Index

a
micephel-like microcrawler 191
acetic acid (HAc) 125, 127, 131, 236
acid-induced swelling 151
acid-triggered burst release 176, 177, 178, 179, 181, 182
acorn-shaped configuration 203
acrylamide (AAm) 56, 68, 138, 149, 163, 174–177, 190, 195, 270
3-acrylamidophenylboronic acid (AAPBA) 136, 138, 140, 141, 158
acrylic acid (AAc) 137, 138, 141, 142, 143, 144, 158
acrylonitrile butadiene styrene (ABS) 231, 233
actuators 55, 68, 79, 85, 103, 136, 137, 174, 207, 216, 270
adhesion energy 203, 204
adjustable controlled-release rate 145
adsonption capacity 73, 74, 75, 117
air-cooling 277, 279, 280, 281
alcohol-responsive burst release 171–174
algae cells 205
alginates 6, 123, 131–136, 158, 211, 241, 242, 243, 244–248, 253
alginate hydrogel materials 135
alginate microcapsules 132
alginate microparticles 211
amide groups 55, 60, 61, 65, 171
ammonium persulfate (APS) 56, 57, 62, 86, 163, 190, 213, 217, 218
artificial spider web 248
asymmetry swelling/shrinking volume changes 189
2,2’-azobis(2-amid-nopropane dihydrochloride) 168, 195
2,2’-azobis(2-amid-nopropanedi-hydrochloride) 168
2,2’-azobis(2-methylpropionamide)
dihydrochloride (V-50) 91

b
B/A1/C double emulsions 39
B15C5Am. See benzo-15-crown-5-acrylamide (B15C5Am)
B18C6Am 68, 71, 73, 75, 195–200, 270, 281, 282, 283, 284, 286, 289
B18C6Am/Pb2+ complexes 68, 73, 75, 286
B18C6Am/Pb2+ host-guest complexes 68, 281
benzo-18-crown-6 73
benzo-15-crown-5-acrylamide
(B15C5Am) 174, 175, 176, 177
benzophenone 270
benzyl benzoate (BB) 48, 91, 132, 147, 178, 179, 204, 236, 256
biomimetic soft microrobots 194
Bold’s Basal medium 279
bovine serum albumin (BSA) 117, 118, 135, 136, 195, 196, 197, 200, 201
bowl shape 188, 203, 204, 206
bromoeosin 236, 240, 241
BSA adsorption 117, 118
Index

BSA-FITC 135, 136
soaked microcapsules 135
burst release 162–182
butyl acetate 168, 169, 179

Ca-alginate 134, 135, 136, 241, 242, 243, 244–248
microcapsules 134, 135
microfibers 244
CaCO₃ nanoparticles 48, 132, 138
capillary microfluidic device 93
capillary number 15
carboxymethylcellulose sodium (CMC) 225
cationic pH-responsive microcapsules 151
cell capture 205
cell culture 253, 267, 268, 272–281, 289
cell growth 223, 267, 279
chemical co-precipitation 145
chitosan microcapsules (CS) 147
Chlorella pyrenoidosa cells 279, 280
chlorotrimethylsilane 47
coaXial three-phase jets 224
co-delivery 217–218, 240
coefficient of variation (CV) 15, 40, 57, 82, 125, 163
co-encapsulation 11, 12, 24, 211, 212–217, 219
colloidAl-scale hole-shell microparticles 187
core-sheath configuration 203
core-sheath composite microfibers 5
core-sheath microcapsules 4, 62, 64, 66, 75, 136, 161–183
core-sheath microspheres 55, 68, 69, 70, 71, 72, 73, 74, 75
core-shell PNIPAM microcapsules 55, 63, 64, 65, 67, 75, 95, 169
coverslips 13, 14, 47, 255, 268, 269, 270, 273, 279
colloidal-scale hole-shell microparticles 187
complete engulfing configuration 36, 37
complexes’ stability constant (logK) 73
confined microreaction 161, 187, 201–207, 211
constant-flow pumps 14
constant-pressure pumps 14, 287
contact angle 203, 204
continuous fluid 13, 14, 15, 25, 37
controllable double emulsions 16
controllable emulsion droplets 12
controllable monodisperse single emulsions 14
controllably deformed emulsions 110
controllably deformed W/O/W emulsions 108, 118
controlled capture 187, 201–207
copper 47, 48, 49
core compartment 161, 162
core flow 223, 224, 236
core-sheath flow jet 224, 225, 226
templates 226
core-sheath microfibers 224–235
fabrication 224
morphological characterization 227
temperature regulation 230
thermal property 227
core-sheath poly(vinyl butyral) microfibers 224, 226
core-shell composite microfibers 5
core-shell configuration 203
core-shell microcapsules 4, 62, 64, 66, 75, 136, 161–183
core-shell microspheres 55, 68, 69, 70, 71, 72, 73, 74, 75
core-shell PNIPAM microcapsules 55, 63, 64, 65, 67, 75, 95, 169
coverslips 13, 14, 47, 255, 268, 269, 270, 273, 279
critical ethanol concentration value (CC) 255

