

Index

Note: Page numbers given in italics refer to figures and numbers in bold refer to tables.

- Accessibility
cell wall 24–6, 29, 46, 47, 52, 54,
78, 149
lignin, barrier to 53
swelling and 55
- Accys Chemicals PLC 187
- A-Cell acetyl cellulose AB 183, 186, 187
- Acetaldehyde 95
- Acetic acid
for acetic anhydride production 195
acetylation reactions and 184
curing of resol resin and 74
thermal modification and 103, 110
- Acetic anhydride 45
- Acetoacetylated wood 83
- Acetyl
determination of 55, 56
esterase 68
hemicelluloses 26
- Acetyl peroxide 130
- Acetylated wood
acoustic properties 60
analysis 55
bonding of 73–6
composites from 72–6
decay resistance 60–9
dimensional stability 56
flammability 78
hydrolysis of acetyl groups 72
hygroscopicity 70–2
removing by-products 46, 185, 187
weathering 130, 131
- Acetylation
acetic acid and 45, 47, 49
catalysts for 48
commercialization 183–7
reaction conditions 48–50
- Acid chloride 85
- Acoustic properties
acetylated wood 60
formaldehyde treated wood 95
- Acrylonitrile 96
- Acyl azide 87
- Adhesion
acetylated wood 73–6
thermally treated wood 122
- AKBV 187
- Aldehyde 95
- Alkenyl succinic anhydride 80, 82
- Alkyd 132, 145, 152
- Alkyl halide 93
- Allowable cut 8
- Allyl
bromide 93, 137
chloride 93
glycidyl ether 92, 133
isocyanate 88
isothiocyanate 88
- Amine
bonding with 139
catalyst for epoxidation 90
- Aniline post-treatment 51
- Anionic polymerization 140
- Anti-shrink efficiency (ASE) 34–6, 80, 158,
171, 172
acetylated wood 57
alkyl halide modified wood 93
anhydride modified wood 80
cyanoethylated wood 96
epoxide modified wood 91

- Anti-shrink efficiency (*Continued*)
 formaldehyde modified wood 93, 94
 isocyanate modified wood 86, 87
 resin impregnated wood 151, 152, 155
 silane-modified wood 164, 168
 thermally modified wood 102, 119, 123
- Arsenic 14
- Attenuated total reflection (ATR) 55, 56
- Bacteria 43
- Benzophenone 132, 165
- Benzoyl peroxide (BPO) 92, 137, 138, 168
- Benylation 93, 131, 136
- Biocidal Products Directive (BPD) 15
- BioComposites Centre 183–4
- Biomimetic 143
- Blue stain 43, 66
- Bonding
 proof of 43
 surface activation of wood for 136–45
- BP Chemicals 183
- Bromine as label for EDXA 154, 171
- Brown rot 40, 61, 63, 68
- Brunauer–Emmett–Teller (BET) 30, 70
- Bulking
 of cell wall, *see* Cell wall
 coefficient (BC) 35
- Butyl chloride 93
- Butyl isocyanate 87–9, 130, 131
- Butyric anhydride 45, 57, 64, 65, 77, 79
- Carbon 5–9
- Carbonyl 56, 103, 106
- Carboxymethylation 93
- Catalysts 157, 159, 160
 for chemical modification 48, 85, 86
 for thermal modification 19, 102
- Cell wall
 accessibility, *see* Accessibility
 bulking 21, 33–5, 56, 58, 78, 80, 94
 cross-linking, *see* Cross-linking
 damage 55, 87, 92, 94
 layers 23
 micropores, *see* Micropores
 penetration of 38, 41, 154
 polymers 25–7, 52, 102–9
 reactivity 52
 swelling 49, 55, 57, 58
- Cellobiose 26
- Cellulose 25, 26
 accessible OH groups 26, 30
 acetate 68
 crystallinity 25, 30, 52, 53, 56, 105, 107,
 110, 113, 114
 hydroxyl groups 29, 30
 reactivity 52
 thermal stability 105–7
- Ceric ion 140–2
- Chaetomium globosum* 123
- Chemurgy 4
- Chloroacetic anhydride 53
- Chlorosilane 162, 163
- Chlorosulphonyl isocyanate 89
- Clear coatings 131
- Closed system for thermal treatment 111, 112
- Colour of thermally modified wood 110
- Compatibilizer 134, 135
- Composites
 acetylated wood 72–6, 81, 84
 epoxide modified wood 92
 formaldehyde modified wood 95
 maleated wood 81, 82
 oligoesterified wood 80
 surface modified wood 136–45
 thermally modified wood 122
- Compreg 150, 188
- Compressed wood 125
- Coniophora puteana* 61, 63, 64, 90, 95, 96,
 123, 124, 156, 159, 169
- Contact angle 122, 146
- Copper–chrome–arsenic (CCA) 12–15, 20,
 67, 124
- Coptotermes formosanus* 69, 125, 160
- Coriolus versicolor*, *see* *Trametes (Coriolus)*
versicolor
- Corona discharge 145
- Coupling agent 135, 136
- Creep deformation 38, 73, 158
- Cross-linking 21, 58, 79, 92, 94, 95, 109
- Crotonic anhydride/acid 78, 84, 139
- Crotonyl chloride 93
- Cryptotermes cynocephalus* 69
- Crystallinity, *see* Cellulose
- Cyanoethylation 96, 131, 136
- Cyclic anhydrides 79–83, 160
- Cyclohexane-1, 2-dicarboxylic anhydride
 79, 80
- Decay
 acetylated wood 60–9, 84
 anhydride modified wood 82, 83
 brown rot 40
 DMDHEU modified wood 158–9
 enzymes and 40, 60, 69
 epoxide modified wood 92, 93
 field trials 66, 96
 formaldehyde modified wood 95
 fungi 39
 furfurylated wood 160
 isocyanate modified wood 88–90

