

Series on Advances in Mathematics for Applied Sciences – Vol. 70

MULTIGROUP EQUATIONS FOR THE DESCRIPTION OF THE PARTICLE TRANSPORT IN SEMICONDUCTORS

Martin Galler

Graz University of Technology, Austria

 **World Scientific**

NEW JERSEY • LONDON • SINGAPORE • BEIJING • SHANGHAI • HONG KONG • TAIPEI • CHENNAI

Published by

World Scientific Publishing Co. Pte. Ltd.

5 Toh Tuck Link, Singapore 596224

USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601

UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

Library of Congress Cataloging-in-Publication Data

Galler, Martin, 1977–

Multigroup equations for the description of the particle transport in
semiconductors / Martin Galler.

p. cm. -- (Series on advances in mathematics for applied sciences ; v. 70)

ISBN 981-256-355-5 (alk. paper)

1. Transport theory--Mathematics. 2. Semiconductors--Mathematics. I.

Title. II. Series.

QC793.3.T7 G35 2005

530.13'8--dc22

2005049431

British Library Cataloguing-in-Publication Data

A catalogue record for this book is available from the British Library.

Copyright © 2005 by World Scientific Publishing Co. Pte. Ltd.

All rights reserved. This book, or parts thereof, may not be reproduced in any form or by any means, electronic or mechanical, including photocopying, recording or any information storage and retrieval system now known or to be invented, without written permission from the Publisher.

For photocopying of material in this volume, please pay a copying fee through the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, USA. In this case permission to photocopy is not required from the publisher.

Contents

<i>Preface</i>	vii
1. Introduction	1
2. The Bloch-Boltzmann-Peierls Equations	5
2.1 Introduction	5
2.2 Electrons in Semiconductors	5
2.3 Phonons in Semiconductors	9
2.4 Scattering Mechanisms	11
2.4.1 General Theory of Scattering	12
2.4.2 Phonon Scattering	14
2.4.2.1 Non-polar Phonon Scattering	15
2.4.2.2 Polar Phonon Scattering	19
2.4.3 Ionized Impurity Scattering	22
2.5 Semiclassical Dynamics of Electrons	24
2.6 The Bloch-Boltzmann-Peierls Equations	26
2.7 Mathematical Properties of the BBP Equations	32
3. Multigroup Model Equations for Polar Semiconductors	37
3.1 Introduction	37
3.2 Multigroup Equations to the Bloch-Boltzmann-Peierls Equations	38
3.2.1 The Electron Boltzmann Equation	40
3.2.2 The LO Phonon Boltzmann Equation	45
3.2.3 The Coupling POP Interaction Term	47
3.2.4 The Evaluation of the Collision Coefficients	51

3.3	Conservation Laws	53
4.	Particle Transport in Indium Phosphide	61
4.1	Introduction	61
4.2	Two-valley Model	61
4.2.1	Validation of the Method	64
4.2.2	Electron Distribution Function	66
4.2.3	Phonon Distribution Function	68
4.2.4	Transport Parameters	69
4.3	Three-valley Model	71
5.	Particle Transport in Gallium Arsenide	77
5.1	Introduction	77
5.2	Transport in a Time-dependent Electric Field	78
5.3	The Stationary-state Electron Distribution	82
6.	Multigroup Equations for Degenerated Carrier Gases	87
6.1	Introduction	87
6.2	The Bloch-Boltzmann-Peierls Equations	88
6.3	The Multigroup Model Equations	89
6.4	Mathematical Aspects of the Multigroup Model Equations	93
6.4.1	Boundedness of the Solution	93
6.4.2	Conservation Laws	95
6.4.3	H-theorem	96
6.4.4	Equilibrium Solution	98
6.5	Numerical Results	100
7.	The Two-dimensional Electron Gas	107
7.1	Introduction	107
7.2	General Theory of Transport in Confined Systems	107
7.2.1	Dispersion Laws	107
7.2.2	Scattering Mechanisms	111
7.2.2.1	Acoustic Deformation Potential Scattering	112
7.2.2.2	Piezoelectric Scattering	114
7.2.2.3	Polar Optical Phonon Scattering	115
7.2.2.4	Screening Effects	118
7.2.3	BBP Equations for 2D Systems	120
7.3	Multigroup Equations to the 2D-BBP Equations	124

7.4	Transport in $\text{Al}_x\text{Ga}_{1-x}\text{N}/\text{GaN}$	132
7.4.1	Self-consistent Solution for Confining Potential . . .	135
7.4.2	Transport Properties	139
7.4.3	Distribution Functions	145
8.	The Multigroup-WENO Solver for Semiconductor Device Simulation	147
8.1	Introduction	147
8.2	The Boltzmann-Poisson System	148
8.3	The Multigroup-WENO Scheme	150
9.	Simulation of Silicon Devices	155
9.1	Introduction	155
9.2	Transport in Bulk Silicon	157
9.3	The Silicon $n^+ - n - n^+$ Diode	158
9.4	The Si-MESFET	162
9.5	The Si-MOSFET	172
10.	Simulation of Gallium Arsenide Devices	191
10.1	Introduction	191
10.2	Bulk GaAs	193
10.3	The GaAs $n^+ - n_i - n^+$ Diode	195
10.4	The GaAs-MESFET	200
11.	Conclusion	213
	<i>Bibliography</i>	217
	<i>Related Publications of the Author</i>	223
	<i>Index</i>	225