cross linked polymer network 85
cross-linker 270
gluteraldehyde (GA) 146
cross linking degree 92, 96, 99, 101, 132, 259
18-crown-6 68
crown ether 73, 198
crystallization enthalpy 229
CS-M-T microcapsules 152
cyclohexane 168, 169
cylinder glass capillaries 12
dimethyl sulfoxide (DMSO) 225, 226
diphenyliodonium nitrate (PAG) 132
direction-specific burst release 170, 171
dispersd fluid 14, 15
Disperse Red 242
Donnan potential 137, 281
double emulsion droplets 125
double emulsions, 3, 12, 35, 62, 123, 161, 188, 212
Dow Corning 749 (DC749) 38, 41, 44, 45, 47, 48, 50, 217
dripping 15, 18, 24
droplet coalescence 37, 47, 48, 50
droplet maker 22, 24, 25, 27
droplet-making units 12, 13, 14, 21
droplet-pairing 44, 45–47
droplet-triggered droplet formation 44
pairing 44
drug delivery 3, 11, 55, 79, 80, 85, 103, 105, 123, 136, 142, 144, 145, 156, 158, 163, 166, 219, 224
drug delivery systems 79
drug loading levels 145
drug release kinetics 79, 105, 123
dry film photoresist (DFR) 13
dynamic swelling rate 284
dynamic thermo-responsive swelling ratio 101
eccentric core-shell structures 188
eccentric oil core 168
EC microcapsule preparation 125
EGDMA dyed with LR300 116
emulsification 4, 11, 16, 17, 18, 19, 20, 21, 35, 91, 92, 93, 123, 124, 127, 132, 133, 158, 214
emulsion droplet 1, 2, 3, 4, 12–16, 19, 22, 36, 37, 38, 39, 41, 42, 43, 44, 46, 47, 48, 49, 50, 51, 57, 58, 62, 63, 64, 81, 93, 94, 125, 127, 136, 140, 187
emulsion droplet system 1
emulsion templates 57, 63, 69, 70, 71, 91, 92, 93, 94, 95, 96, 109, 110,
113, 114, 116, 133, 135, 136, 139,
140, 149, 150, 166, 169, 181, 187,
188, 195, 196, 197, 203, 213, 217, 218
encapsulation ratio 230, 231
energy storage 123, 223
systems 223
enhanced mass transfer 106, 118
epoxy resin 14, 80, 270, 272
equilibrium deswelling ratio 149
equilibrium state 58, 59, 99, 102, 274
ethanol-responsive permeability control
260, 263
ethanol-responsive volume change 255
ethoxylated trimethylolpropane
triacrylate (ETPTA) 201, 202,
203, 204, 207
ethyl cellulose (EC) 123, 124–131
ethylene glycol dimethacrylate
(EGDMA) 81, 108, 111, 112,
113, 114, 115, 116, 117, 118
ethyl gallate (EG) 55, 62–67
expanded double emulsions 188, 207
expanded microchamber 38, 41, 45, 46

f
fast-responsive PNIPAM microgels 206, 207
Fe$_3$O$_4$ magnetic nanoparticles (MNPs) 68, 195
Fe$_3$O$_4$ nanoparticles 163, 164
ferrofluid 163, 168, 195, 241
fishbowl-shaped hole-shell
microparticles 201, 204
FITC-dextran 156, 157
FITC-insulin 142, 143, 144
FITC-labeled BSA (BSA-FITC) 135,
136
FITC labeled insulin (FITC-insulin) 142, 143, 144
FITC-PNIPAM nanogels 201, 203, 205
flow circulation loop 268, 273
flow-focusing 4, 12, 13, 14, 21, 38, 41,
44, 46, 47, 50, 80
cross-junction geometry 14
g
glass-capillary microfluidic device 12,
14, 15, 16, 17, 18, 20, 22, 108, 201,
224
glass plates 12, 21, 44, 46
glass slide 13, 14, 47, 80, 124, 132, 167,
255, 268, 270, 272, 273, 279
glucose-induced shrinking 138
Index

glucose-induced swelling 137, 140, 141, 142, 143
glucose regulation 136
glucose-responsive microcapsules 123, 137, 138, 139, 140, 158
glucose-responsive release 142, 143, 144
glutaraldehyde (GA) 146, 147, 181, 236
glycerin 108, 138, 195
glycerol 62, 81, 91, 201, 212, 217, 218
glycidyl methacrylate (GMA) 114–116, 117, 118
gold nanoparticles 205

h
Hagen-Poiseuille’s law 281
heavy metal 67, 71, 72
ions 71, 72
hierarchically engineered poly(methyl methacrylate-co-ethylene glycol dimethacrylate)
(poly(MMA-co-EGDMA)) microcapsules 108
hierarchical porous microcapsules 105–118
hierarchical porous poly(MMA-co-EGDMA-co-GMA) microcapsules 108, 113, 114, 115, 116, 117, 118
hierarchical porous structures 105, 106, 107, 108, 116, 118
higher order multiple emulsions 11, 12, 19, 41–44, 46, 212, 219
high interconnectivity 105
highly-interconnected hierarchical porous structures 105, 106–108, 118
highly monodisperse size 15, 18
hole-shell microparticles 187–207
hole-shell structures 188, 203, 205
hollow calcium alginate microcapsules 123, 134, 158
hollow fiber membranes 5
hollow microcapsules 123–158, 162
hollow tubular microfibers 5
homogenizer-produced W/O emulsions 166
hydrated Ca-alginate microfibers 243
hydrogel micro particles 55–75
hydrogel microvalve 267, 268, 269, 270, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 289
hydrogel-microvalve-integrated micro-heat-exchanging system 273, 277
hydrogen-bonding interaction 55
hydrophilic microlancets 48
hydrophilic spider-silk-like Ca-alginate microfiber 247
hydrophilic-swelling/hydrophobic-shrinking phase changes 162
hydrophobic interaction 60, 62, 65
1-hydroxy-cyclohexyl-phenylketone 270
hydroxyethyl cellulose (HEC) 47, 147, 151, 152, 178, 241
2-hydroxyethyl methacrylate (HEMA) 79–84, 103
2-hydroxy-2-methyl-1-phenyl-1-propanone (HMPP) 108, 201, 204

