

Contents

Preface XI

1	Hall-Current Ion Sources	1
1.1	Introduction	1
1.2	Closed Drift Ion Sources	2
1.3	End-Hall Ion Sources	5
1.4	Electric Discharge and Ion Beam Volt–Ampere Characteristics	19
1.5	Operating Parameters Characterizing Ion Source	24
	References	26
2	Ion Source and Vacuum Chamber. Influence of Various Effects on Ion Beam Parameters	29
2.1	Introduction	29
2.2	Mass Entrainment	32
2.3	Charge-Exchange Influence on Ion Beam Flow	34
2.4	Doubly Ionized Particles and Their Role	36
2.5	Influence of Vacuum Chamber Pumping Rate	40
2.6	Dielectric Depositions on an Anode During Operation with Reactive Gases	41
2.7	Estimation of Returned Sputtered Particles to Ion Source	43
2.8	Influence of Ion Source Heating on its Operation	47
2.9	Negative Ions and their Role	48
2.10	Conclusion	50
	References	50
3	Oscillations and Instabilities in Hall-Current Ion Sources	53
3.1	Introduction	53
3.2	Oscillations and Instabilities	56
3.3	Types of Oscillations	56
3.3.1	Ionization Oscillations	56
3.3.2	Flight Oscillations	58
3.3.3	Contour Oscillations	58

3.3.4	Hybrid Azimuthal Oscillations	60
3.3.5	Oscillations Due to High Pressure	61
3.3.6	Oscillations Due to Ion Beam Underneutralization	61
3.3.7	Oscillations Due to Incorrect Operation	62
3.3.8	Oscillations Due to Presence of Water Vapors	62
3.4	Conclusions and What to Do About Oscillations	63
	References	64
4	Optimum Operation of Hall-Current Ion Sources	67
4.1	Introduction	67
4.2	Regime of Nonself-Sustained Discharge and Optimum Operation Conditions of End-Hall Ion Source	70
4.2.1	Discharge Volt–Ampere Characteristics	70
4.3	Operation of End-Hall Ion Source with Excessive Electron Emission	71
4.4	Ion Beam Energy of End-Hall Ion Source	73
4.5	End-Hall Ion Source Optimum Magnetic Field for Ion Beam Current	76
4.6	Ion Beam Energy Distribution as a Function of Angle With Various Emission Currents	81
4.7	Conclusion	82
	References	83
5	Cathode Neutralizers for Ion Sources	85
5.1	Introduction	85
5.2	Ion Beam and its Practical Neutralization	87
5.3	Hot Filament Electron Source and Thermoelectron Emission	93
5.3.1	Richardson–Dushman Formula for Thermoelectron Emission Current Density	93
5.3.2	Recent Improvements in HF Design	101
5.4	Hollow Cathodes	105
5.4.1	Introduction	105
5.4.2	Hollow Cathode Physics	109
5.4.3	Hollow Cathodes for Industrial Ion Sources	115
5.4.4	HC Modes of Operation	121
5.4.5	Hollow Cathode Tip and Keeper	123
5.4.6	General Conclusions about Hollow Cathodes	125
5.4.7	Other Cathodes for Ion Sources	126
5.4.7.1	Plasma Bridge	126
5.4.7.2	Neutralizer with Closed Electron Drift	128
5.4.7.3	Radio-Frequency Neutralizers	129
5.4.7.4	Cold Cathodes	134
5.4.7.5	Neutralization with Alternating Current	135
5.4.7.6	Plasma Bridge Based on Magnetron Discharge Principles	136
5.4.7.7	Ion Beam Neutralization with Magnetron Electrons	139

5.4.7.8	Ion Beam Neutralization with Electron Gun	140
5.4.7.9	Microwave Discharge Neutralizer	141
5.4.8	Cathode Erosion Rates	141
5.4.9	Important Features of Cathode Neutralizers	142
5.5	Conclusions about Cathode Neutralizers	142
	Appendix 5.A: Web Addresses	144
	References	144
6	Industrial Gridless Broad-Beam Ion Source Producers, Problems and the Need for Their Standardization	149
6.1	World Producers of Ion Sources	149
6.1.1	Theoretical Consideration for Closed Electron Drift Design	154
6.2	Specific Designs of End-Hall-Current Ion Sources for Thin Film Technology	159
6.3	Nontraditional Broad Beam Ion Sources	168
6.4	Linear Ion Sources	178
6.5	Hall-Current Ion Sources Basic Operation Parameter Problems	183
6.6	The Need for Standardization of Ion Sources	190
6.7	Conclusions	194
	Appendix 6.A: Web Addresses	194
	References	195
7	Operation of Industrial Ion Sources with Reactive Gases	197
7.1	Introduction	197
7.2	Low- and High-Temperature Oxidation	198
7.3	Ion Source Operation with Dielectric and Insulating Depositions on an Anode	199
7.4	End-Hall with Grooved Anode and Baffle	203
7.5	End-Hall With Hidden Anode Area for Continuing Discharge Operation	205
7.6	Practical Operation of Hall-Current Ion Sources with Reactive Gases	206
	References	208
8	Ion Beam and Radiation Impact on Substrate Heating	209
8.1	Introduction	209
8.2	Target-Substrate Heating By Radiation and Ion Beam	211
8.3	Experimental Measurements of Ion Beam and Radiation Impact on a Target-Substrate	218
8.4	Conclusion	222
	Appendix A.8: Web Addresses	222
	References	222

9	Ion Beam Energy and Current	223
9.1	Introduction	223
9.2	Ion Beam Energy Distribution	225
9.3	Retarding Potential Probes	228
	References	240
10	Plasma Optical Systems	241
10.1	Introduction	241
10.2	Plasma Optics Evolution	242
10.3	Electrostatic Fields in Plasma	243
10.4	Plasma Optical Systems with Equipotential Magnetic Field Lines	244
10.5	Plasma Lenses	245
10.6	Practical Applications of Plasma Optical Systems in Technology	248
10.6.1	Ion Beam Focusing and Defocusing with Plasma Lens	248
10.6.2	Ion Beam Soldering with Focused or Partially Focused Ion Beam	249
	References	254
11	Ion and Plasma Sources for Science and Technology	255
11.1	Introduction	255
11.2	Vacuum Pump	255
11.3	Commutating Properties of Gas Discharge in Magnetic Field	256
11.3.1	Plasma Switch	257
11.4	Hollow Cathode as Vacuum Valve	258
11.5	Ion Source for Levitation	260
11.6	Hydrogen Motion through Metal Membrane for MPD Plasma Source	261
11.7	Plasmaoptical Mass Separator	262
11.8	Plasma Stealth and Other Effects in Modern Aerodynamics	263
11.9	Conclusion	266
	References	266
12	Ion Assist, and Its Different Applications	269
12.1	Introduction	269
12.2	Ion Beam Sputtering	270
12.3	Ion Assisted Deposition	272
12.4	Biased Target Deposition	278
12.5	Ion Assisted Magnetron Deposition with Magnetron Electrons for Ion Beam Neutralization	280
12.5.1	Ion Afflux and Ion Assist	281
12.6	Ion Assisted Magnetron Discharge for Enhancement of Cathode Sputtering	283
12.6.1	Magnetron Discharge with Ion Beam Assist	283

12.7	Conclusion	285
	References	285
13	Magnetron with Non-equipotential Cathode	287
13.1	Introduction	287
13.2	Short History of Magnetron Development	288
13.3	Magnetron with Segments at Different Potentials	292
13.4	The Phenomenology of a Magnetron Discharge with NEC	304
13.5	Conclusion	306
	References	307
	Index	309