- low molecular weight degradative agents
and 68
mechanisms of 40, 67–9
protection threshold 67, 68
pure culture tests 41, 60–4, 83,
88–90, 92–6, 123–5, 156–61,
164, 165, 169
resin impregnated wood 151, 155–7
silicon compound modified wood 162, 164,
168, 169
soft rot 40, 64, 65, 123
thermally modified wood 123–5
unsterile soil tests 41, 65, 66, 84, 89
white rot 40
- Degree of polymerization (DP) 25, 104, 105
Depac Engineering Ltd. 185
Desorption 31, 121
Deuterium exchange 29
Dielectric barrier discharge 146
Dielectric properties 71, 94
Differential thermal analysis (DTA) 104
Diffusion
cell wall and 145, 150, 163
controlled reaction kinetics 50, 51, 54, 55
Dihydroxy benzophenone (DHBP) 132
1, 6-Diisocyanatohexane (HDI) 89
Diisopropyl carbodiimide (DIPCI) 139
Diketene 83
Dimensional stability 20, 34, 144, 158
acetylated wood 56–8, 72, 78, 79
alkyl halide modified wood 93
anhydride modified wood 57, 78, 80, 82
bulking of cell wall and 56, 78
determination of 33–7
epoxide modified wood 91
formaldehyde modified wood 93–5
isocyanate modified wood 86, 87
thermally modified wood 119
Dimethyl formamide (DMF) 77, 82, 85–7,
96, 135
Dimethylsulphoxide (DMSO) 87
Dimethyldichlorosilane 163
Dimethylol dihydroxy ethylene urea
(DMDHEU) 71, 157–9
Distribution of reactant
cell wall 53
macroscopic 46, 47, 56, 63
Dymonwood 188
Dynamic mechanical properties 24, 38, 39, 60,
92, 94, 116
- Eberstadt method 55
Ecotan 183
Ecotoxicity 162, 179
Electron diffuse X-ray analysis (EDXA), *see*
Scanning electron microscopy–electron
diffuse X-ray analysis (SEM–EDXA)
Electron energy loss spectroscopy (EELS), *see*
Transmission electron microscopy–
electron energy loss spectroscopy
(TEM–EELS)
Electron spin resonance (ESR) 105, 143–5
Embodied energy 16, 193
Envelope 47, 78, 90
Environmental impact 16, 20, 192
Enzymes
access to the cell wall interior 40, 144
modification of wood by 143–5
Epichlorohydrin 79, 91
 β -(3, 4, Epoxycyclohexyl) trimethoxysilane
(EETMS) 167, 168
Equilibrium moisture content (EMC) 30,
37, 42
acetylated wood 59, 68, 70–2
formaldehyde modified wood 95
reduced (EMC_R) 32
reduction in due to modification 32, 42
thermally treated wood 120, 121
Ethylene oxide 91, 92, 130
EX Wood 183
Externalities 199
Extractives 27
removal by solvent 46
and thermally treated wood 100, 101, 109,
110, 122
- Fenton's reagent 63, 140, 141
Fibre saturation point (FSP) 31, 37, 70–2,
121, 170
Field trials 67, 96
Finnish ThermoWood Association 176–8
Fire resistance 78
Food and Agriculture Organisation of the United
Nations (FAO) 7
Forest Products Laboratory 58, 99, 175, 186
Formaldehyde 152, 154
modification 93–5
Fourier transform infrared (FTIR) *see* Infra red
spectroscopy
Free-radicals 105, 109, 140–2, 144
Fungi 40–2
Furan 102, 107
Furfural 102, 142
Furfuryl alcohol (FA) 159
Furfurylation 189, 190
- Gloeophyllum trabeum* 60, 61, 63, 66, 89, 90,
92, 93, 95–7, 123, 124
Glucomanan 104
Glucopyranose 25

