Index

a
- achiral molecules on achiral surfaces 113–114
- acid leaching 222
- adsorption Langmuir–Hinshelwood-type mechanism 87
- aerobic oxidation of benzyl alcohol
  - active sites determination in 385–392
  - in situ ATR-IR spectra 390, 391
  - in situ NMR 398–400
  - in situ X-ray absorption spectra 386, 387
- mechanism, elucidating 381–385
- alcohol oxidation, MOFs 310–311
- alcohol selective oxidation 11–33
- alcohol selective oxidation, see also metal-catalyzed alcohol selox
  - mechanistic studies of 11–33
  - oxidant considerations 12
  - oxide catalysis 22
  - selective oxidation 11–12
  - sulfide catalysis 22
- vanadate catalysis 22
- alkene epoxidation 262–263
- alternative energy reactors for green chemistry 7–9
  - microchannel reactors 7
  - microwave reactors 7–9
  - microwaves in electromagnetic spectrum 8
- alternative solvents 5–6
  - biphasic systems 6
  - fluorous solvents 5
  - ionic liquids 5
  - phase transfer catalysts (PTCs) 6
  - supercritical fluids 5
- amberlyst-15 132
- amberlyst-70 132
- ambient-pressure X-ray photoelectron spectroscopy (APXPS) 437–465
  - application to electrochemistry 460–464
  - applications of 445–464
  - basic concept 438–441
- carbon nanotube-based catalysts investigation 453–457
- chiral molecules chemistry on metal surfaces 450–452
  - electrons attenuation by gas phase 441–442
  - insulating samples measurement 444
  - photoelectron spectroscopy of the gas phase 443
  - sample contamination 443–444
  - selective CO oxidation in hydrogen on Pt/CeO$_2$ and Pd/CeO$_2$ 457–460
  - technical aspects 438–445
  - water vapor interaction with metal oxide surfaces 446–450
  - X-rays interaction with gas phase 443
- anion-exchange resins 157
- artificial neural network (ANN) 146
- asymmetric epoxidation 263
- asymmetric synthesis, MOFs in 316–320
  - asymmetric aldol reaction 316–318
  - asymmetric diethyl zinc addition to aldehydes 319
  - asymmetric olefin epoxidation 318–319
  - asymmetric transesterification 320
  - atline technique 414
  - atom efficiency/economy 4
  - attachment techniques, types 173
  - attenuated total reflection (ATR) 40–42
  - attenuated total reflection infrared spectroscopy (ATR-IR) 15
  - aza-Michael addition 315–316
Index

**B**  
_Bacillus subtilis_ 229

Baeyer–Villiger oxidation 125

band target entropy (BTE) methods, _see also_ solid acids and base-catalyzed clean technologies 125–163

