

Contents

Preface	vii
Acknowledgments	xi
1 SPECIFIC ELEMENTS OF PLASMA PHYSICS APPLIED TO ELECTRON CYCLOTRON RESONANCE ION SOURCES (ECRIS)	1
1.1 The breakthrough of the ECRIS and its plasma background	1
1.2 Preliminary aspects of plasma at the electron cyclotron resonance	14
1.3 Collective plasma phenomena	25
1.4 Atomic physics background in ECRIS plasma	60
1.5 Motions of charged particles in ECRIS plasma	93
1.6 Confinement in magnetic mirror fields	115
1.7 The difficult modelling of diffusion processes in magnetoplasmas	131
2 WAVE-PLASMA INTERACTIONS	147
2.1 Basic aspects of small amplitude EM waves incident on a cold magnetoplasma	147
2.2 Specific aspects of waves in warm plasma	158
2.3 Electron heating in the ECR plasma	168
2.4 Wave launchers and coupling structures	200
3 THE ECRIS PLASMA STATES—BREAKDOWN, STEADY STATE AND AFTERGLOW	216
3.1 ECRIS breakdown at low pressure in a vacuum cavity	216
3.2 ECRIS steady state discharges, a tentative physical analysis	222
3.3 Simple magnetic bottle ECRIS; experimental steady state characteristics	236
3.4 Min- <i>B</i> ECRIS: steady state electron characteristics	249
3.5 ECRIS afterglow regimes (or post-discharge)	256

4	ION CHARACTERISTICS AND ION PROCESSES IN ECRIS PLASMA	266
4.1	Ion heating	266
4.2	Improvement of multicharged ion confinement in ES potential traps	267
4.3	Theoretical ion confinement times with electrostatic potentials at steady state	268
4.4	Criteria for multiply charged ion production	271
4.5	The power flux criterion and the importance of the lifetime of energy τ_{en} in ion sources	273
4.6	The necessity of electron confinement, and low power dissipation	275
4.7	The neutral gas density criterion for MI production in steady state	276
4.8	Semi-theoretical analysis of highly charged ion production	278
4.9	Ion extraction from the ECRIS plasma	289
4.10	Emittance of a source (generalities)	303
4.11	ECRIS beam emittances	307
5	SIMPLE MIRROR AND BUCKET ECRIS FOR LESS HIGHLY CHARGED IONS	311
5.1	The history of the first ECR ion sources (1965–1973)	311
5.2	Modern simple mirror ECRIS	325
5.3	Overdense ECRIS at 2.45 GHz for ion beam processing	331
5.4	Industrial ECR plasma and ion sources research at Michigan State University	346
5.5	ECR plasma cathode (also called microwave plasma cathode)	351
5.6	ECRIS for specific weakly charged ions	357
6	MIN-<i>B</i> ECRIS FOR HIGHLY CHARGED IONS	362
6.1	A brief history of the development of ECRIS for multiply charged ions	362
6.2	The status of understanding of min- <i>B</i> ECRIS	365
6.3	The magnetic structure in modern min- <i>B</i> ECRIS	376
6.4	Highly charged metal ions production in min- <i>B</i> ECRIS	380
6.5	Specific applications of the min- <i>B</i> ECRIS	391
6.6	Scaling rule attempts and practical results	394
6.7	Comparative min- <i>B</i> ECRIS	398
6.8	Conclusions and prospects of min- <i>B</i> ECRIS	409
	References	413
	Index	430