- Glutaraldehyde 95
 Glutaric anhydride 79, 80
 Glycerol 158, 161
 3-Glycidoxypropyltrimethoxysilane 167, 169
 Glycidyl methacrylate 92, 138
 Glyoxal 95
 Gross annual increment (GAI) 8
- Hailwood–Horrobin (H–H) 30, 70–2
 Heartwood 47, 48, 94
 Heat of wetting 71
 Helium pycnometry 24, 56
 Hemicelluloses 26, 27, 29
 thermal stability of 104–6, 119
 Hexamethyldisiloxane (HMDSO) 145
 Hexamethylene diamine (HMDA) 139
 Hexanoic anhydride 45, 57, 64, 77, 79
 High pressure liquid chromatography (HPLC) 55
 Holocellulose 53
 Hydrogen chloride 55, 85, 94, 162, 163
 Hydrogen peroxide 142, 143, 145
 Hydrolysis 72, 82
 Hydrothermal modification 101
 2-Hydroxyethyl methylmethacrylate (HEMA) 171, 172
 Hydroxyl group 21, 26–30, 55, 56, 60
 Hygroscopicity 88, 120
 Hygrothermal modification 101
Hylotrupes bajulus 70
 Hyphae 63
 Hysteresis 121
- Impreg 150
 Impregnation
 and cell wall accessibility 149
 modification 23
 Indurite® 188
 Industrial ecology 194
 Infra red spectroscopy 44, 53, 55, 88, 89, 92, 95, 103, 136, 137, 139, 140
 Intergovernmental Panel on Climate Change (IPCC) 8
 Internal bond strength (IBS) 73–5, 137, 143
Irpex lacteus 124
 Isobutyric anhydride 77, 78
 Isocyanate
 blocked 86
 and dimethyl formamide 86
 modification 85–90
 oligomeric 92
 resin 69, 75, 76
 3-Isocyanatopropyltriethoxysilane (IPTES) 167, 168
 Isotopic exchange 29–31
- Jablo 176
 Janka hardness 59
 Jicwood 176
 Juvenile wood 10, 47
- Kebony 189
 Ketene 83
 Kinetics
 acetylation 54
 formaldehyde modification 94
 isocyanate modification 88
 thermal modification 100, 103, 112
 Koppers' acetylated wood 183
- Laccase 144
 Le Bois Perdure 182
 Leaching 164
Lentinus lepideus 61
Lenzites trabea, see *Gloeophyllum trabeum*
 Levoglucosan 107
 Life cycle assessment (LCA) 16, 192–4
 Lignin 27, 28
 barrier 53, 54
 decay and 63
 radicals in 140, 143, 144
 reactivity 52, 53
 ultraviolet instability of 43, 129
 Lignofol 99, 188
 Lignostone 99, 175
 Limiting oxygen index (LOI) 78
 Low molecular weight diffusible agents 41
 Lumen 56
 filling 21
- Macrotermes gilvus* 70
 Maleic anhydride 80, 161
 Maleic anhydride polypropylene (MAPP) 135
 Marine borers 70
 Materials pool 8
 Mechanical properties
 acetylated wood 58, 59
 and moisture content 31, 38, 58
 problems of determining 58
 thermally modified wood 114–18
 Melamine formaldehyde (MF) 75, 150
Meruliporia (Poria) incrassata 61
 Methacrylic acid 137
 Methacrylic anhydride 131, 138
 γ -methacryloxypropyltrimethoxysilane (TMPS) 167–9
 Methyl iodide 93
 Methyl isocyanate 88
 Methyl methacrylate (MMA) 138
 Methylchlorohydrogensilane 163
N-Methylolacrylamide (NMA) 162