i
imitated solar irradiation 234, 235
in-chip membranes 253, 254, 264
inclusion constant 68, 286
independent single emulsion droplets 39
initiator 56, 57, 62, 81, 86, 87, 91, 138, 163, 213, 218
injection tube 14, 16, 57, 91, 108, 226, 236, 241
inner fluid 14, 22, 93, 94, 109, 125, 127, 138, 140, 146, 147, 178, 179, 201, 212, 214, 218, 226, 227
in situ polymerization 202, 268
insulin 136, 142, 143, 144, 253
interfaces 1, 2, 3–6, 37, 59, 93, 95, 105, 106, 117, 125, 163, 178, 191, 202, 204, 237, 253, 254, 255, 257, 258, 264, 295, 296
interfacial energy 36, 188
interfacial reactions 253, 254
interfacial tension 15, 16, 36, 37, 38, 39, 45, 83, 204
internal gelation 123, 132, 134, 158
ionic crosslinking 132
isolated co-encapsulation 211, 212, 213, 215, 217, 219
isopentyl acetate 195
isopropanol 86, 87, 91, 92, 93, 94, 95, 133, 139, 140, 148, 178, 257
isothermal volume phase transition 58, 59, 60

j
Janus microspheres 4
jetting 15

k
K⁺-recognition 174, 175
K⁺-responsive
burst release 174–176
core-shell microcapsules 174, 175
K⁺-triggered volume shrinking 175

l
lab-on-a-chip 1, 2
laminar flow 1, 2, 4, 5, 6, 253, 254, 257, 264
interfaces 1, 6, 253, 264
lead (Pb²⁺) 67
linear solid microfibers 5
liquid droplets 11
liquid extractors 22, 23, 25, 26, 213
liquid-liquid interfaces 1, 2, 3–6, 295, 296
lithographically fabricated devices 35
lithography 12, 268
lock-key 206
log K 73
lower critical solution temperature (LCST) 55–58, 61, 62
LR300. See Lumogen Red 300 (LR300)

