

Table of Contents

	Page
1 Reactions with Nitrogen	1
1.1 General	1
1.2 Phase Diagram	2
Solubility of N in W	2
Nitrides	3
1.3 Nitrogen Absorption and Degassing	4
1.4 Diffusion, Permeation	5
1.5 Ion Implantation	8
1.6 Vapor Deposition of W–N Thin Films	9
1.6.1 Physical Vapor Deposition	9
1.6.2 Chemical Vapor Deposition	11
2 Reactions with Halogens	12
2.1 Fluorine	12
Reactions with Fluorine–Oxygen Mixtures	14
2.2 Chlorine	15
General	15
Products	16
Kinetics	17
Reactions with Chlorine–Oxygen Mixtures	19
2.3 Bromine	24
General	24
Products	24
Kinetics and Thermodynamics of the Reactions	25
Influence of Additions and Impurities	26
Bombardment Effects	29
2.4 Iodine	30
General. Products	30
Kinetics and Thermodynamics of the Reactions	31
Influence of Additions and Impurities	32
Bombardment Effects and Diffusion	32
2.5 Transport Reactions in Tungsten–Halogen Lamps	34
2.5.1 General	34
Features of Tungsten–Halogen Lamps	34
General Characteristics of the Transport Processes in Tungsten–Halogen Lamps	35
Thermochemical Analyses	36
Kinetic Analyses	45
2.5.2 Tungsten–Fluorine Systems	46
W–F Containing Systems	46

	Page
W-F-H Containing Systems	50
W-F-O Containing Systems	51
W-F-O-H Containing Systems	51
W-F-C(-H) Containing Systems	54
W-F-O-C Containing Systems	56
W-F Systems with Additional B, Si, P Components	58
2.5.3 Tungsten-Chlorine Systems	61
W-Cl Containing Systems	61
W-Cl-H Containing Systems	64
W-Cl-O Containing Systems	66
W-Cl-O-H Containing Systems	69
W-Cl-N Containing Systems	71
W-Cl-C(-H) Containing Systems	71
W-Cl-O-C Containing Systems	71
W-Cl-O-Si Containing Systems	75
W-Cl-F-C and W-Cl-F-Si Containing Systems	76
2.5.4 Tungsten-Bromine Systems	79
General	79
W-Br Containing Systems	80
W-Br-H Containing Systems	81
W-Br-O Containing Systems	85
W-Br-O-H Containing Systems	87
W-Br-N Containing Systems	89
W-Br-C(-H) Containing Systems	90
W-Br-O-C Containing Systems	91
W-Br-O-C-H Containing Systems	94
W-Br-F-C Containing Systems	99
2.5.5 Tungsten-Iodine Systems	102
General	102
Reaction Mechanisms. Thermodynamics	103
W-I-H Containing Systems	104
W-I-O Containing Systems	104
W-I-O-H Containing Systems	106
W-I-O-C-H Containing Systems	107
W-I-Br-H Containing Systems	108
W-I Systems with Additional Sc, Na, Sn	109
3 Reactions with Sulfur	110
Phase Diagram. Products	110
Reaction Characteristics	111
Diffusion	114
4 Reactions with Selenium	116
General. Products	116
Reaction Characteristics	117

5 Reactions with Tellurium	122
6 Reactions with Polonium	123
7 Reactions with Boron	123
Phase Diagram	123
Reaction Characteristics	126
Bombardment Effects	128
Diffusion	128
8 Reactions with Carbon	131
8.1 Phase Diagram	131
Intermediate Phases	132
W_2C Phase	132
$WC_{1-x}(\gamma)$ Phase	133
WC Phase	133
Eutectics	134
Solid Solubilities of Carbon in Tungsten	134
8.2 Reaction Characteristics	137
Reaction Products and Reaction Extent	137
Carbides Formed in Melts	137
Carbides Formed in Heated Powder Mixtures	137
Carbides Formed from Dense W Samples	142
Carbide Formation in W-C Films and Multilayers	142
Carbides Formed in an Argon Plasma and by Spark-Treatment	143
Kinetics	143
Mechanism	144
Thermodynamics	145
Influence of Impurities and Additions	145
Bombardment Effects	146
8.3 Diffusion	150
Carbon Diffusion Through Tungsten	150
Carbon Diffusion Through Tungsten Carbide Layers	152
Grain Boundary Diffusion	152
Carbon Diffusion in Molten Tungsten	153
9 Reactions with Silicon	154
9.1 Phase Diagram	154
Intermediate Phases	156
W_5S_3 , WSi_2	156
W_3Si , W_2Si , and WSi	157
Solid Solubilities	158
9.2 Reaction Characteristics	160

	Page
9.2.1 Silicide Formation on Compact Tungsten	160
Solid Phase Reactions Between Bulk Samples	160
Reactions of W With Si Powder	161
Reactions in Mixtures of W and Si Powders	162
Reactions Involving Melts	163
Reactions Between Tungsten and Silicon Vapor	164
Reactions of Tungsten With Silicon Films	164
9.2.2 Reactions of Tungsten Films With Silicon	169
Silicide Formation	169
in CVD Generated W Films	170
in Sputter-Deposited W Films	170
in W Films Generated by Electron-Beam Evaporation	170
Effects of Laser Annealing	171
Effects of Electron-Beam Irradiation	171
Effects of Pulsed Proton-Beam Irradiation	171
Influence of Oxygen	171
Influence of Other Impurities and Dopants	172
Influence of Ion Implantation and Ion-Beam Irradiation	172
Effects of Annealing Atmosphere	173
Reactions in Sandwich Structures	173
Reactions in Multilayers	174
Reactions in Codeposited W-Si Films	175
Cosputtered WSi_x Films on GaAs	176
Stresses Induced by Silicide Formation	176
Influence of Ti, TiN, and $TiSi_2$ Interlayers	177
Effects of Alloying	177
Epitaxy	178
Kinetics	178
9.2.3 Gas Phase Reactions	186
9.3 Diffusion	186
Diffusion of Tungsten in Silicon	186
Diffusion of Silicon in Tungsten	187
Tungsten-Silicon Interdiffusion	188
Diffusion in the Silicide Layer	188
10 Reactions with Phosphorus	191
Phase Diagram	191
Reaction Characteristics	192
Diffusion	192
11 Reactions with Arsenic	194
Physical Constants and Conversion Factors	195