1,4-benzenedicarboxylate (BDC) groups 296

bifunctional catalyst, double catalytic activation using 186–189

bimetallic selox catalysts 15–17

biodiesel production 155–159

– triglycerides transesterification

– with alcohol over Brønsted acid catalysts 156, 157

– with methanol 155

biomass conversions 144–163

– biodiesel production 155–159

– glycerol carbonate synthesis 159–163

– hydrolysis of cellulose 145–147

– lactic acid synthesis 153–155

– sugars to furfurals transformation 147–153, _see also_ individual entry

Biot number 336

4,4-biphenyldicarboxylates (bphdc) 318

1,1-bis-2,2-naphthol (BINOL) derivative 319

2,2′-bis(diphenylphosphino)-1,1-binaphthyl (BINAP) groups 111

Bodenstein number (Bo) 349

Brunauer–Emmett–Teller (BET) surface 127, 297

1-butyl-3-methylimidazolium chloride (BMIMCl) 146

**C**

carbenelike intermediates 133

carbenium cation 133

carbon nanotube (CNT)-based catalysts

– investigation 453–457

– growth on conductive supports 453–457

– carbon nanotubes (CNTs) 21

– carbon templating 224–227

– hard templating by polymers 227

– carbon-based materials 130–131

– new carbon–carbon bond formations 133–141

– carbon–carbon bond formation, MOFs in 303–310

– cyanosilylation reactions 306–308, _see also_ individual entry

– Heck coupling reactions 308–310

– Knoevenagel condensation 303–306, _see also_ individual entry

– MIL-101-supported palladium nanoparticles 309

– Sonogashira coupling reactions 308–310

– Suzuki–Miyaura coupling reactions 308–310

– Ullmann coupling reactions 308–310

– catalysis within pores of support 107–108

– catalyst life 380–381

– in situ analysis 367–369

– light scattering 372

– molecular methods 369–370

– NMR 370

– physicochemical methods 369

– secondary building unit (SBU) mechanism 371

– silicalite-1 molecular sieves synthesis 367

– small X-ray scattering 371–372

– synthesis 367

– vibrational spectroscopy 370

– XRD 371

– catalytic microstructured reactors 342–350

– catalytic wall microchannels 342–344

– cation-exchange resins 158

– cell assemblies 219

– cellulose hydrolysis 145–147

– mathematical modeling in, importance 146

– sulfonated silica/carbon nanocomposites 146

– chirality molecules chemistry on metal surfaces, APXPS for 450–452

– chiral solids uses 109–112

– chiral metal–organic catalysts 110–112

– chiral zeolites 110

– in enantioselective catalysis 111

– metal or metal oxide on a chiral support 109–110

– chiral zeolites 110

– chirally modified metal surfaces 112–120

– achiral molecules on achiral surfaces 113–114

– enantioselectivity 114–120

– clean technology and catalysis 1–9, _see also_ alternative solvents; green chemistry

– heterogeneous catalysis 6–7

– homogeneous catalysis 6–7
Index

colloidal crystals 219
colloidal crystal-templating method 217
continuous-wave cavity ring down spectroscopy (CW-CRDS) 96
coordination shift 417
copolymerization, covalent immobilization by 107
cosurfactants 219
coupled in situ spectroscopic techniques in organic synthesis 39–61
  – attenuated total reflection (ATR) 40–42
  – EPR 40
  – EXAFS 40, 41
  – FBRM 40
  – FTIR 39
  – HERFD XAS 41
  – heterogeneously catalyzed hydrogenation of imines 50–56
  – in situ techniques 42
  – method coupling 41–45, see also individual entry
  – NMR 40
  – online 44
  – PVM 40
  – Raman 39, 40
  – SAXS 40, 41
  – spectroscopic reactors and practical aspects 45–50
  – fiber-optic probes 46
  – polyetheretherketone (PEEK) 47
  – process analytical technology 46
  – ReactIR™ system 46
  – three-phase hydrogenation of nitrobenzene over nanosized Au on TiO2 56–58
  – UV–vis 39, 40
  – vibrational spectroscopies 39
  – WAXS 40, 41
  – XANES 40, 41
  – XAS 40, 41
covalent immobilization
  – by copolymerization 107
  – on inorganic supports 105–106
  – on polymeric resins 106–107
covalent tethering 105–107
cross-polarization magic-angle-spinning (CP-MAS) 182
crotyl alcohol selox 20
cubo-octohedron model 275–276
cyanoethoxycarbonylation, surface acid/base interaction for 187
cyanoisilylation reactions in MOFs 306–308
  – Cd-based MOF catalyzing 306–307
  – HKUST-1 307
  – MIL-101 307–308
cyclohexanedicarboxylate 219

