

Contents

1	Introduction.....	1
1.1	Critical Technology	1
1.2	History and Trends of Boiling	2
1.3	Micro Boiling	3
	References	4
2	Thermal Physical Fundamentals	6
2.1	Phase and Phase Equilibrium.....	6
2.2	Phase Transition.....	9
2.3	Interfacial Aspects	12
2.4	Contact Angle and Dynamical Contact Behavior	16
2.4.1	Contact Angle at Equilibrium	16
2.4.2	Contact Angle Hysteresis.....	17
2.4.3	Dynamical Contact Angle	19
2.5	Cluster Dynamics	21
2.5.1	Clusters	21
2.5.2	Number Balance of Activated Molecules in a Cluster	21
2.5.3	Cluster Evolution with Internal Perturbations	24
2.5.4	Cluster Evolution with External Perturbations	25
	References	26
3	Boiling Nucleation.....	28
3.1	Nucleus Formation	29
3.1.1	Mean Free Path	29
3.1.2	Self-Aggregation.....	29
3.1.3	Aggregate Formation	31
3.1.4	Critical Aggregation Concentration	33
3.1.5	Infinite Aggregation Formation	34
3.1.6	Physical Configuration of Nucleus Formation.....	35
3.2	Interfacial Effects on Nucleation.....	36
3.2.1	Nucleus Structure Evolution	36
3.2.2	Interfacial Tension of a Nucleus	37
3.2.3	Modification of Nucleation Rate	38
3.3	Microscope Activation near a Flat Surface.....	39
3.3.1	Liquid Behavior near a Heated Wall.....	39

3.3.2	Nucleation Position.....	42
3.3.3	Embryo Bubble Evolution	44
3.4	Bubble Evolution from a Cavity.....	46
3.4.1	Description of Heterogeneous Nucleation	46
3.4.2	Nucleation with One Barrier.....	50
3.4.3	Heterogeneous Nucleation with Two Barriers	54
	References	59
4	Jet Flow Phenomena	60
4.1	Experimental Phenomena	61
4.1.1	Boiling on a Plate Heater	61
4.1.2	Boiling on Small Wires.....	64
4.2	Bubble-Top Jet Flow Structure	69
4.2.1	General Features	69
4.2.2	Jet Structure	70
4.2.3	Multi Bubble-Top Jet Flow.....	71
4.3	Dynamical Behavior of Bubble-Top Jet Flows.....	72
4.3.1	Jet Flow Evolution	72
4.3.2	Competition and Self-Organization of Jet Flows.....	75
4.4	Models of Bubble-Top Jet Flow	78
4.4.1	Governing Equations	78
4.4.2	Fundamental Considerations.....	79
4.5	Characteristics of Bubble-Top Jet Flow.....	80
4.5.1	Jet Flow Driving Force and Pumping Effect.....	80
4.5.2	Jet Flow Bifurcation Phenomenon.....	82
4.6	Formation of Bubble-Top Jet Flow.....	85
4.6.1	Temperature Evolution.....	85
4.6.2	Temperature Evolution on Bubble Interface	88
4.6.3	Flow Evolution	89
	References	91
5	Bubble Dynamics on Fine Wires.....	92
5.1	Modes of Bubble Motion.....	93
5.1.1	Bubble Sweeping	93
5.1.2	Bubble Interaction.....	95
5.1.3	Bubble Oscillation Phenomena.....	97
5.1.4	Bubble Leaping.....	99
5.2	Fundamentals of Bubble Dynamics.....	102
5.2.1	Thermocapillary Force.....	102
5.2.2	Force Caused by Bubble Motion	104
5.2.3	Dynamic Equation	107

