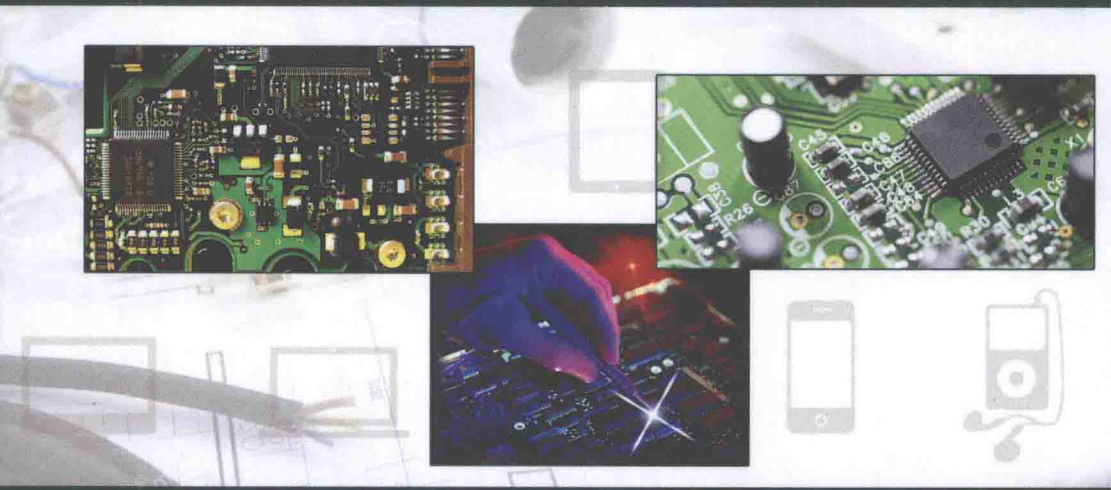
Advanced Materials Series

Series Editor: Ashutosh Tiwari

ADVANCED ELECTRICAL AND ELECTRONICS MATERIALS

Processes and Applications



K.M. Gupta and Nishu Gupta

Scrivener Publishing

WILEY

Advanced Electrical and Electronics Materials

Processes and Applications

K.M. Gupta and Nishu Gupta

WILEY

Co-published by John Wiley & Sons, Inc. Hoboken, New Jersey, and Scrivener Publishing LLC, Salem, Massachusetts.
Published simultaneously in Canada.

Cover design by Russell Richardson

Library of Congress Cataloging-in-Publication Data:

ISBN 978-1-118-99835-9

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Dedicated to
my respected mother **BELA,**
father (Late) **Ram Nath,**
Godfather (Late) **Lakhan Lal,**
father-in-law (Late) **Kishori Lal,**
brother-in-law and sister: **Jawahar and Savitri,**
nephew (Late) **Jayant (Babul)**
and
all forefathers and foremothers
whose
blessings have always been a boon in my life

Preface

This book is intended to cover the vast and fast growing field of electrical and electronic materials and their science in accordance with the modern trends. The level of the book covers the syllabi being taught at graduate and undergraduate standard of Engineering Colleges in many countries around the world including the United States and India. It also covers the syllabi of various Indian national level examinations. The contents of the book will also be very helpful to the students of postgraduate studies.

Basic and pre-requisite information has been included for easy transition to newer topics. Latest developments in various fields of materials; their sciences, processes and applications have been accommodated. Latest topics like spintronics, high energy hard magnetic materials, ferrites, plzt, vacuum as insulator, fibre-optics, high temperature superconductors, ferroelectrics, smart materials, ferromagnetic semiconductors etc. have been included.

Illustrations, examples, and details of sciences are such that they include different disciplines of engineering e.g. robotics, electrical, mechanical, electronics, instrumentation and control, computer, and inter-disciplinary branches. Topics like electron theories, magnetostriction, high voltage engineering, brillouin zone theory, gas-filled conductors etc. have been explained. A variety of materials ranging from iridium to garnets, resistors, capacitors, printed circuit boards to microelectronics, micro alloys to memory devices, left-handed materials, advance and futuristic materials are described.

Review and Objective Type Questions are based on concepts, design, construction, applications and practical orientations. Objective questions of all kinds viz.; 'Multiple Choice' type, 'Assertion and Reasoning' type, 'Matching' type, 'Fill in the Blanks' type, 'Pick up the Correct Choice', 'True-False' type are included. A large number of numerical examples have

been worked out. Numerical exercises for practice and self evaluation are also given with their answers. SI units, in general, have been incorporated throughout the text but for familiarity the MKS units have also been used.

The book is substantiated by a large number of diagrams, tables, equations, review questions, objective questions, solved numericals, unsolved numerical exercises, question-answers, and terms in quick revision summary. I gratefully acknowledge the authors and publishers of the books and other literature quoted in references which have have been consulted in preparing this book.

