

Volume 53

**SOLID
STATE
PHYSICS**

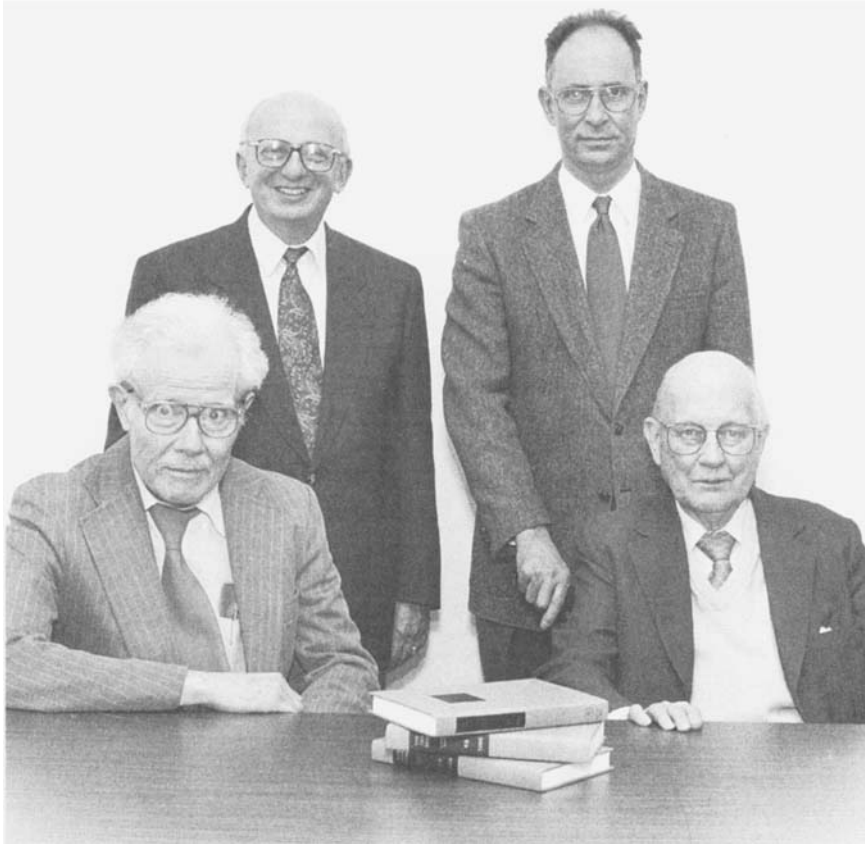
**1955-1999:
Overview, Contents,
and Authors**



ACADEMIC
PRESS

SOLID STATE PHYSICS

VOLUME 53



Front Row from left to right: David Turnbull, Frederick Seitz
Back Row from left to right: Henry Ehrenreich, Frans Spaepen

SOLID STATE PHYSICS

Advances in
Research and Applications

Editors

HENRY EHRENREICH

FRANS SPAEPEN

*Division of Engineering and Applied Sciences
Harvard University
Cambridge, Massachusetts*

VOLUME 53

1955–1999: Overview, Contents and Authors



ACADEMIC PRESS

San Diego San Francisco New York Boston
London Sydney Tokyo

THIS BOOK IS PRINTED ON ACID-FREE PAPER. ∞

COPYRIGHT © 1999 BY ACADEMIC PRESS
ALL RIGHTS RESERVED.

NO PART OF THIS PUBLICATION MAY BE REPRODUCED OR TRANSMITTED IN ANY FORM OR BY ANY MEANS, ELECTRONIC OR MECHANICAL, INCLUDING PHOTOCOPY, RECORDING, OR ANY INFORMATION STORAGE AND RETRIEVAL SYSTEM, WITHOUT PERMISSION IN WRITING FROM THE PUBLISHER.