cyclohexanediethyl (CHDM) 271
d
2D exchange spectroscopy (EXSY) 416
Damköhler number 335, 338, 340
dealumination 222–223
Debye–Scherrer formula 371
density functional theory (DFT) 51
desilication 223
deuterium-free samples 418
diagonally offset Raman spectroscopy (DORS) 374–376
diffuse reflectance fourier transform infrared spectroscopy (DRIFTS) 66, 377
diffuse reflectance spectroscopy (DRS) 55
4-dimethylaminopyridine (DMAP) 132
direct synthesis, mesoporous materials 212
Domino coupling 316
double catalytic activation using bifunctional catalyst with both acid and base on solid surfaces 186–189
drain-off effect 401
dynamic nuclear polarization (DNP) enhanced NMR 302
e
e factor 4
effective mass yield 4
electron paramagnetic resonance (EPR) 28, 79–90, 302
  – electron hole pairs, photoactivated formation of 85
  – reactive oxygen species 85–89
  – semiconductor charge separation and transfer 79–85
  – sulfur-doped TiO2 85
  – under visible light illumination 84–85
enantioselective heterogeneous catalysis 103–121
  – chirally modified metal surfaces 112–120
  – comparison of various approaches 120–121
  – creation strategies 105–120
  – – catalyst construction within pores of support 107–108
  – – chiral solids uses, see also individual entry 109–112
  – – copolymerization, covalent immobilization by 107
  – – covalent tethering 105–107
  – – electrostatic interactions, immobilization by 108
enantioselective heterogeneous catalysis
(continued)

- encapsulation, immobilization by 107–108
- immobilization of homogeneous or enzyme catalysts 105–109
- industrial application of immobilized catalysts 109
- inorganic supports, covalent immobilization on 105–106
- polymeric resins, covalent immobilization on 106–107
- support construction around the catalyst 108
- enhancing selectivity, challenge 104

encapsulation, immobilization by 107–108
energy-dispersive X-ray diffraction (ED-XRD) 371
epoxidations, MOFs 312–313
*Equisetum arvense* 230
ethylenediaminetetraacetic acid (EDTA) 97
extended X-ray absorption fine structure (EXAFS) 138, 302, 380

fiber catalysts 355–358
- sintered metal fibers (SMFs) 355
flow NMR 422–426
- flow scheme and hyphenation 423–425
- flowing samples 423
- residence times 425–426
fluorous biphasic solvent systems 5–6
fluorous solvents 5
focused beam reflectance measurement (FBRM) 45
functional MOFs, characterization 301–302
- DNP enhanced NMR 302
- EPR 302
- EXAFS 302
- HYSCORE-EPR 302
- NMR 301
- PXRD analysis 301
2,5-furandicarboxylic acid (FDCA) 12
furoic acid (FuA, 2-furancarboxylic acid) 132

glycerol carbonate synthesis 159–163
- glycerol transesterification 160
green chemistry 1–3, see also alternative solvents
- alternative energy reactors for, see also individual entry 7–9
- ideals of 2–3
- metrics 3–4
- atom efficiency/economy 4
- conventional methods 4
- E factor 4
- effective mass yield 4
- external communication 4
- in-house communication 4
- reaction mass efficiency 4
- traditional chemical manufacturing, resource demands of 2
Guinier region 371

5-hydroxymethylfurfural synthesis from fructose and glucose 148–149
H-SAPO-34 molecular sieves 398–400
H-ZSM-5 molecular sieves 394–397
- confocal fluorescence microscopy 395
- scanning transmission X-ray microscopy (STXM) 396
- *in situ* NMR of 398–400
Hagen–Poiseuille equation 344, 346
hard templating by polymers 227
Heck coupling reactions 308–310
heterogeneous catalysis
- advantages of 6–7
- disadvantages 7
heterogeneously catalyzed hydrogenation of imines 50–56
hexoses 147
hierarchical porous materials 227–233
- cell assemblies 219
- colloidal crystals 219
- cosurfactants 219
- microemulsions 219
- ordered macroporous-mesoporous materials 218–219
- properties of 220–222
- active phases dispersion improvement 201–222
- deactivation by pore blockage, robustness against 221
- mass transfer enhancement 221
- total available surface area, increase in 220
- polymer spheres 219
- zeolites with, combining microporous with meso-/macroporous 219
hierarchical zeolites 201–202
- for cleaner technologies 230–233
- synthesis of 222
- *Bacillus subtilis* in 229
- carbon templating 224–227
- dealumination 222–223
– desilication 223–224
– Equisetum arvense 230
– hard templating by polymers 227
– hierarchically macro-/meso-/microporous structured catalyst, Hp-ZSM 230
– improved polymerization-induced colloid aggregation (im-PICA) method 230
– nanocasting 226
hierarchically macro-/meso-/microporous structured catalyst, Hp-ZSM 230
high-angle annular dark field-scanning transmission electron microscopy (HAADF-STEM) 13
high-energy resolution fluorescence detection (HERFD) mode 44, 401
high-pressure liquid chromatography (HPLC) 422
high-pressure NMR 426
high-resolution transmission electron microscopy (HR-TEM) 83
homogeneous Brønsted acid (HCl) catalysts 149
hydrocarbon oxidation 69–74
hydroxyapatite 21
hydroxymethyl furfural (HMF) 12

