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RADIATION LABORATORY SERIES

LOUIS N. RIDENOUR, *Editor-in-Chief*

CRYSTAL RECTIFIERS

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CRYSTAL RECTIFIERS

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CRYSTAL RECTIFIERS

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Foreword

THE tremendous research and development effort that went into the development of radar and related techniques during World War II resulted not only in hundreds of radar sets for military (and some for possible peacetime) use but also in a great body of information and new techniques in the electronics and high-frequency fields. Because this basic material may be of great value to science and engineering, it seemed most important to publish it as soon as security permitted.

The Radiation Laboratory of MIT, which operated under the supervision of the National Defense Research Committee, undertook the great task of preparing these volumes. The work described herein, however, is the collective result of work done at many laboratories, Army, Navy, university, and industrial, both in this country and in England, Canada, and other Dominions.

The Radiation Laboratory, once its proposals were approved and finances provided by the Office of Scientific Research and Development, chose Louis N. Ridenour as Editor-in-Chief to lead and direct the entire project. An editorial staff was then selected of those best qualified for this type of task. Finally the authors for the various volumes or chapters or sections were chosen from among those experts who were intimately familiar with the various fields, and who were able and willing to write the summaries of them. This entire staff agreed to remain at work at MIT for six months or more after the work of the Radiation Laboratory was complete. These volumes stand as a monument to this group.

These volumes serve as a memorial to the unnamed hundreds and thousands of other scientists, engineers, and others who actually carried on the research, development, and engineering work the results of which are herein described. There were so many involved in this work and they worked so closely together even though often in widely separated laboratories that it is impossible to name or even to know those who contributed to a particular idea or development. Only certain ones who wrote reports or articles have even been mentioned. But to all those who contributed in any way to this great cooperative development enterprise, both in this country and in England, these volumes are dedicated.

L. A. DUBRIDGE.

Preface

With the development of microwave radar, the crystal rectifier, which had been little used since the invention of the vacuum tube several decades ago, again became important—as important as the magnetron, klystron, or other microwave components.

In the past five years crystal rectifiers have been manufactured, literally by the millions, for use primarily as microwave detectors. A correspondingly large amount of fundamental research and engineering development has taken place in the commercial and governmental laboratories in the United States and in England. As a result the crystal-rectifier unit that has emerged is a compact, stable device which is superior in many applications to the vacuum-tube diode. Its most extensive use up to now has been as a frequency converter in microwave reception, where its performance has not been equaled. It has also been used to a lesser extent as a low-level microwave detector.

The recent development of germanium rectifiers capable of withstanding relatively high inverse voltages holds great promise for applications as second detectors in wideband receivers and in a variety of other circuits where vacuum-tube diodes are ordinarily used.

The purpose of this book is to present the fund of knowledge on crystal rectifiers that has accumulated during the course of World War II. Because of the need in radar systems for high-quality microwave converters, a large fraction of the work was expended for the development of crystal rectifiers for this application. A correspondingly large fraction of the book has, therefore, been devoted to the theory and properties of the crystal converter. Other applications are discussed in Part III as Special Types.

As in every other branch of microwave work, the development of measuring equipment and techniques has taken place simultaneously with that of the crystal rectifier itself. We have, therefore, included detailed discussions of methods of measurement of crystal properties and a description of standard test equipment for production and routine testing.

The techniques for manufacturing converter crystals are discussed in Chap. 10. Special techniques required for the manufacture of other types are described in the appropriate chapters. The procedures presented in detail are drawn largely from the work done at the MIT

Radiation Laboratory and by NDRC contractees, but no attempt has been made to include the details of all of the procedures that have been successfully employed.

Because of the unique nature of war research and development, it is impossible to acknowledge adequately individual contributions to this subject. Much of the work is a result of the joint efforts of many individuals. At the present writing most of the available literature is in the form of reports that, for reasons of security, have not yet been published in scientific journals. Much of the literature referred to will undoubtedly appear later, however, in journal articles, or will be declassified and made available by the United States government. We have therefore given references to some of the more important of these documents.

In England the chief contributors to crystal research and development were the General Electric Company, British Thompson-Houston, Ltd., Telecommunications Research Establishment, and Oxford University; in this country they were the Bell Telephone Laboratories, Westinghouse Research Laboratory, General Electric Company, Sylvania Electric Products, Inc., and E. I. duPont de Nemours and Company. The crystal groups at the University of Pennsylvania and Purdue University, who operated under NDRC contracts, were responsible for much of the fundamental research and development work reported herein.

DuPont and the Eagle-Picher Company developed manufacturing processes and produced in quantity highly purified silicon and germanium oxide, respectively, without which much of the improvement in crystal rectifiers would have been impossible.

We are particularly indebted to our colleagues at the Radiation Laboratory whose contributions and stimulating discussions have been invaluable in writing this book.

The preparation of this manuscript would have been impossible, finally, without the splendid aid of the editorial staff. In addition to those names listed as editors, we wish particularly to emphasize our gratitude to Barbara E. Myers, Marjorie S. Tariot, and Natalie C. Tucker, editorial assistants.

HENRY C. TORREY.
CHARLES A. WHITMER.

CAMBRIDGE, MASS.
June, 1946.

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