- Methylolated melamine formaldehyde (MMF) 152
- Methyltrichlorosilane 163
- Methyltrichlorosilane 163
- Methyltriethoxysilane (MTES) 165
- Methyltrimethoxysilane (MTMS) 164
- Microfibrils 23, 25, 26, 29
- Micropores
 access to the cell wall 25, 46, 52, 149
 dimensions 24, 27, 52, 118, 149
 enzymes and 40
- Microwave
 for acetylation 50, 52
 for butyrylation 77
 treatment for improved permeability 47
- Modulus of elasticity (MOE)/ modulus of rupture (MOR) 31, 38, 95, 135, 143, 144, 157
 acetylated wood 58, 59, 74–6
 epoxides wood 91
 thermally modified wood 115–17, 122, 126, 179
- Moisture content
 cell wall 30, 31
 and decay 63, 68
 effect upon rate of acetylation 47
- Moisture Exclusion Efficiency (MEE) 33
- Molecular weight and penetration of cell wall 151, 171
- Moulds 66
- Mu-tech Wood 183
- Net annual increment (NAI) 8
- Nitrogen atmosphere for thermal modification 181
- Nuclear magnetic resonance (NMR) 44, 52, 105, 109, 118, 139
- OH, *see* Hydroxyl group
- Oil heat treatments 126, 182, 183
 Ecotan 183
 Menzholz 182
 Royal/Royale 183
- Oligoesterification 80, 81
- Oligomeric isocyanate 92
- Oligomerization 91
- Oligoporus placenta* (*Poria monticola*) 61, 85, 96, 124
- Open system in thermal modification, *see* Thermal modification
- Organo-silane modified wood 166–70
- Oriented strand board (OSB) 47
- Oxygen in thermal modification, *see* Thermal modification
- Ozone treatment of acetylated wood 75
- PCI Industries Inc. 182
- Percolation theory 55
- Perdure® 182
- Peroxidase 143, 145
- Phanerochaete chrysosporium* 62, 169
- Phenol formaldehyde (PF)
 in composites 66, 69, 74–6, 81, 92, 122, 135
 impregnated wood 150–7
- Phenol oxidase 143
- Phenoxy radical 141, 143–5
- Phenyl isocyanate 86–8
- Phenylhydrazine 88
- Phthalic anhydride 70, 79, 80
- Pit aspiration 48
- Plantations 10
- Plasma 145, 146
- Plato® 99, 114, 123, 179–81
- Polydimethylsiloxane (PDMSO) 146
- Polyethyleneglycol (PEG) 158
- Polyglycerol 161
- Polyglycerolmethacrylate (PGMA) 172, 173
- Polymethylene polyphenylene isocyanate (PMPPIC) 135
- Polypropylene 135, 146
- Polyurethane 75
- Polyvinyl acetate 73, 122
- Polyvinyl chloride (PVC) 17
- Poria monticola*, *see* *Oligoporus placenta* (*Poria monticola*)
- Poria placenta* 61, 92, 95, 96, 156, 161
- Poria vaporaria* 96
- Preservation 11
- β -Propiolactone 96
- Propionic anhydride 45, 57, 64, 78, 79, 139
- Propylene oxide 91–3
- Propyltriethoxysilane (PTES) 165
- n*-Propyltrimethoxysilane (PTMS) 167, 168
- Pure culture tests for determining decay resistance, *see* Decay
- Pycnoporus sanguineus* 62, 63, 90
- Pyridine 48, 64, 85, 88, 89, 93, 119, 163
- Quinone methide 97
- Recycling 13–17
- Relative humidity (RH) 30, 31, 38, 56
- Resin impregnated wood 150–7
- Resol 74
- Resorcinol 69
- Reticulitermes flavipes* 69
- Reticulitermes speratus* 69, 125, 164
- Retification® 181, 182
- Retitech 182
- Royal/Royale 183