THE APPEARANCE OF THE CODE AT THE BOTTOM OF THE FIRST PAGE OF A CHAPTER IN THIS BOOK INDICATES THE PUBLISHER'S CONSENT THAT COPIES OF THE CHAPTER MAY BE MADE FOR PERSONAL OR INTERNAL USE, OR FOR THE PERSONAL OR INTERNAL USE OF SPECIFIC CLIENTS. THIS CONSENT IS GIVEN ON THE CONDITION, HOWEVER, THAT THE COPIER PAY THE STATED PER COPY FEE THROUGH THE COPYRIGHT CLEARANCE CENTER, INC (222 ROSEWOOD DRIVE, DANVERS, MASSACHUSETTS 01923), FOR COPYING BEYOND THAT PERMITTED BY SECTIONS 107 OR 108 OF THE U.S. COPYRIGHT LAW. THIS CONSENT DOES NOT EXTEND TO OTHER KINDS OF COPYING, SUCH AS COPYING FOR GENERAL DISTRIBUTION, FOR ADVERTISING OR PROMOTIONAL PURPOSES, FOR CREATING NEW COLLECTIVE WORKS, OR FOR RESALE COPY FEES FOR PRE-1997 CHAPTERS ARE AS SHOWN ON THE CHAPTER TITLE PAGES; IF NO FEE CODE APPEARS ON THE CHAPTER TITLE PAGE, THE COPY FEE IS THE SAME AS FOR CURRENT CHAPTERS.

0081-1947/99 \$30.00

ACADEMIC PRESS
525 B Street, Suite 1900, San Diego, CA 92101-4495, USA
<http://www.apnet.com>

Academic Press
24–28 Oval Road, London NW1 7DX, UK
<http://www.hbuk.co.uk/ap/>

International Standard Serial Number: 0081-1947
International Standard Book Number: 0-12-607752-5

Printed in the United States of America

99 00 01 02 03 MB 9 8 7 6 5 4 3 2 1

Contents

I. Introduction	1
II. Overview	7
III. Contents: Subject Index	23
IV. Authors: Author Index and Article Contents	49

I. Introduction

This Page Intentionally Left Blank

I. Introduction

The Solid State Physics series, founded by Frederick Seitz and David Turnbull in 1955, is certainly the oldest review series in the field. It was so widely recognized that, in its early days, it even acquired a nickname, the “Seitzschrift.” The series is an outgrowth of Seitz’s treatise, *The Modern Theory of Solids*, published in 1940, which played a major role in defining the then fledgling discipline of solid state physics. The field grew sufficiently rapidly during the post-World War II period, that by the time of the mid-1950s, as Seitz notes in the Introduction to Volume 47, marking the retirement of Turnbull as a series editor, “it became clear that the time was again right to provide something in the nature of a comprehensive overview of the field.” He goes on to point out that “several individuals suggested that I consider a new edition,” but rejects that possibility on the grounds that “any such endeavor would be truly massive if it was to be comprehensive” and furthermore that “the field was in a dynamic state of development and hence was open-ended.” He and Turnbull discussed various alternatives during 1954, focusing “on the feasibility of establishing a series of volumes devoted to solid state physics that could serve the needs of the growing group of professional scientists involved in the field and be sufficiently flexible that it could be regarded as open-ended.” The series was visualized as “books rather than a review journal in order to provide some element of cohesion,” in short, “something intermediate between what are commonly called ‘advances’ that have a year-to-year characteristic and a single comprehensive text.”

The Preface to the first volume stated the intent and goals explicitly. What was said then bears repeating, for it has and will continue to define the contents of these books:

The viewpoints and activities in certain closely allied fields, particularly electronics, metallurgy, crystallography and chemistry of solids, have been influenced markedly by developments in solid state science. As a result of this expansion of knowledge solid state physicists are finding that, in order to make significant contributions, it is necessary to concentrate their efforts. . . . Because of this specialization it is desirable that a mechanism exist whereby investigators and students can readily obtain a balanced view. . . . The purpose of the present series is to fulfill this need, at least in part, by publication of compact and authoritative reviews of the important areas of the field. . . . Three general types of articles are solicited: (1) broad elementary surveys that have particular value in orienting the advanced graduate student or an investigator having little

I. INTRODUCTION

previous knowledge of the subject; (2) broad surveys of fields of advanced research that serve to inform and stimulate the more experienced investigators; and (3) more specialized articles describing important new techniques, both experimental and theoretical.

The interdisciplinarity alluded to here, which counterpoises increased research specialization on the one hand, with the need to be ever more broadly informed on the other, has ever increasing influence on the condensed matter and materials science fields. The present editors of the series are fully aware of their responsibility in continuing to attract authoritative and well-written reviews that reflect these broadened scopes of interest.

The present editors, Henry Ehrenreich and Frans Spaepen, have served since 1968 and 1994, respectively. Frederick Seitz relinquished his official responsibilities in 1984 and David Turnbull did the same in 1994.

