Electron and Ion Optics

MICRODEVICES
Physics and Fabrication Technologies

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To Jutka, Gabor, and Zoltan
For the time that should have belonged to them

Preface

The field of electron and ion optics is based on the analogy between geometrical light optics and the motion of charged particles in electromagnetic fields. The spectacular development of the electron microscope clearly shows the possibilities of image formation by charged particles of wavelength much shorter than that of visible light.

As new applications such as particle accelerators, cathode ray tubes, mass and energy spectrometers, microwave tubes, scanning-type analytical instruments, heavy beam technologies, etc. emerged, the scope of particle beam optics has been extended to the formation of fine probes. The goal is to concentrate as many particles as possible in as small a volume as possible.

Fabrication of microcircuits is a good example of the growing importance of this field. The current trend is towards increased circuit complexity and pattern density. Because of the diffraction limitation of processes using optical photons and the technological difficulties connected with x-ray processes, charged particle beams are becoming popular. With them it is possible to write directly on a wafer under computer control, without using a mask. Focused ion beams offer especially great possibilities in the submicron region. Therefore, electron and ion beam technologies will most probably play a very important role in the next twenty years or so.

Many books have been published on different aspects of the theory and applications of electron and ion optics. This one is intended to be a self-contained, systematic and *up-to-date* introduction to the field. The reader can find the derivation of the most essential relationships, the understanding of which is absolutely necessary to do any meaningful work with particle beams and optics, but which are usually presented without proof in most books. *Modern computer methods are especially emphasized.* The book can serve as a textbook for engineers, scientists, and graduate students who wish to understand the basic principles of electron and ion optics and apply them to the design and/or operation of beam-type devices and instruments.

The author is well aware of the fact that it is not easy to reach these goals. One volume is hardly adequate even to cover the theoretical foundations and most important applications. Therefore, the treatment is restricted to the presentation of the basics and the most recent results of research, including the author's own. Throughout the book the relevance of the presented material to practical applications is emphasized, but no attempt has been made to review the applications themselves. We have given over 400 basic references, including publications that report on recent developments in the field. Owing to limitations of space, the list of references is very far from being complete.

To study this book no previous acquaintance with physical electronics is required. The necessary introductory information is presented in Chapter 1. The theoretical material is derived from basic principles. Because of the mathematical nature of the subject, however, a thorough knowledge of calculus (including vector calculus) is presupposed.

The author has been working in this field since 1958. It was a great joy for me to be able to sit down and summarize the basics of my knowledge in the present volume. This knowledge has been accumulated in the course of interaction with numerous people. I am especially greatful to Professors V. M. Kelman, S. Ya. Yavor, and A. D. Sushkov and to the memory of the unforgettable Dennis Gabor. My research work in the last three years has been supported by the National Science Foundation. I appreciate the continuous support of Dean T. Triffet of the University of Arizona, the inspiration of the editors of this series, and the high-quality work of Plenum Press. The book would have never been completed without the encouragement, patience, and love of my family.

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