Experimental Techniques in Physics and Materials Science

Principles and Methodologies

This page intentionally left blank

Experimental Techniques in Physics and Materials Science

Principles and Methodologies

R Srinivasan, retired
Indian Institute of Technology Madras, India
T G Ramesh, retired
CSIR – National Aerospace Laboratories, India
G Umesh, retired
National Institute of Technology Karnataka, India
C S Sundar, retired
Indira Gandhi Centre for Atomic Research, India

World Scientific
NEW JERSEY • LONDON • SINGAPORE • BEIJING • SHANGHAI • HONG KONG • TAIPEI • CHENNAI • TOKYO

Published by

World Scientific Publishing Co. Pte. Ltd.
5 Toh Tuck Link, Singapore 596224
USA office: 27 Warren Street, Suite 401-402, Hackensack, NJ 07601
UK office: 57 Shelton Street, Covent Garden, London WC2H 9HE

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

EXPERIMENTAL TECHNIQUES IN PHYSICS AND MATERIALS SCIENCE
Principles and Methodologies

ISBN 978-981-127-888-4 (hardcover)
ISBN 978-981-127-889-1 (ebook for institutions)
ISBN 978-981-127-890-7 (ebook for individuals)

For any available supplementary material, please visit
https://www.worldscientific.com/worldscibooks/10.1142/13485#t=suppl

Desk Editor: Rhaimie Wahap

Typeset by Stallion Press
Email: enquiries@stallionpress.com

Printed in Singapore

PREFACE

In the past century, there has been tremendous progress in the techniques for the preparation of materials, their characterization, and the methods of measurement of various physical properties of these materials. At the same time, advances in vacuum techniques, low-temperature techniques, and high-pressure techniques have led to extensive studies on the changes in the properties of materials when subjected to such environmental conditions. Research in materials science has produced novel materials which have changed the lifestyle of humans drastically. It is no surprise that master's degree courses in materials science have been started in many universities globally.

The curriculum for the MSc Physics course in all universities in India is dominated by theoretical courses, such as mathematical techniques in physics, classical and quantum mechanics, statistical physics, and condensed matter physics. Although it is an accepted fact that experiments form the bedrock of science, it is ironic that new advances in experimental physics do not find a place in the curriculum. True, the students do some experiments in the laboratory, but the instructions given to them to do the experiments are rather cursory. The principle behind an experiment is not explained in sufficient detail. It is necessary to explain why a particular method of measurement is adapted, why the analysis of the data should be carried out in the specified way, and why a certain formula should be used in calculating the results. Most often, the student does the experiment mechanically and records the data following the instructions without any understanding of the aim of the experiment, the theory behind the experiment, or the limitations of the technique he or she is using.

In the past 20 years, two of the authors of this book, along with their colleagues from Goa University, have developed low-cost experiments at

the BSc, MSc, and post-MSc levels in physics and materials science. All four authors, along with other resource persons, have conducted more than a hundred two-week refresher courses to train more than 2,500 teachers and student participants from across India in conducting these experiments. These courses have been sponsored by the Indian Academy of Sciences, the Indian National Science Academy, and the National Academy of Sciences, Allahabad. A detailed laboratory manual, covering 62 such experiments, has been published as an e-book by the Indian Academy of Sciences, Bengaluru. These experiments can be performed using the low-cost equipment manufactured by Ajay Sensors and Instruments, Bengaluru, under license from the Indian Academy of Sciences.

The COVID-19 pandemic in 2020–2022 resulted in a temporary suspension of the refresher courses in experimental physics. During this period of inactivity, the authors of this book decided to write brief chapters on the techniques for preparing solid-state materials in bulk and thin-film forms and on the characterization techniques, such as powder X-ray and neutron diffraction, ESCA, ellipsometry for thin films, electron microscopy and surface probe techniques, and positron annihilation as a tool to study defects in materials. The methods for measuring the elastic, thermal, electrical transport, dielectric, and magnetic properties are discussed. Spectroscopic techniques, such as NMR, EPR, IR, visible, UV, and Mossbauer spectroscopies, are discussed. A fairly detailed chapter on the study of phase transitions is included.

Each chapter is about 20–30 printed pages in length and is self-contained. Naturally, in such short chapters, one can only present the basic principles of each technique with some typical examples. Different chapters have been written by different authors. So, some differences in the style of presentation could not be avoided. There could be some overlap, but this has been reduced to a minimum.

The scope of the book is limited to meeting the requirements of students at the level of a master's degree in physics or materials science. At the master's level, the curriculum can be made more balanced by introducing at least a one-semester course in experimental techniques, choosing appropriate chapters from the book. The book should also be useful for students engaged in research in the domain of materials science and for teachers teaching courses in experimental physics.

R. Srinivasan T. G. Ramesh G. Umesh C. S. Sundar

ACKNOWLEDGEMENT

The authors are grateful to World Scientific Publishing Company, Singapore, Ms. Lakshmi Narayanan in particular, for agreeing to publish the book. We are thankful to Mr. Rhaimie Wahap and his Team for their cooperation in agreeing to our repeated requests for proof correction and bringing out the book in print.

This page intentionally left blank

CONTENTS