The present conspectus of the Solid State Physics series, covering the years 1955 to 1999 (Volumes 1–51), is intended to be more than an index. As it covers almost 45 years, it represents an essentially coherent account of some of the principal developments of the field during its time of most rapid growth. It will therefore serve as a convenient reference for those needing to locate specific information or others looking for a didactic introduction to a given area. It can also be viewed as an itemized collection that presents a schematic historical overview of the field.

This book has therefore been organized to meet these different needs.

The Overview

This introductory section provides an overview of some of the developments of key areas in the solid state area together with references to some of the articles in the series as illustrations.

The Subject Index

In keeping with the pedagogical orientation of the series, subjects are arranged much as they would be in an extensive text or treatise covering the field. Each category lists all the pertinent articles in the series. An article appropriate to several headings is listed multiply. However, every review and supplement volume is referenced at least once. Moreover, the list for each category is arranged chronologically in order to provide historical perspective. The primary contributions for a given time period, as cited in the references, are thus also more easily accessible.

I. INTRODUCTION

The Author Index

This index is given an encyclopedic format. Each article title and the table of contents preceding each in the published text is listed in this index under the name of the first author. Every author is cross-referenced in the case of reviews having multiple authors. A *précis* of each article or book is therefore available to the user, which should help substantially in locating reference or pedagogically oriented material.

We are grateful to Ms. Christine M. Mullaney for her indispensable help in preparing this volume, and to Professor David Turnbull for a critical reading of the manuscript.

HENRY EHRENREICH
FRANS SPAEPEN

This Page Intentionally Left Blank

II. Overview

This Page Intentionally Left Blank

II. Overview

Materials Synthesis

The development of fabrication techniques that could produce well-characterized materials has often been the critical step that made reliable solid state experiments possible. Single crystals, with the lowest possible concentrations of lattice defects and impurities, were essential for the development of semiconductor physics and the study of Fermi surfaces. That much of the early fundamental work on the kinetics of phase transformations was performed on metallic alloys, rather than on ceramics or polymers, was no doubt the result of metallurgical synthesis being the most advanced at the time.

The development of zone refining by Pfann (Vol. 4, 1957) was a major advance in the fabrication of chemically pure crystals. As the method was ideally compatible with single crystal growth techniques introduced earlier by Bridgman, Pfann's work was key to the invention of the transistor and became the basis of semiconductor fabrication. Another important electronic material, single crystal quartz, became available on a large scale by the development of the high pressure hydrothermal growth technique, as described by Laudise and Nielsen (Vol.12, 1961). The energetics and kinetics of the atomistic mechanisms that govern the crystal growth process have been reviewed by Parker (Vol. 25, 1970).

More specialized topics include the use of metal catalysts in the high-pressure synthesis of diamond (Bundy and Strong, Vol. 13, 1962); the synthesis of liquid crystals (Keller and Liebert, Suppl. 14, 1978); the formation of small metal clusters from the vapor using nozzles or gas aggregation (de Heer *et al.*, Vol. 40, 1987); and the preparation of fullerenes, which was revolutionized by the Krätschmer-Huffman graphite arc-vaporization technique that enabled the low-cost production of large quantities of these materials (Lieber and Chen, Vol. 48, 1994).

Experimental Techniques

Von Laue's discovery in 1912 that crystals diffract X-rays marked the beginning of solid state physics as we know it today, and that technique remains one of the foremost tools of the field. The dynamical theory of diffraction was reviewed for X-rays by James (Vol. 15, 1963), and for electrons by Dederichs (Vol. 27, 1972). Neutron diffraction was discussed by one of its pioneers (Shull and Wollan, Vol. 2, 1956).

II. OVERVIEW

Guinier (Vol. 9, 1959) provides a comprehensive overview of how X-ray diffraction, and in particular small angle scattering, can be used to study compositional order and the formation of precipitates in solid solutions. An extensive update of this subject was given by Cohen (Vol. 39, 1986). Complementary information in such microstructural investigations is often obtained from transmission electron microscopy. Amelinckx (suppl. 6, 1964) provides a complete review of the technique and its applications to the study of interfaces and defects.

The emergence of synchrotron light sources has stimulated the growth of new techniques, such as the use of extended X-ray absorption fine structure for studying the coordination of specific chemical species (Hayes and Boyce, Vol. 37, 1982) or new applications of ultraviolet spectroscopy (Brown, Vol. 29, 1974).