m
magnetic-guided
assembly 245, 246
magnetic-guided
patternning 244–246
magnetic-guided targeting delivery 152, 163, 164
magnetic hierarchical porous
poly(MMA-co-EGDMA-co-GMA) microparticles 117
magnetic knots 242, 243, 244, 245
magnetic minipillars 244, 245, 246
magnetic nanoporous
poly(MMA-co-EGDMA-co-GMA) microparticles 117
magnetic PNB core-shell microspheres 74, 75
magnetic spindle-knots 224, 241, 242, 243, 244, 246–248
magnetic targeting 145
manually assembled glass-capillary devices 35
mass transfer 1, 2, 11, 35, 79, 105, 107, 111, 112, 118, 207, 283, 295, 296
mass transport 187
MC-W-W EC microcapsules 127
mechanical strength 83, 112, 165, 217, 231
melting enthalpy 229, 230
membrane-in-a-chip
in biomedical fields 253
ethanol-responsive self-regulation 260
fabrication of 254
nanogel-containing smart membrane 253, 255
reversible and repeated
thermo/ethanol-responsive self-regulation 263
in situ formation 253
smart membranes 253
temperature-responsive self-regulation of the membrane permeability 257
membrane permeability 254, 255, 256, 257–264
methanol 172, 173, 174
methyl methacrylate (MMA) 79–84, 103, 108, 111, 113, 114, 115, 116, 117, 118, 201
micro-actuator 195, 196, 197, 198, 199–201
micro-analysis 1, 4, 5
microcapsules, 1, 11, 35, 55, 91, 123, 161, 211, 295
microchannel, 1, 11, 37, 170, 195, 213, 223, 253, 267, 295
microfibers 2, 3–6, 223–248, 295
microfluidic-constructed stable phase interface structure systems 2
microfluidic device 1, 11–31, 35–51, 56, 62, 63, 68, 69, 70, 75, 80, 81, 86, 87, 91, 92, 93, 94, 108, 109, 124, 125, 132, 138, 139, 146, 147, 163, 169, 178, 190, 195, 196, 197, 201, 202, 212, 213, 217, 223, 224, 225, 226, 236, 241, 242
microfluidic emulsification 132, 133
microfluidic flow control system (MFCS) 273, 274, 277, 283, 287
microfluidic laminar flow technology 5
controllable fabrication of functional materials 1
microscale closed liquid-liquid interfaces 3
microscale nonclosed annular laminar interfaces 5
microscale nonclosed layered laminar interfaces 4
technology 1, 2, 4, 6, 83, 136, 295, 296, 297
microgel-based Pb2+ sensor 272
microgel-incorporated glass capillary 271, 272
micro-heat-exchanger 273, 274, 277, 278, 279
micro-heat-exchanging system 268, 273–274, 277, 279
micro-lancet 37, 38, 47, 48, 49, 50, 51
microlancets 48
micrometer-sized pores 105, 106, 107, 108–118
micro-reaction 1, 4, 5, 50, 51, 161, 187, 201–207, 211, 219, 253
microscale closed liquid-liquid interfaces 3
microscale emulsion interfaces 4
microscale nonclosed layered laminar interfaces 4
micro-scale phase interfaces 3
microscope glass slides and coverslips 14
micro-separation 1, 4, 5
microsphere(s), 1, 11, 55, 79, 123, 161, 192, 295
microvalve-controlled water cooling 277, 278, 280, 281
microvalve-in-a-chip 267–289
mask-based lithography 268 Pb2+-responsive hydrogel microvalve 270
in situ polymerization 268 thermo-responsive hydrogel microvalve 268
microvalve-integrated micro-heat-exchanging system 273
microvalves 123, 145, 147, 155, 157, 158, 267–289
middle fluid 16, 108, 109, 125, 138, 140, 146, 147, 163, 178, 190, 201, 204, 212, 213, 217, 218, 226, 227
monodisperse calcium alginate hollow microcapsules
droplet generation and ionic cross-linking 132
microfluidic fabrication strategy 132
morphologies and structures of 133
monodisperse controllable double emulsions 38
monodisperse core-shell hydrogel microparticles, Pb²⁺ adsorption behaviors 71
core-shell microspheres 68
industrial wastewater 68
microfluidic fabrication 68
thermo-responsive swelling/shrinking configuration change 68
monodisperse core-shell microcapsules alcohol-responsive burst release 171
chitosan microcapsules 179
controllable fabrication 161
direction-specific thermo-responsive burst release 168
double emulsions 161
fabrication 177
K⁺-responsive burst release 174
microfluidic strategy 162
nanoparticles 166
oil-soluble substances 162
pH-responsive burst release 176
monodisperse core-shell PNIPAM hydrogel microparticles, ethyl gallate antioxidan activity 62
intact-to-broken transformation behaviors 65
microfluidic fabrication 62
thermo-responsive phase transition behaviors 65
volume phase transition temperature 62
monodisperse emulsion droplets 12, 13
monodisperse ethyl cellulose hollow microcapsules
microfluidic fabrication strategy 124
morphologies and structures of 125
monodisperse glucose-responsive hollow microcapsules
adsorption behaviors of microcapsules 140
glucose-responsive behaviors 142
microfluidic fabrication strategy 136
