Index

analytical modeling equations 8
analytical transport model equation 53

Boltzmann transport equation (BTE) 9, 59
BTE, see Boltzmann transport equation
bundles of carbon nanotube 29

capacitance 37, 41, 70, 73, 89, 92, 94, 99, 108, 110, 113, 127
capacitively driven low-swing interconnect (CDLSI) 58
carbon 2–3
carbon atoms 3, 60, 86, 90
carbon nanomaterials 58
carbon nanotube (CNT) 1–2, 5, 7, 9–10, 27–28, 33–35, 46, 57–59, 61, 86, 89, 93, 107, 109, 111
carbon nanotube field-effect transistor (CNT-FET) 1, 5–10, 29, 33–35, 44–49, 52–53, 57, 98, 120–121, 123, 127, 139
doped 27, 42
electrical properties of 4
CDLSI, see capacitively driven low-swing interconnect
chemical vapor deposition (CVD) 2
chiral vectors 8–9, 19–20, 25–28, 33–34, 43, 45, 48–53
circuit designs 120, 125
electronic 120
modern electronic 119
classical electrodynamics 10, 59
CMOS, see complementary metal-oxide semiconductor
CMOS circuits 7, 120, 122
CNT see carbon nanotube
metallc 5–7, 110
semiconducting 5, 10
CNT-based circuit modeling 7, 9
CNT-based circuits 8–9
CNT-based integrated circuits 5
CNT bundle 101, 114
CNT bundle inductors 115
CNT bundle wire inductors 111, 116
CNT bundles interconnects 5
CNT-FET see carbon nanotube field-effect transistor
channel length 139
n-type 6, 49–52, 127–128, 138
CNT-FET circuits 8, 119–120, 122, 124–125, 127
energy recovery 120
simulated 98
CNT-FET energy recovery XNOR/XOR circuits 124
Index

CNT-FET inverter 52, 98, 124
CNT-FET modeling 8
CNT-FET XNOR/XOR energy recovery circuits 125
CNT interconnect modeling 9
CNT interconnects 8, 59, 64, 93, 96, 99–101, 111
short length 96
complementary CNT-FETs 8–9, 34, 49–50, 123
complementary metal-oxide semiconductor (CMOS) 6, 48, 51, 112, 122–123
conductance 6–7, 90
conduction electron charge density 60, 86
conduction electrons 60, 64–65, 86
conductivity, axial 68, 94
conductor, perfect 69
Cu inductors 110, 114–116
Cu interconnects 58, 72, 74–75, 77, 95–96, 99–101, 107
Cu resistivity 72–73
Cu wire 73
Cu wire inductor 113–116
current transport equations 34
current transport equations for CNT-FETs 121
current transport in carbon nanotubes 19–20, 22, 24, 26, 28
current transport in CNT field-effect transistors 33–34, 36, 38, 40, 42, 44, 46, 48, 50, 52
current transport modeling 34–35, 37, 39, 41, 43, 45, 47
current transport models 8, 29, 50
CVD, see chemical vapor deposition
device geometry 8–9, 52
dielectrics 6, 58
disorder 7
eddy currents 108–109
electric capacitance 69
electromagnetic field 61, 86
electromagnetic field propagation 9, 58
electromagnetic waves 93
electromigration 1, 7, 57–58
electron–electron correlation 59, 67, 78
electron fluid 65–66, 69, 88, 91
two-dimensional 62, 64
electron gas, two-dimensional 9, 59
electron mobility 5
electron relaxation frequency 61
electron transport 10, 59–60, 64, 90
electronic charge 61
electrostatic capacitance 88, 92, 94–95
energy bandgap 25
energy dispersion relation 20, 38
energy recovery logic (ERL) 122–123
energy recovery techniques 10, 119–120, 124
ERL, see energy recovery logic

Fermi energy 7
Fermi liquid model 9, 59
Fermi velocity 61, 63, 66, 77–78, 87, 109
field effect transistors 29
fluid
one-dimensional 62, 64–65, 78
two-dimensional 62, 64–65
fluid model 9, 59, 61–63, 72, 76, 78
extended one-dimensional 93
semi-classical one-dimensional 10, 94
two-dimensional 10, 60–61, 64