Since the pioneering work of Bridgman, application of high pressure has become a valuable tool to determine equations of state of solids (Swenson, Vol. 11, 1960; Drickamer *et al.*, Vol. 19, 1966); to induce phase transformations (Bundy and Strong, Vol. 13, 1962); and to study the atomistic mechanisms of diffusion (Lazarus, Vol. 10, 1960). Complementary information can be obtained from transient experiments using shock waves (Rice *et al.*, Vol. 6, 1958; Doran and Linde, Vol. 19, 1966).

Extensive reviews in the series covered newly introduced techniques that included positron annihilation (Wallace, Vol. 10, 1960); cyclotron resonance (Lax and Mavroides, Vol. 11, 1960); electron spin resonance (Jarrett, Vol. 14, 1963); and optical modulation spectroscopy (Cardona, Suppl. 11, 1969). Articles on the rapidly expanding field of scanning probe microscopy will appear in upcoming volumes.

Structure of Condensed Matter

Knowing and understanding the structure of a material on the atomic scale is central to all of condensed matter physics. At the inception of the series, diffraction had revealed the structure of even the most complex crystals. Since then, however, a fascinating sequence of new structural problems has arisen, and new insights into old structural questions have been gained.

The structure of liquids, glasses, and quantum solids remains challenging. Ashcroft and Stroud (Vol. 33, 1978) review the thermodynamics and the correlations in simple liquid metals. Guyer (Vol. 23, 1969) discusses solid helium. The study of glasses is particularly useful, as the structural and thermal broadening of the correlations is less than in high temperature liquids. Diffraction studies on metallic glasses—the simplest kind—established the dense random packing of hard spheres as the structural model (Cargill, Vol. 30, 1975). The many tetrahedral configurations in this model supported F.C. Frank's early suggestion of an icosahedral paradigm

II. OVERVIEW

for the liquid structure, and inspired the polytetrahedral packing model, which is the closest we have come to a unified theory for the liquid structure (Nelson and Spaepen, Vol. 42, 1989; Yonezawa, Vol. 45, 1991).

A different approach was needed to understand the structure of directionally bonded amorphous materials, such as silicon or silica (Phillips, Vol. 37, 1982). Careful diffraction work and extensive modeling and simulation showed that the continuous random network, originally proposed by Zachariasen, is the model of choice (Wooten and Weaire, Vol. 40, 1987).

The discovery of quasi-crystals by Shechtman and coworkers, which was a serendipitous outgrowth of a study of rapidly solidified aluminum alloys, caused a revolution in crystallography: Like crystals, quasi-crystals have a polyhedral morphology and a sharp diffraction pattern, but because of their quasi-periodic structure they can exhibit symmetries, such as 5-fold rotational symmetry, that are prohibited in periodic structures (Nelson and Spaepen, Vol. 42, 1989). Quasi-periodicity is also key to the study of excitations in incommensurate crystal phases (Currat and Janssen, Vol. 41, 1988).

Bednorz and Müller's discovery of high-temperature superconductivity in La-Ba-Cu-O sparked the interest in the structure of cuprates, in particular the Y-B-C-O and its many derivatives (Beyers and Shaw, Vol. 42, 1989). Similarly, the synthesis of large quantities of fullerenes led to intensive structural investigation of their crystalline phases. (Axe, Moss, and Neumann, Vol. 48, 1994) De Heer *et al.*, (Vol. 40, 1987) review the structure of small metal clusters.

The structure of intercrystalline boundaries was elucidated greatly by the theoretical work of Bollmann and the experimental work of Balluffi and coworkers. An extensive review by Pond and Hirth (Vol. 47, 1994) shows the symmetries of these interfaces and how they can be modeled as arrays of defects. The structure of the crystal-melt interface remains a challenging problem. Although direct experimental structural evidence is lacking, modeling and indirect evidence from nucleation indicates that the liquid becomes increasingly ordered near the crystal (Spaepen, Vol. 47, 1994).

Electronic Structure

The power of the one-electron theory of solids, presaged by the work of Wigner and Seitz (1933; Vol. 1, 1955), was not appreciated until materials synthesis permitted the fabrication of crystals sufficiently perfect to permit cyclotron resonance (Lax and Mavroides, Vol. 11, 1960) and optical properties experiments in semiconductors (Cardona, Suppl. 11, 1969; Phillips, Vol. 18, 1966), and Fermi surface experiments in metals (Sellmyer, Vol. 33, 1978).

The methods for calculating band structures, like Herring's orthogo-