PREFACE

MANY observed effects in semiconducting materials are determined in part by the densities of electrons and holes in the various bands and levels. A carrier density cannot of course be measured directly; the magnitude of an observed quantity is always concerned with other attributes of carriers as well as their density. (Thus electrical conductivity depends on the densities of electrons *and* on their mobilities.) Several recently published books (e.g. 1953:**4**, 1958:**9**, 1960:**19**) dwell at length on the relationships between carrier densities and transport effects, and the subject matter of this volume is complementary to that topic.

The book is divided into two parts. Part I, of three chapters, provides introductory material on the electron theory of solids and then discusses carrier statistics for semiconductors in thermal equilibrium. Of course a solid cannot be in true thermodynamic equilibrium if any electrical current is passed; but when currents are reasonably small the distribution function is but little perturbed, and the carrier distribution for such a "quasi-equilibrium" condition is inappreciably different from that of thermal equilibrium itself. Thus the results of Part I are not invalidated when the properties of a semiconductor are measured using small current densities.

The seven chapters of Part II consider non-equilibrium statistics, for semiconductors with appreciable excess carrier densities. The various kinds of recombination mechanism are considered in turn, and the consequences discussed for steady state and transient situations. No attempt is made to expose the special problems of semiconductor contacts and junctions, since these have been treated so extensively in other recent volumes (e.g. 1957:**32**, 1960:**17**).

The subject matter of this book is deliberately restricted in scope so that the volume may be of maximum value to scientists with an active interest in the basic properties of semiconducting materials. The introductory material of Chapter 1 should help to make the book useful to those who are approaching semiconductors as a new field of

specialization. Appreciation of Chapter 1 is aided by some awareness of basic quantum-mechanical principles, but a detailed knowledge of that subject is certainly not necessary in order to make use of the results presented here.

Dr. Henisch first suggested the writing of this book in 1952, and I have been conscious since that time of his encouragement. Enough is now known about recombination processes to permit a hope that this volume might remain useful for some time.

I should like to express my appreciation of the help given by a number of other colleagues and friends. My first interest in thermal equilibrium carrier statistics was stimulated by Mr. G. King, Mr. T. R. Scott and Mr. A. C. Sim. It is a pleasure to acknowledge the encouragement given by Dr. V. W. Bearinger and Dr. F. J. Larsen to basic recombination studies at Honeywell. In both the experimental and theoretical aspects of these studies I have enjoyed a close collaboration with Dr. K. C. Nomura, and many of the ideas in Chapters 8 and 10 were developed jointly with Dr. Nomura. His comments on this manuscript, and those of Dr. S. R. Morrison Dr. A. Nussbaum, and Professor P. T. Lansberg have helped in the elimination of many errors and obscurities. The difficult task of typing the manuscript has been undertaken by Mrs. C. Lehr, and that of preparing the figures by Mrs. V. Squier; hearty thanks are due to both. My wife, June Blakemore, has been forced into the role of an observer as the writing process has enveloped her husband's existence for many months; her faith and constant encouragement have indeed been appreciated.

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