i
immobilized catalysts, industrial application of 109
impregnation 374–376
improved polymerization-induced colloid aggregation (im-PICA) method 230
in situ characterization 365–407
in situ flow MAS NMR spectroscopy 431–433
in situ investigations 66–98
– in situ XANES 92–94
– EPR techniques 97
– ethylenediaminetetraacetic acid (EDTA) 97
– FTIR 66–79
– gas-phase analysis 74
– hydrocarbon oxidation 69–74
– XAFS 92–94
– local structure of active sites 89–90
– UV–Vis 92–94
– XPS 90–92
– NMR spectroscopy 94–96
– NOx depollution 66–69
– oxygen-containing compounds oxidation 75–79
– photocatalytic decomposition of formic acid over Pt/TiO2 76
– photocatalytic mineralization
– of dicarboxylic acids 77
– of malonic acid over TiO2 78
– photocatalytic oxidation 75, 76
– quantum-dot-(QDs)-assisted photocatalysis 98
– real-time gas-phase in situ FTIR studies of 67
– sunlight-driven Ag/Ag3PO4 plasmonic nanocatalysts 97
– surface acidity role in photocatalysts deactivation 73
in situ method 413
– of selox catalysts 24–32
incipient wetness impregnation (IWI) 374
indirect hard modeling (IHM) 421–422
infrared spectroscopy 379–380
inline technique 414
inorganic supports, covalent immobilization on 105–106
insulating samples measurement 444
ion-exchanged resins 131–132
ionic liquids 23–24
isoreticular metal–organic framework (IRMOF) series 296

k
Knoevenagel condensation 139, 140, 303–306
– in MOFs 303–306
– Am-functionalized MIL-53 304
– ED-MIL-101 catalyst generated by postsynthetic modification 304
– IRMOF-3 304
– malononitrile as substrate 303
– SIM-1 (substituted imidazolate material-1) 305–306

l
lactic acid synthesis 153–155
left-handed enantiomers 103
levulinic acid (LA) 132
life cycle assessment 4
lignocellulose 144
Lobry de Bruyn–van Ekenstein transformation 148
local structure of active sites 89–90
– XPS 90–92
Lorentz–Gauss functions 421