sugar-responsive systems 136
tumor cells 136
monodisperse higher-order multiple emulsions 41
monodisperse hole-shell microparticles core droplet 188
effect of inner cavity 191
functionality 205
interfacial properties 188
microfluidic fabrication 201
microfluidic strategy 188
particle-template/emulsion-template methods 187
Pb²⁺ sensing and actuating 195
poly(NIPAM-co-B18C6Am) 195, 196, 199, 200
shell droplet 188
structure control 203
thermo-driven crawling movement 188, 190, 193
versatility 187
monodisperse multi-stimuli-responsive hollow microcapsules controlled-release characteristics 154
environmental changes 144
intelligent drug delivery systems 144
microfluidic fabrication strategy 145
microvalves 145
“on-off” mechanism 144
pH 145
site-specific targeting 158
stimuli-responsive behaviors 150
monodisperse oil droplets 239
monodisperse oil-in-water (O/W) emulsions 80
monodisperse oil-in-water-in-oil (O/W/O) emulsions 41, 68, 91
monodisperse PNIPAM hydrogel microparticles, tannic acid
microfluidic fabrication 56
volume phase transition behaviors 57
monodisperse porous microparticles 79
monodisperse porous poly(HEMA-MMA) microparticles 79
biodegradability 79
microfluidic fabrication strategy 80
structures 82
monodisperse quadruple-component O/W/O double emulsions 214
monodispersity 11, 14, 24, 40, 55, 57, 71, 79, 80, 82, 83, 93, 131, 134, 140, 149, 150, 187, 204
multicompartamental microparticles 211–219
compound-fluidic electrospray technique 211
controllable co-encapsulation 213
capsulation systems 211
fabrication 212
immunoprotection 211
isolated co-encapsulation 211
microbioreactions 211
multi-core/shell microparticles 212
synergistic release 216
Trojan-horse-like microparticles 217
troublesome multi-step process 211
multicomponent multiple emulsions 11, 12, 14, 22–31, 27, 213
multi-core microspheres 4
multi-core/shell microparticles 212–217
multiple emulsions 3, 4, 11–31, 35–51, 158, 211, 212, 213, 219
multi-stimuli-responsive microcapsules 123, 144–157
n
Na-alginate 132, 133, 241
nanogel(s) 201, 203, 253, 254, 255–264
nanogel-containing chitosan membrane 255, 256, 257, 260, 262
nanogel-containing membrane 254, 257, 258, 259, 260, 261, 262, 263, 264
nanogel-containing smart membranes 253, 254, 255–257, 264
nanoparticles 166
nanoparticles-in-microcapsule system 166
nanoporous PEGDMA microparticles 113, 117
nano-porous poly(MMA-co-EGDMA-co-GMA) microparticles 117, 118
nano-porous structure 107, 108, 111, 112, 113, 114, 116, 117, 118
nanovalves 255, 256, 257, 264
N-butyl acetate 241, 242, 244
N-2 microgel 98
N,N'-methylene-bis-acryamide (MBA) 86, 190
N,N'-methylene-bis-acrylamide (MBA) 56, 62, 86, 91, 92, 93, 96, 97, 99, 100, 102, 138, 163, 168, 190, 195, 212, 217, 270
N,N,N',N'-tetramethylethylenediamine (TEMED) 56, 57, 86, 218
n-octane 227
non-engulfing configuration 36
nonporous PEGDMA microparticles 113, 117
non-spherical particles 4, 11, 35
oil-core/hydrogel-shell microcapsules
oil-filled compartments
oil-in-water-in-oil (O/W/O) emulsion droplets
oil-in-water-in-oil (O/W/O/O) triple emulsions
oil-in-water-in-oil-in-oil (O/W/O/W/O) quadruple emulsions
oil-in-water (O/W) primary emulsions
oil jets
oil-soluble 2,2-dimethoxy-2-phenyl-acetophenone (BDK)
oil-soluble substances
oil/water interface
oleic-acid-modified magnetic nanoparticles (OA-MNPs)
on-demand release
OP-10
open-celled porous microgels
open-celled porous PNIPAM microgels
open-celled porous structure
OPH-2 and OPI-2 microgels
osmotic pressure
outer fluid
O/W emulsions
O/W/O double emulsion droplets
O/W/O/O triple emulsions
O/W/O/W triple emulsions
parallel laminar flows
partial engulfing configuration
partially dewetting
pathologically acidic conditions
Pb\(^{2+}\)-adsorption
Pb\(^{2+}\) detection platform
Pb\(^{2+}\) pollution discharge
Pb\(^{2+}\)-recognition
Pb\(^{2+}\)-responsive hydrogel microvalve
Pb\(^{2+}\)-responsive microgel
pollution warning
real-time online detection of trace Pb\(^{2+}\)
selectivity and repeatability of the Pb\(^{2+}\) detection platform
sensitivity of the Pb\(^{2+}\) detection platform
wastewater
Pb\(^{2+}\)-responsive P(NIPAM-co-B18C6Am) microgel
Pb\(^{2+}\) sensing
Pb\(^{2+}\) sensing and actuating
PDMS microfluidic device
peapod-like chitosan microfibers
peapod-like jet
peapod-like jet containing discrete oil droplets
peapod-like microfibers
fabrication
flow rates
synergistic encapsulation
peristaltic pump
permeability coefficient
PGPR90
phase change materials
phase transition
phenols
photoacid generator
photoacid generator diphenyliodonium nitrate (PAG) 132