Lüttinger liquid 59
Lüttinger liquid model 59, 67, 72,
   76–77
Lüttinger liquid theory 9, 59

magnetic inductance 69, 88, 92
metallic MWCNT interconnects 88–89
metallic MWCNTs 5, 109
metallic nanotubes 89–90, 101
metallic shells 86, 88–89
metallic SWCNT interconnects 70, 78
metallic SWCNTs 5, 8, 10, 65,
   67–69, 77, 90–93
MWCNT modeling, mathematical 10, 59
models
analytical 34, 52
two-dimensional electron gas 59
multi-walled carbon nanotube (MWCNT) 2–4, 7, 33, 58,
MWCNT
see multi-walled carbon nanotube
small-diameter 94
MWCNT inductors 115
MWCNT interconnect model parameters 95
MWCNT interconnection modeling 85, 87
MWCNT interconnects 88–89, 93,
   95–96, 99, 101
MWCNT wire inductors 111, 113, 115

magnetoelectric inductance 69, 88, 92
metallic MWCNT interconnects 88–89
metallic MWCNTs 5, 109
metallic nanotubes 89–90, 101
metallic shells 86, 88–89
metallic SWCNT interconnects 70, 78
metallic SWCNTs 5, 8, 10, 65,
   67–69, 77, 90–93
MWCNT modeling, mathematical 10, 59
models
analytical 34, 52
two-dimensional electron gas 59
multi-walled carbon nanotube (MWCNT) 2–4, 7, 33, 58,
MWCNT
see multi-walled carbon nanotube
small-diameter 94
MWCNT inductors 115
MWCNT interconnect model parameters 95
MWCNT interconnection modeling 85, 87
MWCNT interconnects 88–89, 93,
   95–96, 99, 101
MWCNT wire inductors 111, 113, 115

nanoelectronics 57
NEGF, see non-equilibrium Green function
non-equilibrium Green function (NEGF) 46

on-chip inductor modeling 108–109
on-chip inductors 107–109
on-chip power density 120, 122, 124–125
one-dimensional fluid model 10, 60, 62–65, 67, 85–86, 90, 95, 97, 101
one-dimensional fluid theory 101

phase-locked loop (PLL) 10, 107–108
phase noise 108, 114–116
phonons, optical 7, 46, 61
PLL, see phase-locked loop
power density 119–120, 122, 124–125
power density of CNT-FET circuits 125

QSERL, see quasi-static energy recovery logic
quasi-static energy recovery logic (QSERL) 122

ring oscillator 8–9, 139
five-stage 139

semiconducting SWCNTs 90
silicon 4–5, 27–28
silicon substrate 108

spiral inductors 108, 110
SWCNT see single-walled carbon nanotube
one-dimensional 63
SWCNT bundle 85–86, 89–92, 94, 96–97, 99–100, 109–110, 113
SWCNT bundle inductors 114
SWCNT bundle interconnection modeling 89, 91
SWCNT bundle interconnection wires 98
SWCNT bundle interconnects 90, 92–93, 96, 99
SWCNT bundle wire inductors 114–115
SWCNT fabrication techniques 89
SWCNT FETs, fabricated 7
SWCNT interconnects 60, 71–72, 74, 77–78, 85, 101
SWCNT transmission line 72, 74
SWCNT transmission line behavior 71
SWCNT transmission line model 68

transistors 5–6, 29, 33, 46, 94, 112, 119–120
transmission line model 9, 59, 68–69, 78
multiconductor 58
transport
ballistic 1, 6, 46, 57, 95, 99
current 8–10, 34, 46, 52, 57, 121
VCO, see voltage-controlled oscillator
very large scale integrated (VLSI) 1, 101
VLSI, see very large scale integrated
VLSI interconnects 58
next-generation 58
voltage-controlled oscillator (VCO) 107, 111, 113–116