

Preface to the Second Edition

Since the first edition of this book was written there has been a great amount of research on thermoelectric energy conversion, particularly on the development of new materials for use in generators. The number of papers in the field seems to be growing at an ever-increasing rate. A search of the literature shows that there are perhaps a hundred new papers each month that relate to the topic of thermoelectricity. I have attempted to incorporate some of this new material into this second edition, while retaining the general structure of the first edition.

As new materials with higher thermoelectric figures of merit have appeared, the possibility of large-scale thermoelectric generation, as part of the worldwide strategy for making better use of energy resources, has become more obvious. The most notable feature of recent work has been the production of bulk nanostructures, often incorporating inexpensive and readily available elements. These materials have remarkably small values of the lattice thermal conductivity. However, the reduction in this quantity has not yet been matched by any substantial advance in the electronic parameters. It is my hope that this new edition will stimulate research that will yield an improvement in the thermoelectric power factor to complement the reduction of heat conduction by the lattice.

Kingston Beach, Tasmania, Australia

H. Julian Goldsmid

Preface to the First Edition

This book has been written at a time when thermoelectric energy conversion is showing great promise. It was in 1953 that I first carried out the experiments on bismuth telluride that demonstrated the potential of thermoelectric refrigeration. The present-day thermoelectric modules are based on the work that was carried out during the late 1950s and the early 1960s on bismuth telluride and its alloys. Since that time, there have been significant advances in materials for thermoelectric generation but at all temperatures the efficiency of energy conversion using thermocouples has fallen far short of that expected for an ideal thermodynamic machine. At last, with the advent of nanostructured thermoelements, there is the promise that substantial advances will be made.

The basic principles of thermoelectric devices have not changed over the years and the theory presented in the first few chapters will always be applicable as new materials are discovered. A review of existing thermoelectric materials is presented with a chapter devoted to bismuth telluride showing how improvements in its synthesis and composition have led to the present-day performance. It is not always appreciated that the behaviour of a specific alloy is strongly dependent on the manner in which it is prepared and a chapter is devoted to the production of materials, the stress being on principles rather than experimental detail.

The assessment of the transport properties of thermoelectric materials presents special problems. The chapter on measurement techniques includes a discussion of the errors that can arise when the so-called figure of merit is determined for non-uniform specimens. Indeed, I myself was led astray in the interpretation of experimental observations on polycrystalline samples of anisotropic material before I realised the extent of the problem.

It is usual to make use of modules rather than simple thermocouples. There is an outline of the method of selecting commercial modules for any particular application and a discussion of the problems that arise from attempts to miniaturise the size of modules so as to economise on space and material. Throughout the book I have tried to emphasise practical considerations.

A full understanding of the behaviour of nanostructured thermoelectric materials requires the mastery of difficult theoretical concepts, but it is hoped that the elementary treatment in this book will allow the reader to comprehend the basic principles. It is expected that so-called bulk nanostructures will find their way into commercial production in the very near future.

It is only during the past two or three years that I have appreciated the potential of the synthetic transverse thermoelement and I have included a chapter that reviews this unusual configuration. I have also included discussions of energy conversion using the transverse thermomagnetic effects and the thermionic effects in solids and in vacuum. The latter, in particular, will lead to greatly improved efficiencies if they live up to their theoretical promise.

This book draws on my experience of thermoelectricity and its applications over the past 55 years. During that time I have been supported by many people and I acknowledge with gratitude the help that I have received from all of them.

In 1953, as a very junior scientist at the research laboratories of the General Electric Company, I was encouraged by my group leader, R.W. Douglas, to look into the possibility of using the Peltier effect in semiconductors as a practical means of refrigeration. He continued to support the project, in spite of scepticism from some of his senior colleagues, and the success of bismuth telluride as a thermoelectric material stems from his foresight. I received support from many others in the Solid Physics Group over the next few years and should mention particularly D.A. Wright who supervised my Ph.D. studies and Ray Drabble who helped me to understand transport theory.

In my academic life between 1964 and 1988, first as Reader in Solid State Physics at the University of Bath and then as Professor of Physics at the University of New South Wales, I was fortunate to be working in institutions that had been founded to promote applied science. I was encouraged to continue my research on thermoelectricity and was joined by some excellent students. I am sure that I learned much more from them than they did from me.

I acknowledge the support that I have received over much of my career from Marlow Industries. Raymond Marlow enabled me to work closely with his company and kept me in touch with practical developments. In recent years, I have been stimulated by my contact with George Nolas and Ted Volckmann and I appreciate the fact that I am still able to work with Jeff Sharp and Jim Bierschenk.

Perhaps my greatest inspiration has been the work of Abram Ioffe and I greatly valued the opportunity in 2005 to join in the celebration of the 125th anniversary of his birth in the town of Romny in Ukraine. This was made possible through an invitation from Professor L.I. Anatyshuk and I am most appreciative of his encouragement for me to continue with my research.

Over the whole of my career I have received enthusiastic support from my wife Joan and it is to her that I dedicate this book.

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H. Julian Goldsmid



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Goldsmid, H.J.

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