m
magic angle spinning (MAS) 430–431
magnetic resonance imaging (MRI) 374–375
manganese 1,4,7-trimethyl-1,4,7-triazacyclononane (tmtacn) complexes 181–184
mass transfer coefficient 345
matrix-assisted laser desorption/ionization-time-of-flight mass spectrometry (MALDI-TOF MS) 270
Meerwein–Ponndorf–Verley (MPV) reaction 125
memory effect 140
mesoporous materials with zeolitic crystal within walls 215–216
mesoporous materials, 203–216, see also ordered mesoporous materials
mesoporous metal oxide solid acids 129
– Nb–W and Ta–W mixed oxides 129
mesoporous nonsiliceous metallic oxide materials 214–215
mesoporous oxide architectures 21
mesoporous silica nanoparticles (MSNs) 216
metal or metal oxide on a chiral support 109–110
metal organic frameworks (MOFs) 104, 111
metal oxide nanosheets solid acids 127, 128
metal oxides 126–130
metal phthalocyanine (MPc) 314
metal-catalyzed alcohol selox 13–22
– Au–Pd catalysts 15–17
– bimetallic selox catalysts 15–17
– crotyl alcohol selox 20
– mesoporous aluminas 19
– monometallic catalysts 13–15
– support effects 17–22
metal-containing silica mesostructured materials 209–211
metal-organic frameworks (MOFs) 293–326, see also functional MOFs
– as heterogeneous catalysts 293–302
– catalytic features of 298–299
– diversity of 293–298
– Domino coupling 316
– enzymes as source of inspiration 322–325
– in asymmetric synthesis 316–320
– in carbon–carbon bond formation 303–310
– in fine chemical synthesis 293–326
– isoreticular metal-organic framework (IRMOF) series 296
– laboratory-scale synthesis 294
– mechanochemical synthesis 295
– oxidation reactions 310–315
– – α-oxidation of alkenes to give corresponding enol or enone 313–314
– – alcohol oxidation 310–311
– – aza-Michael addition 315–316
– – epoxidations 312–313
– – of alkanes to give alcohols or ketones 314–315
– – sulfoxidation 311–312
– – polymetallic nodes and organic linker self-assembly giving access to 294
– – postsynthetic modification, engineering MOFs by 299–301
– – self-assembly versus 300
– – representatives 296–297
– – HKUST-1 296–297
– – MIL-101 297
– – MIL-53 297
– – MOF-5 296
– – ZIF-8 297–298
– – salt-free electrochemical procedure 294–295
– – solvothermal synthesis strategy 294
– – strengths of 321–322
– – weaknesses of 321–322
metathesis 184–186
methanol-to-hydrocarbon (MTH) reaction 392–400
– coke-forming process 393
method coupling 41–45
methylcyclohexane 73, 74
methylthio-ethyl methacrylate (MTEMA)-based microgel 22
microwaves in electromagnetic spectrum 8–9
modified Ergun equation 354
moderator 112–120
modulation-enhanced spectroscopy (MES) 406
molecular sieves 195
monolithic honeycombs 350–353
– fast deactivating catalysts 352
– sphere-packed monolith reactors 352
monometallic catalysts 13–15
morphology effects on catalytic performance 272–282
– cubic-octahedron model 275–276
– in Pt group metals 279, 281
– in ring enlargement reactions 278
– metal oxide nanoparticles 280–281
– – Au nanoparticle during CO oxidation 281
Index

- - direct effect 280
- - indirect effect 280–281
- in selective hydrogenation 277
- tetradecyltrimethylammonium bromide (TTAB) 276
- multifunctional zeolites 202
- multimetallic heterogeneous catalysts 210
- multiwalled carbon nanotubes (MWCNTs) 21

n
Nafion NR50 132
Nafion SAC13 132
nanocrystalline zeolites 200–201
nano-size effects 262–272, see also tailored nanoparticles for clean technology
- 3d transition metals 271–272
- alkene epoxidation 262–263
- Au-catalyzed aerobic epoxidation of alkenes 265–266
- catalyst activation treatment 263–265
- gas-phase epoxidation 266
- reference catalyst system 265
- reproducible fabrication of catalysts 267
- selective oxidation of hydrocarbons 262
- water–gas shift (WGS) reaction 267–268
- nanostructured metal oxide solid acids 127–130
- mesoporous 129
- metal oxide nanosheets solid acids 127
- metal oxide nanotube solid acid 128
- near-edge X-ray absorption fine structure (NEXAFS) 28
- noninvasive technique 414
- ‘novel process windows’ 333
- novel solid acids 130
- nuclear magnetic resonance (NMR) spectroscopy 94–96
- Nusselt number 345

