
  - wood, fire protective coating for 426
- sodium periodate ( $\text{NaIO}_4$ ) 7
- sodium salicylate (NaSA) loading, of CNFs-PEI aerogels 381
- solar cells 411–415
- solid phosphor-tungsten acid 26, 27
- solid-state shear pulverization process (sssp/S3P) 256
- solution mixing method 156, 157, 159, 161, 165, 166, 179
- solution plasma process (SPP) 441
- solvent casting 177, 255, 256
- solvolytic desulfuration 36
- sorbitan monostearate 120
- special tissue bioscaffold 361
- sphere-like cellulose particles (SCPs) 94

- spin-coating method 281, 282  
 spray-dried CNFs 71  
 stable turbid colloidal suspensions 24  
 static fermentative cultivation 93  
 static solution casting 320  
 steam explosion 57, 61, 117  
 stiff magnetic nanopaper synthesis 444  
 sub-elementary fibrils (SEF) 87  
 sulfonation, of CNC 121–122  
 sulfuric acid hydrolysis 21, 23, 24, 27,  
     28, 30, 39, 121, 128, 159, 337  
 supercapacitors (SCs)  
     with carbonized nanofiber electrodes  
         409  
     cellulose mesoporous membrane  
         410–411  
     description 404  
     electric double layer capacitors 404  
     nano-templates 405  
     nanocellulose 405–406  
     pseudocapacitors 404  
     specific energy density 404  
 surface acetylation of CNC 39, 124,  
     166  
 surface energy ( $\gamma_S$ ) 38  
 surface immobilization, of  
     enzyme/protein 355, 356  
 surface silylation, of CNF 125, 126  
 surfactants, physical adsorption of 119
- t**
- tail-like BC pellets 94  
 temperature-sensitive  
     polymer-modified CNF cryogel  
         microspheres 382  
 template processing scheme, for  
     nanocellulose/polymer  
         composites 442  
 TEMPO-mediated oxidation 64, 118,  
     122–123, 144  
 TEMPO-oxidized CNC (TOCN) 3,  
     31, 177, 294  
 tensile modulus  
     of percolating filler network 206  
     of tunicin whisker reinforced  
         amorphous PHO latex 209  
     of tunicin whisker/POE composites  
         210  
 terminal complexes (TCs) 81  
*tert*-butanol 120  
 tetrahydrofuran (THF) 43, 59, 120  
 tetramethyl-piperidin-1-oxyl (TEMPO)  
     3  
 2,2,6,6-tetramethylpiperidine 1-oxyl  
     (TEMPO) 31, 64, 116, 400, 438  
 2,6,6-tetramethylpiperidine-1-oxyl  
     radical (TEMPO)-mediated  
     oxidation 64  
 thermal building insulation materials  
     432–433  
 thermal conductivity 432  
     of expanded polystyrene 433  
     of mineral wool 433  
     of NFC-zeolites 438  
     of PMSQ-CNF composite aerogels  
         435  
     of polyurethane 167, 433  
 thermal decomposition, of melamine  
     424  
 thermal stability 26, 28, 35–38, 65, 90,  
     95, 117, 121, 158, 159, 165–169,  
     174, 176, 180–186, 202, 228, 234,  
     253, 256, 399, 401, 403, 412  
 thermoplastic starch (TPS)-based  
     composites 171, 183  
 thin stillage (TS) 100, 101  
 thiol-ene coupling process,  
     CNC-polymer matrix 230–232  
 three-dimensional (3D) cell cultures  
     364, 365  
 3D hybrid CNC aerogels 408  
 three-dimensional (3D) scaffolds 81  
 TiO<sub>2</sub> nanotubes  
     dispersion in ethanol 460  
     film deposition on Si (100) 461  
 TiO<sub>2</sub>/silica composites 290  
 tissue engineering 4, 71, 81, 92, 349,  
     364, 366–382  
 tissue repair and regeneration  
     bone tissue regeneration 370–371  
     skin tissue repairing 368–370  
 tissue replacement  
     artificial blood vessels 371–373

- tissue replacement (*contd.*)
- nucleus pulposus replacement 375
  - soft tissues, meniscus and cartilage 373–375
- TOCNFs 173, 178, 181
- transesterification, of CNF 124
- transmembrane regions (TMDs) 88
- transmission electron microscopy (TEM) 64, 89
- transmittance electron microscopy (TEM) 2
- treated-nanocellulose 28, 30
- triboelectric nanogenerators (TENGs) 414
- tricarboxylic acid (TCA) 84, 85
- Trichoderma reesei* 32, 102
- trickling bed reactor 95
- trifluoroacetic acid 27
- tunicin whisker/glycerol plasticized starch (amylopectin) based composites 216
- tunicin whisker percolation threshold 206
- tunicin whisker reinforced amorphous PHO latex 209
- tunicin whisker/sorbitol plasticized waxy maize starch composites 217, 218
- twin-screw extrusion 11, 62–63, 73, 176, 183, 256, 257
- two-dimensional (2D) scaffolds 81
- u**
- UDP-glucose pyrophosphorylase 84, 85
- ultracapacitors 404
- ultracentrifugation–redispersing 23
- ultrafine thin fibrous structure 90–91
- ultrasonication 59–60
- uridine-di-phosphoglucose (UDP-glucose) 83
- UV-vis spectra, of CNF/chitosan thin films 330
- v**
- vacuum-assisted resin impregnation (VARI) 255
- vacuum assisted self-assembly (VASA)
- method 283–284, 320, 321
- vacuum filtration 69–70, 281, 320, 399, 400, 403, 408, 412
- w**
- wastewater from candied Jujube (WWCJ) 104
- water adsorption *vs.* lignin content, for MFC films 334, 335
- waterborne
- acrylate/polyurethane-based wood coating 339
- waterborne epoxy resin-based nanocomposites 155, 170
- waterborne polymer systems 257–258, 260
- waterborne polyurethane 131, 155, 167–169, 180–182, 239
- water contact angle (CA) 38, 39, 267, 305, 306, 333, 340, 435
- water holding capacity (WHC) 81
- water-resistant nanopaper 329–334
- water-soluble fragments 25
- water vapor barrier properties 326, 332, 336, 337
- water vapor transmission rates (WVTR) 267, 332
- wear resistance, of CNF/oil coated wood surfaces 340
- wood
- MTM-CNF fire protective coating for 426
  - properties 423
- wood coatings 339–341
- x**
- X-ray diffraction (XRD) 32, 89, 125, 216–218, 428, 461
- xanthan 100
- z**
- ZnO-coated aerogels 459
- ZnO-deposited BC composites 441, 442



