photo-initiator 63, 80, 108, 138, 163, 190, 191, 213, 270
photoinitiator dimethoxy-2-phenylacetophenone (BDK) 63
pH-responsive burst release 176–182
pH-responsive capsule membrane 123, 158
pH-responsive controlled-release behaviors 154
pH-responsive core-shell microcapsules 177
pH-responsive swelling 147, 151, 152
physiological temperature 136, 137, 141, 142
pK_a 137, 140, 146, 147, 151, 154, 516
plug-n-play microfluidic devices 21
Pluronic F127 62, 91, 108, 125, 132, 138, 147, 163, 168, 178, 190, 195, 201, 212
P(NIPAM-co-B18C6Am) microgel 270, 281, 282, 283, 286
PNB microactuators 195, 196, 197, 198, 199, 200, 201
PNIPAM hydrogel 55–61, 95, 166, 172, 189, 191, 192, 193, 195, 216, 270, 274, 276, 289
microvalve 270
shell 166, 216
PNIPAM microactuators 198
PNIPAM microgels 55, 56, 57, 58, 59, 60, 61, 75, 79, 85, 86, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 206, 207
PNIPAM microparticles with open-celled porous structure microfluidic fabrication strategy 91
morphologies and microstructures 93
thermo-responsive volume change behaviors 98
PNIPAM microspheres 57, 58, 62, 65, 192, 193
PNIPAM polymeric networks 59, 61, 73
pollution terminating 289
pollution warning 286, 287–289
poly(EGDMA) (PEGDMA) 111
poly(HEMA-MMA) 79–84, 103
poly(hydroxyethyl methacrylate-methyl methacrylate)
(poly(HEMA-MMA)) 79
poly(methyl methacrylate) (PMMA) 79
poly(MMA-co-EGDMA) 108, 111, 113, 114, 115, 116
poly(N-isopropylacrylamide) (PNIPAM) 55, 79, 136, 162, 189, 254, 270
poly(N-isopropylacrylamide-co-acrylamide)
(P(NIPAM-co-AAm)) 149
poly(N-isopropylacrylamide-co-benzo-15-crown-5-acrylamide) (PNB) 175
poly(N-isopropylacrylamide-co-benzo-18-crown-6-acrylamide) (PNB) 68, 270
poly(NIPAM-co-AAm-co-B15C5Am) (PNAB) 175, 176, 177
poly(NIPAM-co-AAPBA) (PNA) 138, 140, 141
poly(NIPAM-co-AAPBA-co-AAc) (PNAA) 138, 141, 142, 143, 144, 158
poly(NIPAM-co-B15C5Am) 176
poly(vinyl alcohol) (PVA) 81, 217, 218
poly(vinyl butyral) (PVB) 224, 225, 226, 227, 228–235
poly(vinyl pyrrolidone) (PVP) 79, 80, 81, 82, 83, 103
poly(HEMA-MMA) copolymers 80
polydimethylsiloxane (PDMS) 12, 14, 15, 217, 244, 253
plates 12
polyelectrolyte microparticles 38, 211
polyethylene (PE) 80, 132, 270
Polyfluor 570, 255, 256
polyglycerol polyricinoleate (PGPR 90 or PGPR) 38, 41, 43, 44, 45, 46, 50, 56, 57, 62, 63, 81, 86, 91, 108, 110, 111, 112, 113, 116, 132, 138, 147, 163, 168, 178, 190, 195, 204, 212
poly(NIPAM-co-B18C6Am) hole-shell microparticles 195
effect of hollow cavity 199
effect of Pb$^{2+}$ 196
magnetic-guided targeting behavior 195
micromanipulation 200
poly(N-isopropylacrylamide) (PNIPAM) hydrogel 189
poly(PNIPAM-co-B18C6Am) (PNB) hydrogel 195
polymeric microparticles 187
polymeric networks 55, 59, 60, 61, 73, 80, 86, 88, 100, 102
poly(NIPAM-co-AAPBA-co-Ac) (PNAA) microcapsule 138
poly(NIPAM-co-AAm-co-B15C5Am) microcapsules 177
poly(N-isopropylacrylamide-co-benzo-18-crown-6-acrylamide)
(P(NIPAM-co-B18C6Am)) microgel 68, 270, 281, 282, 283, 286
poly(N-isopropylacrylamide) (PNIPAM) microgels 85
poly(methyl methacrylate-co-ethylene glycol dimethacrylate)
(poly(MMA-co-EGDMA)) microparticles 108, 111, 113, 114, 115, 1164
poly(MMA-co-EGDMA) microparticles 108, 111
poly(MMA-co-EGDMA-co-GMA) microparticles 114, 115, 116, 117, 118
poly(N-isopropylacrylamide) (PNIPAM) nanogels 254
poly(N-isopropylacrylamide-co-methyl methacrylate-co-allylamine) nanogels 201
poly(dimethylsiloxane) oil (PDMS) 217
poly(methyl methacrylate) (PMMA) particles 79
poly(HEMA-MMA) porous microspheres 80, 82
poly(vinyl butyral) (PVB) resin 225
polystyrene (PS) 86, 87, 88, 195, 196
polystyrene beads 86, 87, 88
poly(N-isopropylacrylamide-co-acrylamide)
(P(NIPAM-co-AAm)) sub-microspheres 149
poresize 5, 105, 106, 108, 113, 118, 135
porogens 79, 80, 82, 83, 86, 91, 103
porosity 83, 103, 105, 106, 108, 109, 112, 113, 118
porous microparticles 79–103, 105–118
porous PNIPAM microparticles with tunable response behaviors dramatic response and stimuli-specific behavior 85
gel swelling 85
heterogeneous internal microstructures 85
linear side chains 85
microfluidic fabrication strategy 86
temperature-dependent equilibrium volume-deswelling ratio 85
tunable response behaviors 87
void structures 86
porous polymeric microparticles 105, 106
post-array-containing microfluidic device 16
precipitation polymerization 145, 255
precursor droplets 40, 41, 42, 44
programmed synergistic release
P(NIPAM-co-AAm) sub-microspheres 149
pulsed release 218
PVB/8P microfibers 229
PVB/24P microfibers 230, 233, 235