o
- offline analytics 414
- one-pot sequential reactions 141–144
  - furfurals synthesis from monosaccharides and disaccharides 149–153
  - mesoporous materials 212
  - using acid and base sites on same solid 142–143
  - using different particles of solid acid and base catalysts 143–144
- online monitoring with NMR 413–434
  - advanced experiments 417
  - benefits of 414–415
  - catalysts in heterogeneous reactions, direct monitoring 430–433
  - flow NMR 422–426
  - fundamentals 415–417
  - heterogeneous liquid reactions 426–430
  - high-pressure NMR 422–426
  - homogeneous liquid reactions 426–430
  - in situ methods 413
  - operando method 413
  - quantitative NMR in technical samples 417–422
- reaction monitoring and process analytical technology 414
- operando characterization 365–407, 413
- of selox catalysts 24–32
- ordered macroporous materials 216–218
- direct synthesis 212
- metal-containing silica mesostructured materials 209–211
- modification of 207–214
- morphology control in 216
- multimetallic heterogeneous catalysts 210
- one-pot synthesis 212
- organic functionalization of 211–213
- periodic mesoporous organosilicas (PMOs) 213–214
- synthesis of, mechanism 207
- - conventional 207
- - mesoporous materials with zeolitic crystal within the walls 215–216
- - mesoporous nonsiliceous metallic oxide materials 214–215
- - new trends in 214–216
- ordered porous materials preparation 194–218
- templated methods for 194–218
- zeolites and zeotypes, see also zeolites 195–203
- organic functionalization of mesoporous silica materials 211–213
- organic–inorganic hybrid zeolites 202
- organosilane-based methods 227–229
- oxidant considerations 12
- catalyst development 12
- explosion hazards 12
- platinum group metal (PGM) alcohol selox catalysts 12
- oxidation reactions 310–315, see also metal–organic frameworks (MOFs)
- oxygen-containing compounds oxidation 75–79
\[ P \]

\( p \)-toluenesulfonic acid (\( p \)-TsOH) 132

packed bed reactors 340–342

particle vision measurement (PVM) 45

particle X-ray diffraction (PXRD) analysis 301

perfluorinated carboxylic acids (PFCAs) 86

perfluorooctanoic acid (PFOA) 85

periodic mesoporous organosilicas (PMOs) 213–214

phase transfer catalysts (PTCs) 6

phenylaminopropyltrimethoxysilane (PHAPTMS) 228

photo-Kolbe reaction 77

photocatalytic materials, \textit{in situ} studies 65–99

polarization-modulation infrared reflection absorption spectroscopy (PM-IRAS) 30

poly(methyl methacrylate) (PMMA) 227

poly(vinyl alcohol) (PVA) 14

polyaniline (PANI) 16

polyetheretherketone (PEEK) 47, 424

polyhydroxy fullerenes (PHFs) 86

polymer spheres 219

polymeric resins, covalent immobilization on 106–107

polyvinylpyrrolidone (PVP) 14

porous coordination polymers (PCPs) 322

– homochiral PCP 322

porous inorganic architectures, designing 193–234, see also hierarchical porous materials; ordered macroporous materials; ordered mesoporous materials; ordered porous materials preparation

– aqueous and gaseous streams, pollutants removal from 194

– chemical processes enhancement 193

– waste compounds valorization into high-value products 194

porphyrinic Illinois zeolite analog (PIZA) 313

pressure gap 390

process intensification (PI) for clean catalytic technology 333–362

– transport phenomena effect on, see also \textit{individual entry} 334–340

prochiral carboxylic acid

4-(\textit{trans}-2-(pyrid-4-yl-vinyl)]benzoic acid (PVBA) 119

propane dehydrogenation 400–405

– \textit{in situ} HERFD XANES 403, 404

– HERFD 401

– supported metal catalyst materials 400–404

– supported metal oxide catalysts 404–405

\[ q \]

