
Contents

1	Basics of the Einstein Relation	1
1.1	Introduction	1
1.2	Generalized Formulation of the Einstein Relation for Multi-Band Semiconductors	2
1.3	Suggestions for the Experimental Determination of the Einstein Relation in Semiconductors Having Arbitrary Dispersion Laws	4
1.4	Summary	7
	References	8
2	The Einstein Relation in Bulk Specimens of Compound Semiconductors	13
2.1	Investigation on Tetragonal Materials	13
2.1.1	Introduction	13
2.1.2	Theoretical Background	14
2.1.3	Special Cases for III–V Semiconductors	16
2.1.4	Result and Discussions	19
2.2	Investigation for II–VI Semiconductors	26
2.2.1	Introduction	26
2.2.2	Theoretical Background	27
2.2.3	Result and Discussions	28
2.3	Investigation for Bi in Accordance with the McClure–Choi, the Cohen, the Lax, and the Parabolic Ellipsoidal Band Models	29
2.3.1	Introduction	29
2.3.2	Theoretical Background	29
2.3.3	Result and Discussions	33
2.4	Investigation for IV–VI Semiconductors	34
2.4.1	Introduction	34
2.4.2	Theoretical Background	34
2.4.3	Result and Discussions	35

2.5	Investigation for Stressed Kane Type Semiconductors.....	35
2.5.1	Introduction	35
2.5.2	Theoretical Background	36
2.5.3	Result and Discussions	37
2.6	Summary	38
2.7	Open Research Problems	38
	References	48
3	The Einstein Relation in Compound Semiconductors	
	Under Magnetic Quantization	51
3.1	Introduction	51
3.2	Theoretical Background	52
3.2.1	Tetragonal Materials	52
3.2.2	Special Cases for III-V, Ternary and Quaternary Materials	56
3.2.3	II-VI Semiconductors	63
3.2.4	The Formulation of DMR in Bi	65
3.2.5	IV-VI Materials	75
3.2.6	Stressed Kane Type Semiconductors	75
3.3	Result and Discussions	77
3.4	Open Research Problems	95
	References	104
4	The Einstein Relation in Compound Semiconductors	
	Under Crossed Fields Configuration	107
4.1	Introduction	107
4.2	Theoretical Background	108
4.2.1	Tetragonal Materials	108
4.2.2	Special Cases for III-V, Ternary and Quaternary Materials	112
4.2.3	II-VI Semiconductors	116
4.2.4	The Formulation of DMR in Bi	118
4.2.5	IV-VI Materials	127
4.2.6	Stressed Kane Type Semiconductors	127
4.3	Result and Discussions	130
4.4	Open Research Problems	150
	References	155
5	The Einstein Relation in Compound Semiconductors	
	Under Size Quantization	157
5.1	Introduction	157
5.2	Theoretical Background	158
5.2.1	Tetragonal Materials	158
5.2.2	Special Cases for III-V, Ternary and Quaternary Materials	159

5.2.3	II–VI Semiconductors	162
5.2.4	The Formulation of 2D DMR in Bismuth	163
5.2.5	IV–VI Materials	169
5.2.6	Stressed Kane Type Semiconductors	173
5.3	Result and Discussions	174
5.4	Open Research Problems	189
	References	195
6	The Einstein Relation in Quantum Wires of Compound Semiconductors	197
6.1	Introduction	197
6.2	Theoretical Background	198
6.2.1	Tetragonal Materials	198
6.2.2	Special Cases for III–V, Ternary and Quaternary Materials	199
6.2.3	II–VI Materials	202
6.2.4	The Formulation of 1D DMR in Bismuth	203
6.2.5	IV–VI Materials	207
6.2.6	Stressed Kane Type Semiconductors	210
6.2.7	Carbon Nanotubes	211
6.3	Result and Discussions	212
6.4	Open Research Problems	227
	References	231
7	The Einstein Relation in Inversion Layers of Compound Semiconductors	235
7.1	Introduction	235
7.2	Theoretical Background	236
7.2.1	Formulation of the Einstein Relation in n-Channel Inversion Layers of Tetragonal Materials	236
7.2.2	Formulation of the Einstein Relation in n-Channel Inversion Layers of III–V, Ternary and Quaternary Materials	241
7.2.3	Formulation of the Einstein Relation in p-Channel Inversion Layers of II–VI Materials	248
7.2.4	Formulation of the Einstein Relation in n-Channel Inversion Layers of IV–VI Materials	250
7.2.5	Formulation of the Einstein Relation in n-Channel Inversion Layers of Stressed III–V Materials	255
7.3	Result and Discussions	260
7.4	Open Research Problems	272
	References	277