quadruple-component double emulsions 22–28, 169, 214
quadruple-component O/W/O double emulsions 213
quadruple emulsions 21, 212, 219
quintuple-component double emulsions 22, 27, 29
quintuple-component multiple emulsions 29
quintuple-component triple emulsions 22, 27, 29

real-time detection 268, 281–289
real-time on-line detection of trace Pb^{2+} 281–283
real-time Pb^{2+} detection 281, 289
response rate 59, 88, 90, 91, 99, 100, 103, 144, 192, 193, 200
reversible glucose-induced swelling/shrinking behaviors 137
reversible glucose-responsive swelling/shrinking 138
reversible swelling/shrinking volume transitions 254, 255
rhodamine B 50, 111, 142, 143, 269, 270
route-specific targeting drug delivery 163

scale-up 14, 16, 21, 22, 27
Scanning Electron Microscope (SEM) 83, 84, 85, 96, 97, 111, 112, 113, 114, 126, 127, 128, 129, 130, 131, 205, 206, 227, 228, 239, 243, 255, 256
Schiff base 177
bonding 177

sealing performance 253, 276–277
selective adsorption 55, 68, 75
selective detection 268, 270, 289
selective permeability 5
self-regulated drug delivery 136
self-regulated permeability 253–264
sequential shear-induced emulsifications 35
sextuple-component triple emulsions 22, 27, 28, 30, 31
shape angle 203, 204
shear-induced generation of controllable multiple emulsions
controllable double emulsions 16
controllable emulsion droplets 12
controllable monodisperse single emulsions 14
controllable quadruple-component double emulsions 22
controllable triple emulsions 19
inner droplet number 11
microchannel wettability 12
multicomponent multiple emulsions 27
sequential bulk emulsification 11
T-junction geometries 12
volume fractions 11
sheath flow 224, 225, 226, 236
shell permeability 143
shell thickness 40, 41, 110, 158, 175, 237, 238, 239
shrunken state 99, 137, 141, 146, 174, 189, 205, 275, 281
silicone oil (SiO) 37, 38, 40, 41, 44, 45, 46, 47, 48, 50
single emulsions 4, 12, 13, 14–16, 31, 39, 41, 42, 43, 46, 50, 51, 63, 79, 81, 103, 111, 124, 132, 133
site-specific targeting drug delivery 145
size-classification 206
size distributions 4, 14, 15, 57, 58, 63, 64, 70, 71, 82, 93, 94, 96, 112, 123, 125, 131, 133, 134, 139, 140, 145, 163
size-match 206
size monodispersity 11, 40, 71, 134, 187
smart core-shell microcapsules
  alcohol-responsive burst release 171
core-shell chitosan microcapsules 179
direction-specific thermo-responsive burst release 168
fabrication 177
K⁺-responsive burst release 174
nanoparticles 166
oil-soluble substances 162
pH-responsive burst release 176
smart hydrogel microvalves 267, 268, 279, 289
smart-membrane-in-chip 253, 264
smart microvalve-in-a-chip
cell culture 279
microvalve-integrated micro-heat-exchanging system 273
pollution warning 287
real-time online detection of trace Pb2+ 281
sealing performance 276
selectivity and repeatability of the Pb2+ detection platform 284
sensitivity of the Pb2+ detection platform 283
temperature self-regulation 277
thermo-responsive switch performance 274
wastewater 289
smart-microvalve-integrated microchips 267
sodium acrylate 217
sodium alginate
  (Na-alginate) 132, 241
sodium dodecyl sulfate (SDS) 38, 41, 44, 45, 46, 47, 50, 191, 192, 193
solvent diffusion 123, 125, 158
solvent evaporation 3, 68, 69, 169, 195, 196
solvent quality 204
soybean oil (SO) 38, 56, 57, 62, 63, 91, 132, 138, 147, 163, 168, 169, 170, 178, 179, 190, 195, 196, 212, 256
soybean oil containing emulsifier PGPR 90, 62
specific surface area 5, 79, 83, 108, 117, 118, 192
spider-silk-like Ca-alginate microfibers 241, 242, 243, 244, 246, 247
spider-silk-like microfibers 241–248
fabrication 241
magnetic-guided patterning and assembling 244
morphological characterization 242
water collection ability 246
spider-web-like structures 224, 247, 248
spreading coefficient 36, 37, 38, 39, 41, 42, 43, 45, 46
square glass tubes 12
squirting cucumbers 166
stable microscale phase interfaces 3
star-shaped microchannels 268, 269, 270
stimuli-responsive controlled-release systems 145
stimuli-responsive hydrogel microparticles 55, 75
stimuli-responsive hydrogel shell
stimuli-responsive microcapsules 144
stimuli-responsive microparticles 55
stimuli-responsive smart membranes 5, 264
stimuli-sensitive hydrogel microparticles/microgels 55
stress-strain curves 232
Sudan Black 236, 240, 241
Sudan III 163, 164, 195, 212
Sudan Red 139, 190
superparamagnetic nanoparticles 152
supramolecular host-guest complexes 68
surface wettability  13, 37, 47, 48, 51, 205
surfactant bilayers  109, 110
sustained drug release  143, 151
swelling ratios  101, 151, 152
swollen state  57, 99, 137, 140, 141, 143, 144, 146, 174, 182, 205, 261, 275
symmetry breaking  187, 191, 194
synergistic delivery systems  11
synergistic drug delivery  224
synergistic encapsulation  235–241, 248
synergistic release  212–218