quadrupole mass spectrometry (QMS) 72

quantitative NMR spectroscopy

– in technical samples 417–422

quantum-dot-(QDs)-assisted photocatalysis 98

\[ r \]

racemic reaction 113–114

reaction mass efficiency 4

reaction mechanisms, \textit{in situ} studies on 65–99, see also \textit{in situ} investigations

reaction monitoring in multiphase systems 39–61, see also coupled \textit{in situ} spectroscopic techniques in organic synthesis

reactive oxygen species 85–89

residence time distribution (RTD) function 338, 425

residence time distribution in MSR 348–350

resonance Raman effect 370

response surface methodology (RSM) 146

Reynolds number 344, 354

right-handed enantiomers 103

\[ s \]

‘scaling up’ approach 7

scanning transmission X-ray microscopy (STXM) 396

secondary building unit (SBU) mechanism 371

selective CO oxidation in hydrogen on Pt/CeO2 and Pd/CeO2 457–460

selective oxidation (selox) 11, see also alcohol selective oxidation

– applications of 11–12

– oxidant considerations 12

selox catalysts

– \textit{in situ} studies of 24–32

– \textit{operando} X-ray studies of 24–32

– X-ray photoelectron spectroscopy 28–32

Sherwood numbers 345, 353

silicalite-1 molecular sieves spectroscopy 28–32

silicon-constrained monodentate alkylphosphane (SMAP) 174

– Au-supported SMAP–Rh complex 174–176

single-crystal surfaces, metal complexes on 174–177
single-walled carbon nanotubes (SWCNTs) 21
sintered metal fibers (SMFs) 355
site-isolated heterogeneous catalysts/'site isolation' concept 173–189
  – assembled monolayers of metal complexes on single-crystal surfaces 174–177
  – cyano-ethoxycarbonylation using 188
  – double catalytic activation using bifunctional catalyst 186–189
  – Michael reaction using 188
  – tmtacn complexes 181–184
  – well-defined silica-supported Mo–imido alkylidene complexes for metathesis 184–186
small X-ray scattering 371–372
small-angle X-ray scattering (SAXS) 371
soft landing 254
solid acids and base-catalyzed clean technologies 125–163, see also biomass conversions
  – carbon-based materials 130–131
  – ion-exchanged resins 131–132
  – mechanistic studies of 125–163
  – new carbon–carbon bond formations 133–141
  – new catalytic systems 126–144
  – solid acid–base bifunctional catalysts 140–141
solid base catalysts 139–140
solid foams 353–358
solvent selection 22–24
  – ionic liquids and water 23–24
  – supercritical fluids 22–23
  – solvent suppression techniques 418–419
solvents for cleaning 5–6, see also alternative solvents
Sonogashira coupling reactions 308–310
spatially offset Raman spectroscopy (SORS) 375
specific outer surface area 335
sphere-packed monolith reactors 352
structured catalyst 350–358
  – fiber catalysts 355–358
  – monolithic honeycombs 350–353
  – solid foams 353–358
sugars to furfurals transformation 147–153
  – 5-hydroxymethylfurfural synthesis 148–149
  – furfural from xylose 149
  – furfurals from monosaccharides and disaccharides 149–153
  – Lobry de Bruyn–van Ekenstein transformation 148
sulfonated activated carbon (AC-SO3H) 145
sulfoxidation, MOFs 311–312
sunlight-driven Ag/Ag3PO4 plasmonic nanocatalysts 97
supercritical fluid chromatography (SFC) 422
supercritical fluids 5, 22–23
support construction around the catalyst 108
  – supported ionic liquids on microstructured supports 358–360
  – supported metal (oxide) catalysts preparation 373–380, 400–405
    – activation 376–380
    – calcination 376–380
    – diagonally offset Raman spectroscopy (DORS) 374–376
    – impregnation 374–376
    – incipient wetness impregnation (IWI) 374
    – infrared spectroscopy 379–380
    – magnetic resonance imaging (MRI) 374–375
    – X-ray diffraction imaging 377–379
supramolecular assemblies formation 116–118
surface intermediates, in situ studies on 65–99, see also in situ investigations on surfaces 185–189
Suzuki–Miyaura coupling reactions 308–312
tailored nanoparticles for clean technology 241–282
  – catalytic activity importance on side effects 254–262
    – dendrimer-templation approach 258
    – electrocatalytic oxidation of CO 260
    – factors affecting 256
    – Michaelis–Menten approach 258
    – modeling of catalytic activity 256–257
    – morphology effects on catalytic performance 272–282, see also individual entry
    – nano-size effects 262–272, see also individual entry
    – particle size effects on side effects 246–254
    – size effects 242–262
tandem deprotection–aldol reaction with acids and bases 144
temperature-programmed desorption (TPD) 118, 134
tert-butyl hydroperoxide (TBHP) 312