5.3	Bubble Sweeping Dynamics.....	108
5.3.1	Single Bubble Sweeping.....	108
5.3.2	Bubble Separation from an Immobile Bubble	109
5.3.3	Separation of Two Equivalent Moving Bubbles	113
5.3.4	Separation of Two Non-Equivalent Bubbles.....	114
5.4	Bubble Collision Dynamics.....	115
5.4.1	Collision with an Immobile Bubble.....	115
5.4.2	Collision of Two Equivalent Bubbles	117
5.4.3	Bubble Coalescence.....	118
5.5	Bubble Oscillation	119
5.5.1	Temperature Profile of a Two Immobile Bubbles System	119
5.5.2	Bubble Oscillation Characteristics.....	120
5.5.3	Bubble Oscillations with Various Effective Viscosities	122
5.5.4	Coupling Bubble Oscillation.....	124
5.6	Bubble Leaping Dynamics	126
5.6.1	Dynamical Description	126
5.6.2	Simple Leaping Dynamics	128
5.6.3	Heat Transfer Performance during Bubble Leaping and Sweeping.....	131
	References	131
6	Boiling in Microchannels.....	133
6.1	Experimental Observations.....	134
6.1.1	General Behavior	134
6.1.2	Nucleation Superheat.....	135
6.1.3	Experimental Phenomena	137
6.2	Physical Explanation	138
6.2.1	Evaporating Space and Fictitious Boiling.....	138
6.2.2	Thermodynamic Evidence	139
6.2.3	Cluster Dynamical Evidence.....	141
6.3	Nucleation Criterion	143
6.3.1	Thermodynamic Analysis	143
6.3.2	Statistical Mechanics Approach	145
6.3.3	Dynamic Model	149
6.4	Nucleation Kinetics	151
6.4.1	Bubble Evolution Dynamics near Critical Radius	151
6.4.2	Nucleation in Confined Space	154
6.5	Bubble Dynamic Behavior with Local Heating.....	158
6.5.1	Experiments	158
6.5.2	Phase Change Behavior	159
6.6	Interface Oscillation	160
6.6.1	Periodic Feature	160

6.6.2	Evaporating Interface.....	163
6.6.3	Condensing Interface	167
	References	172
7	Boiling in Droplets	175
7.1	Oscillation of Sessile Droplets.....	176
7.1.1	Experimental Observations.....	176
7.1.2	Oscillatory Behavior.....	179
7.1.3	Physical Understanding	181
7.2	Model of Droplet Oscillation.....	184
7.2.1	Physical Model	184
7.2.2	Flow Characteristics	184
7.3	Transitional Boiling Behavior	188
7.3.1	Experimental Description	188
7.3.2	Restricted Cyclical Phase Change	190
7.3.3	Single-Bubble Cyclical Phase Change.....	191
7.3.4	Metastable Cyclical Phase Change	193
7.4	Droplet Spreading During Evaporation and Nucleation.....	194
7.4.1	Phenomenon Observations.....	194
7.4.2	Influential Factors	195
7.4.3	Spread Area and Spread Speed	197
7.4.4	Heat Fluxes	199
	References	200
8	Boiling in Micro-Structures and Porous Media.....	201
8.1	Experimental Observations.....	202
8.1.1	Test Apparatus.....	202
8.1.2	Low Applied Heat Flux.....	203
8.1.3	Moderate Applied Heat Flux.....	207
8.1.4	High Applied Heat Flux	207
8.2	Bubble Behavior in Bead-Packed Structure	208
8.2.1	Boiling Process	208
8.2.2	Static Description of Primary Bubble Interface	210
8.2.3	Comparison of Results.....	212
8.3	Replenishment and Dynamic Behavior of Interface.....	214
8.3.1	Replenishing Liquid Flow.....	214
8.3.2	Dynamic Behavior of Bubble Interface	216
8.3.3	Interfacial Heat and Mass Transfer at Pore-Level.....	219
8.4	Pore-Scale Bubble Dynamics	222
8.4.1	Introduction.....	222
8.4.2	Discrete Rising Bubble	223
8.4.3	Bubble Departure Interference.....	225

8.5	Occurrence of Dryout	226
8.5.1	Lateral Bubble Coalescence and Local Vapor Patch Formation	226
8.5.2	Dryout	227
8.5.3	Discussion and Comparison	228
	References	231
9	Explosive Boiling	233
9.1	Experimental Phenomena	234
9.1.1	Visual Observation Test	234
9.1.2	Jet Flow in/from Mini Tubes	236
9.1.3	Exploding Emission from Micro Tubes	239
9.2	Temperature Behavior During Emitting	241
9.3	Theoretical Discussion	244
9.3.1	Geometrical Parameters	244
9.3.2	Critical Emitting Heat Flux	244
9.3.3	Asymmetrical Effect	247
	References	249
	Index	250
	Postscript	254