tannic acid (TA)  55–61, 56
tap water pipeline  288
temperature- and ethanol-responsive smart membrane
ethanol-responsive self-regulation  260
nanogel-containing smart membrane  255
reversible and repeated thermo/ethanol-responsive self-regulation  263
temperature-responsive self-regulation of the membrane permeability  257
temperature-dependent volume change  140, 147, 155, 198, 206
temperature-dependent volume phase transition  149
temperature regulation  145, 224, 230–235, 248
temperature-responsive permeability self-regulation  260
temperature-responsive sub-microspheres  123, 145, 146, 147, 148, 149, 150, 152, 154, 155, 156, 157, 158
temperature-responsive volume change  73, 155
temperature self-regulation  277–281
template-directed synthesis  105
tensile strength  231
terephthalaldehyde  178
terephthalaldehyde-crosslinked chitosan hydrogel shell  176
tetramethylammonium hydroxide  164
thermal energy  233, 234
thermal stability  227, 230, 231
thermo-driven crawling movement  188–194
thermo-driven locomotion  189, 193, 194
thermo-driven soft microcrawlers  188
thermo-induced shrinking process  100
thermo-regulation  235
thermo-responsive burst release  168–171
thermo-responsive hydrogel microvalve  268, 269, 270, 272
thermo-responsive phase transition  58, 60, 61, 65
thermo-responsive PNIPAM shell  165
thermo-responsive polymer  55
thermo-responsive swelling behaviors  100
thermo-responsive swelling process  100, 101
thermo-responsive switch  274–278
thermo-responsive volume phase transitions  189
thermostatic control  267, 268–270, 272–281
thermo-triggered actuator  216
thermo-triggered burst release  162–171
thermo-triggered synergistic release  216
3D assembly  241–248
3D glass-capillary microfluidic device  15
3D microchannel  12
3D printing techniques  21
<table>
<thead>
<tr>
<th>Index</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>time-dependent deswelling ratio</td>
<td>172, 173</td>
</tr>
<tr>
<td>T-junction</td>
<td>4, 12, 13</td>
</tr>
<tr>
<td>geometries</td>
<td>4, 12</td>
</tr>
<tr>
<td>trace analytes detection</td>
<td>268</td>
</tr>
<tr>
<td>trace threat analytes</td>
<td>267, 268, 270</td>
</tr>
<tr>
<td>transition tube</td>
<td>16, 19, 20, 21, 62, 108, 124, 133, 201, 224, 226, 236, 241, 242</td>
</tr>
<tr>
<td>trans-membrane diffusional permeation</td>
<td>145</td>
</tr>
<tr>
<td>trans-membrane diffusion flux</td>
<td>259</td>
</tr>
<tr>
<td>triggered release</td>
<td>161, 191, 211, 216, 217–218</td>
</tr>
<tr>
<td>3,4,5-trihydroxybenzoic acid ethyl ester</td>
<td>62</td>
</tr>
<tr>
<td>triple emulsions</td>
<td>12, 14, 16, 19–22, 27, 28, 29, 30, 31, 41, 43, 46, 212, 217–218</td>
</tr>
<tr>
<td>Trojan-horse-like microparticles</td>
<td>217–218</td>
</tr>
<tr>
<td>Trojan-horse-like structures</td>
<td>212</td>
</tr>
<tr>
<td>truncated-sphere shape</td>
<td>203, 204</td>
</tr>
<tr>
<td>tubular flows</td>
<td>223</td>
</tr>
<tr>
<td>tubular microfibers</td>
<td>5, 225, 226, 248</td>
</tr>
<tr>
<td>tunable pore size</td>
<td>105, 106</td>
</tr>
<tr>
<td>2D microchannel</td>
<td>12, 13</td>
</tr>
<tr>
<td>2D PDMS microfluidic device</td>
<td>15</td>
</tr>
<tr>
<td>two-stage glass capillary microfluidic device</td>
<td>108, 109, 224</td>
</tr>
<tr>
<td>two-step sequential emulsification</td>
<td>16</td>
</tr>
<tr>
<td>ultra-thin shell</td>
<td>35, 39, 40, 41, 49, 50</td>
</tr>
<tr>
<td>ultra-thin-shelled double emulsions</td>
<td>40</td>
</tr>
<tr>
<td>uniform hierarchical porous microparticles</td>
<td></td>
</tr>
<tr>
<td>enhanced protein adsorption</td>
<td>117</td>
</tr>
<tr>
<td>highly interconnected hierarchical porous structures</td>
<td>106</td>
</tr>
<tr>
<td>magnetic-guided oil removal</td>
<td>115</td>
</tr>
<tr>
<td>microdrop interfaces</td>
<td>106</td>
</tr>
<tr>
<td>microfluidic strategy</td>
<td>106</td>
</tr>
<tr>
<td>monodisperse emulsion drops</td>
<td>106</td>
</tr>
<tr>
<td>nanometer-sized pores</td>
<td>105</td>
</tr>
<tr>
<td>nanometer-sized pores and micrometer-sized pores</td>
<td>111</td>
</tr>
<tr>
<td>oil removal</td>
<td>114</td>
</tr>
<tr>
<td>porosities</td>
<td>105</td>
</tr>
<tr>
<td>porous polymeric microparticles</td>
<td>105</td>
</tr>
<tr>
<td>protein adsorption</td>
<td>116</td>
</tr>
<tr>
<td>W/O/W emulsions</td>
<td>108</td>
</tr>
<tr>
<td>UV-curable adhesive</td>
<td>14, 47, 270, 279</td>
</tr>
<tr>
<td>UV-initiated polymerization</td>
<td>68, 69, 108, 138, 140, 169, 196</td>
</tr>
<tr>
<td>UV-initiator</td>
<td>91</td>
</tr>
<tr>
<td>UV irradiation</td>
<td>63, 80, 81, 92, 93, 94, 133, 139, 163, 201, 202, 270, 271</td>
</tr>
<tr>
<td>vitamin B12 (VB12)</td>
<td>154</td>
</tr>
<tr>
<td>voidless microgel</td>
<td>89</td>
</tr>
<tr>
<td>voidless PNIPAM microspheres</td>
<td>192, 193</td>
</tr>
<tr>
<td>behaviors</td>
<td>57</td>
</tr>
<tr>
<td>kinetics</td>
<td>86, 89</td>
</tr>
<tr>
<td>wastewater</td>
<td>64, 68, 286, 288, 289</td>
</tr>
<tr>
<td>water collection</td>
<td>224, 241–248</td>
</tr>
<tr>
<td>water condensation</td>
<td>247</td>
</tr>
<tr>
<td>water-cooling</td>
<td>277, 278, 280, 281</td>
</tr>
<tr>
<td>water flux</td>
<td>275, 276, 277</td>
</tr>
<tr>
<td>water-in-oil-in-oil (W/O/O) double emulsion</td>
<td>38–39, 41, 43</td>
</tr>
<tr>
<td>water-in-oil-in-water-in-oil (W/O/W/O) droplets</td>
<td>19</td>
</tr>
<tr>
<td>water-soluble monomer</td>
<td>80</td>
</tr>
<tr>
<td>Weber number</td>
<td>15</td>
</tr>
<tr>
<td>wettability modification</td>
<td>12, 18, 25</td>
</tr>
<tr>
<td>wetting-induced droplet coalescence</td>
<td>37, 47</td>
</tr>
</tbody>
</table>
wetting-induced emulsion generation 44
droplet-triggered droplet pairing 44
monodisperse controllable double emulsions 38
monodisperse higher-order multiple emulsions 41
wetting-induced coalescing 37–38
wetting-induced droplet coalescing 47
wetting-induced spreading 36
wetting-induced spreading 36–47, 50
W/O emulsion droplets 57
W/O emulsions 44, 50, 92, 93, 95, 166
W/O/O double emulsions 39, 40, 43, 44, 45
(O1 + O2)/W/O quadruple-component double emulsions 169
W/O/W double emulsions 25, 124, 125, 127, 188, 201
x
X-shaped microchannels 256
y
Young’s modulus 244