tetradecyltrimethylammonium bromide (TTAB) 276
tetraethyl orthosilicate (TEOS) 126, 219
tetrakis(hydroxypropyl)phosphonium chloride (THPC) 14
tetramethyl silane (TMS) 416
tetrapropylammonium hydroxide (TPAOH) 198

Thiele modulus 335–338

three-phase hydrodenation of nitrobenzene over nanosized Au on TiO2 56–58

three-point contact model 51
time-resolved microwave conductivity (TRMC) experiments 73
tomographic energy-dispersive diffraction imaging (TEDDI) 377

trade-off index 348

transport phenomena effect on heterogeneous catalysis 334–340
– intensification of transport phenomena 340–360
triglycerides transesterification
– with alcohol over Brønsted acid catalysts 156, 157
– with methanol 155
trimethylphosphine oxide (TMPO) 128
trimethylsilyltrifluoromethanesulfonate (TMSOTf) 43
two-dimensional (2D) zeolites 201

Ullmann coupling reactions 308–312
ultrahigh-vacuum (UHV) techniques 245
ultralarge pore zeolites 199–200
unsaturated Ru complexes supported on SiO2 surfaces
– epoxidation performance of Ru catalysts 180
– reaction-induced and photoinduced formation of 177–181
Vienna ab initio simulation package (VASP) 281

water–gas shift (WGS) reaction 267–268
water-suppression-enhanced through T1 effects (WET) 419

water-tetrahydrofuran (THF) system 149
wide-angle X-ray scattering (WAXS) 371

X-ray absorption fine structure (XAFS) 45
X-ray absorption near-edge spectroscopy (XANES) 28, 380
X-ray absorption spectroscopy (XAS) 15
X-ray diffraction (XRD) 371, 377–379
– X-ray diffraction–computed tomography (XRD-CT) 377
X-ray photoelectron spectroscopy 28–32
– anaerobic conditions and 30
– electron transfer mechanism 28
– temperature-programmed 29, 31
X-ray studies of selox catalysts 24–28
– Pd during benzyl alholo oxidation 24–26
– untreated and Bi-promoted Pd/Al2O3 for phenyl ethanol selox 26

Yttria-stabilized zirconia (YSZ) 462

zeolite metal–organic framework (ZMOF) 295
zeolites 195–203, see also hierarchical zeolites
– conventional hydrothermal synthesis of 197–198
– crystallization mechanism 196–199, 368
– for cleaner technologies 202–203
– conventional hydrothermal synthesis of 197, 198
– crystallization mechanism 196–198, 368
– hierarchical zeolites 201–202
– large pore size (12 tetrahedra) 195
– medium pore size (10 tetrahedra) 195
– molecular sieves 195
– multifunctional zeolites 202
– nanocrystalline zeolites 200–201
– organic-inorganic hybrid zeolites 202
– preparation 195–203
– small pore size (6–8 tetrahedra) 195
– structure and topology of 196
– two-dimensional (2D) zeolites 201
zeolitic imidazole frameworks (ZIFs) 295