- Sapstain 42
- Scanning electron microscopy–electron diffuse X-ray analysis (SEM–EDXA) 53, 154, 163, 165, 170, 171
- Self-bonding 136, 142–5
- Serpula lacrymans* 61, 123
- Silicon tetrachloride 163
- Silicones 165, 166
- Sodium silicate 165
- Soft rot 64, 65, 67, 124
- Sol-gel 163
- Solute exclusion 25, 32
- Solvent
- exchange 52, 78
 - extraction 50
 - vapour drying 46, 59
 - vapour stripping 59
- Sorption isotherm 31, 70–2
- Staining fungi 42, 66
- Standards for modified wood 44, 199
- Staywood 99
- Staypak 99
- Steam
- blanket 101, 176
 - heat treatment 99, 109, 125, 176
 - pre-treatment 47, 94
 - removing by-products with 52
- Stellac Oy 179
- Stress relaxation 82
- Succinic anhydride 79–83, 139
- Surface energy 73, 135, 146
- Surface modification
- for bonding 133–45
 - definition 22
 - for UV stabilisation 130–3, 146
- Swelling
- cell wall 21, 33
 - coefficient (S) 33
 - of modified wood 56
 - solvent 24, 46, 48, 49
 - water and 56
- Syringyl 27, 108, 109
- Tekmaheat Oy 179
- Teredo navalis* 70
- Termites 67, 69, 92
- Tetraethoxysilane (TES) 163
- Tetramethoxysilane (TMS) 163
- Tetrapropoxysilane (TPS) 163
- Tetroxane 93
- Thermal modification 22, 99–127
- acetic acid 101
 - biological degradation 123–5, 178
 - catalysts 102
 - cellulose 102, 105–7, 113, 114
 - closed system 101
 - colour 110, 178, 179
 - degradation of wood 99
 - dimensional stability 102, 119, 120
 - extractives 109, 110
 - hemicelluloses 102–6
 - hygroscopicity 120–2
 - kinetics 103
 - lignin 102, 108, 109
 - mass loss 111–13
 - open system 101
 - oxygen 101, 106, 107, 118
 - species 101
 - steam 101, 110, 112, 125, 126
 - strength 115–17, 122, 126, 179
- Thermo-D, Thermo-S 178
- Thermogravimetric analysis (TGA) 104, 140
- Thermomechanical pulp (TMP) 53, 92, 138, 145
- Thermoplasticized wood 77, 84, 93, 96, 136
- ThermoWood® 99, 176–9
- Thioacetic acid 84, 85
- Threshold in decay test 64–7
- Titan Wood® 187
- Titanate 170
- Toluene-2, 4-diisocyanate (TDI) 87
- p*-Toluene sulphonyl chloride (PTSC) 89
- Toughness 59, 114, 115
- Trametes (Coriolus) versicolor* 62–4, 66, 90, 92, 97, 124, 156, 158, 160, 161, 164, 165, 169
- Transmission electron microscopy–electron energy loss spectroscopy (TEM–EELS) 154
- Triethylamine 88, 91, 92
- Trifluoroacetic acid 49, 84, 137
- Trifluoroacetic acid/anhydride 84
- Trimethylamine 91, 92
- Trimethylchlorosilane 163
- Trimethylol propane trimethacrylate 92
- Trimethylsilyl ethenone 167, 169
- N*-(Trimethylsilyl)acetamide 167, 169
- 1-(Trimethylsilyl)imidazole 167
- 2-Trimethylsilylmethylglutaric anhydride 167, 169
- 3-Trimethylsilylpropanoic anhydride 167, 169
- Trioxane 93
- Tritium exchange 29
- labelling 53, 171
- Tyromyces palustris* 61, 63, 66, 92, 95, 124, 156, 158, 160, 164
- Ultra violet (UV)
- instability of lignin 43, 130
 - stabilization of wood surface 130–3

- Unsterile soil test 64, 65, 84, 91, 125
- Urea formaldehyde (UF)
 - in composites 66, 73, 122, 143, 144
 - impregnation 150–7
- Vacuum
 - heat treatment 101
 - for removing residual chemicals 51, 52
- Valutec Oy 179
- Vapour
 - phase reactions 49, 72, 73, 86, 87, 91, 93, 94
 - stripping 52, 59
- Vermiculite overlay test 63, 64
- Vinyltrimethoxysilane (VTMS) 167–9
- VisorWood 189
- Void volume 57
- Volatile organic compound (VOC) 110, 161, 179
- Volatility of arsenic 14
- Water
 - and acetylation 47
 - cell wall 30
 - of constitution 103
 - swelling 33–7
- Weight percentage gain (WPG)
 - definition 44
 - dimensional stability and 56, 57, 78
 - time of reaction and 51
- Wet oxidation 103
- White rot 40, 63, 68
- WISTIwood 189
- α Wood 183
- Wood modification (definitions) 20–2
- Wood Polymer Composites Inc. 189
- Wood Polymer Technologies ASA 189
- Woodtech Inc. 189
- Xanthate method of grafting 140, 141
- X-ray diffraction (XRD) 25, 53
- X-ray photo electron spectroscopy (XPS) 131, 133
- Xylans, thermal stability of 104