8	The Einstein Relation in Nipi Structures of Compound Semiconductors	279
8.1	Introduction	279
8.2	Theoretical Background	280
8.2.1	Formulation of the Einstein Relation in Nipi Structures of Tetragonal Materials	280
8.2.2	Einstein Relation for the Nipi Structures of III-V Compounds	281
8.2.3	Einstein Relation for the Nipi Structures of II-VI Compounds	283
8.2.4	Einstein Relation for the Nipi Structures of IV-VI Compounds	285
8.2.5	Einstein Relation for the Nipi Structures of Stressed Kane Type Compounds	288
8.3	Result and Discussions	289
8.4	Open Research Problems	295
	References	298
9	The Einstein Relation in Superlattices of Compound Semiconductors in the Presence of External Fields	301
9.1	Introduction	301
9.2	Theoretical Background	302
9.2.1	Einstein Relation Under Magnetic Quantization in III-V Superlattices with Graded Interfaces	302
9.2.2	Einstein Relation Under Magnetic Quantization in II-VI Superlattices with Graded Interfaces	304
9.2.3	Einstein Relation Under Magnetic Quantization in IV-VI Superlattices with Graded Interfaces	307
9.2.4	Einstein Relation Under Magnetic Quantization in HgTe/CdTe Superlattices with Graded Interfaces	310
9.2.5	Einstein Relation Under Magnetic Quantization in III-V Effective Mass Superlattices	312
9.2.6	Einstein Relation Under Magnetic Quantization in II-VI Effective Mass Superlattices	314
9.2.7	Einstein Relation Under Magnetic Quantization in IV-VI Effective Mass Superlattices	315
9.2.8	Einstein Relation Under Magnetic Quantization in HgTe/CdTe Effective Mass Superlattices	316
9.2.9	Einstein Relation in III-V Quantum Wire Superlattices with Graded Interfaces	318
9.2.10	Einstein Relation in II-VI Quantum Wire Superlattices with Graded Interfaces	319
9.2.11	Einstein Relation in IV-VI Quantum Wire Superlattices with Graded Interfaces	321

9.2.12 Einstein Relation in HgTe/CdTe Quantum Wire
Superlattices with Graded Interfaces 323

9.2.13 Einstein Relation in III-V Effective Mass Quantum
Wire Superlattices 324

9.2.14 Einstein Relation in II-VI Effective Mass Quantum
Wire Superlattices 326

9.2.15 Einstein Relation in IV-VI Effective Mass Quantum
Wire Superlattices 327

9.2.16 Einstein Relation in HgTe/CdTe Effective Mass
Quantum Wire Superlattices 328

9.3 Result and Discussions 329

9.4 Open Research Problems 333

References 339

**10 The Einstein Relation in Compound Semiconductors
in the Presence of Light Waves**..... 341

10.1 Introduction 341

10.2 Theoretical Background 342

10.2.1 The Formulation of the Electron Dispersion
Law in the Presence of Light Waves in III-V,
Ternary and Quaternary Materials 342

10.2.2 The Formulation of the DMR in the Presence of Light
Waves in III-V, Ternary and Quaternary Materials .. 352

10.3 Result and Discussions 354

10.4 The Formulation of the DMR in the Presence of Quantizing
Magnetic Field Under External Photo-Excitation in III-V,
Ternary and Quaternary Materials 360

10.5 Theoretical Background 361

10.6 Result and Discussions 363

10.7 The Formulation of the DMR in the Presence of Cross-Field
Configuration Under External Photo-Excitation in III-V,
Ternary and Quaternary Materials 372

10.8 Theoretical Background 372

10.9 Result and Discussions 376

10.10 The Formulation of the DMR for the Ultrathin Films
of III-V, Ternary and Quaternary Materials Under External
Photo-Excitation 379

10.11 Result and Discussions 387

10.12 The Formulation of the DMR in QWs of III-V, Ternary
and Quaternary Materials Under External Photo-Excitation .. 389

10.13 Result and Discussions 398

10.14 Summary 401

10.15 Open Research Problem 402

References 407

11 The Einstein Relation in Heavily Doped Compound Semiconductors	413
11.1 Introduction	413
11.2 Theoretical Background	414
11.2.1 Study of the Einstein Relation in Heavily Doped Tetragonal Materials Forming Gaussian Band Tails ...	414
11.2.2 Study of the Einstein Relation in Heavily Doped III–V, Ternary and Quaternary Materials Forming Gaussian Band Tails	423
11.2.3 Study of the Einstein Relation in Heavily Doped II–VI Materials Forming Gaussian Band Tails	426
11.2.4 Study of the Einstein Relation in Heavily Doped IV–VI Materials Forming Gaussian Band Tails	428
11.2.5 Study of the Einstein Relation in Heavily Doped Stressed Materials Forming Gaussian Band Tails	432
11.3 Result and Discussions	435
11.4 Open Research Problems	439
References	447
12 Conclusion and Future Research	449
Materials Index	453
Subject Index	455