I acknowledge the inspiration and blessings of my respected mother Smt. BELA DEVI, brother-in-law Sri JAWAHAR LAL, sister Smt. SAVITRI LAL, elder brother Sri GOPAL DAS GUPTA and other family members. I am full of gratitude to my daughter NIDHI, son NISHU, wife RITA, son-in-law RITESH, grandson AKARSH (RAM) and granddaughter GAURI for the patience shown and encouragement given to complete this venture.

I am highly obliged to my postgraduate student Mr. Kishor Kalauni, M.Tech. (Materials Science) without whose help and support it was not possible to publish this book. He took great pains in formatting and typing of a large number of pages, typesetting, making figures etc. I also acknowledge my student Mr. Saurabh Kumar Singh, M.Tech. (Materials Science) for some typing work. I extend my heartfelt gratitude to my friends Er. Ranjeet Singh Virmani, Er. K.R.D. Tewari, and Er. Satish Chandra Srivastava for their technical support in several ways. Last but not the least, I owe a lot to Sri S.C. Sant, Mr. Anurag Sant and Mrs. Shilpa Sant for their continued support, guidance and cooperation in preparing this book.

Enormous effort has been made to avoid errors and mistakes; however, their presence cannot be ruled out. Any suggestion to improve the standard of this book, indication towards errors, omissions and mistakes will be highly appreciated.

January 2015
Allahabad, India

Dr. K.M. GUPTA
kmgupta1948@gmail.com
and
NISHU GUPTA
dce.nishu@gmail.com

Acknowledgement

The Author of this book acknowledges with heartfelt gratitude to Mr. S.C.Sant and Mr. Anurag Sant, the publishers of the Umesh Publications (4230/1 Ansari Road, Daryaganj, Delhi-110002) India, for being kind enough to provide some literature support and valuable information that proved very useful in preparing this book. Author (Dr. K. M. Gupta) thanks especially Mr. Anurag Sant for his courteous gesture.

Dr. K.M. Gupta

About the Authors

Dr. K.M. Gupta is a Professor in the Department of Applied Mechanics, Motilal Nehru National Institute of Technology, Allahabad. He has over 38 years of teaching, research and consultancy experience. He obtained Diploma (with Honours) in Mechanical Engineering, Bachelor of Engineering (Gr. I.E., AMIE) in Mechanical Engineering, Postgraduation (M.E. with Honours) in 1977, and completed his Doctorate (Ph.D.) degree from University of Allahabad. Although a Mechanical Engineer but he has also specialised in Automobile Engineering discipline. He has authored 29 books and edited 2 books on Engineering subjects, and a chapter in Scrivener Wiley published 'Handbook of Bioplastics and Biocomposites Engineering Applications'. He has also authored 120 research papers in reputed International and National Journals and Conferences to his credit. Professor K.M.Gupta has presented his research papers in 16 International conferences abroad at USA, UK, Japan, China, France, Muscat, Bangkok, South Africa, Hongkong etc. He has also chaired 8 International Conferences in China, Singapore, Dubai, Bangkok etc. He has acted as Editor-in-Chief of *The International Journal of Materials, Mechanics and Manufacturing (IJMMM)* Singapore.

Recipient of many Gold Medals and Prizes for his outstanding career from Diploma to Doctorate (a rare achievement in this India); he has served as Head of Automobile Engineering Department at the Institute of Engineering and Rural Technology, Allahabad. He developed several laboratories viz. Automobile related Labs, Materials Science Lab., Strength of Materials Lab., Hydraulics Lab. etc. at different Institutes/colleges.

Currently, Dr. Gupta is teaching materials science, engineering mechanics, thermodynamics of materials, electrical and electronic materials etc. his research interests are in the fields of materials science, composite materials, stress analysis, solid mechanics etc.

Nishu Gupta is a Research Scholar in the department of Electronics and Communication Engineering, Motilal Nehru National Institute of Technology, Allahabad, India. He received his B.Tech. Degree in Electronics and Communication Engineering from U.P. Technical University, M.Tech. Degree in Nanoscience and Technology from Delhi Technological University (formerly Delhi College of Engineering), Delhi. He served as Visiting Faculty in the department of Electronics and Communication Engineering, Motilal Nehru National Institute of Technology, Allahabad; as Adhoc Faculty in the department of Electronics and Communication Engineering at National Institute of Technology, Sikkim. He also served as Deputed Faculty at NIT Calicut.

Prior to coming to academic profession, he has served as Software Engineer at Infosys Technologies Limited, and as Senior Software Engineer at Tech Mahindra Limited. He has 18 Research papers to his credit which were published in various International and National Conferences in India and abroad, and out of these has published 5 papers in International Journals. He has attended 5 International conferences abroad out of which he delivered presentations in 3 conferences, all as a student, which is an incredible accomplishment. His honours and awards include the recommendations for "Top 2000 Intellectuals of the 21st century by International Biographical Centre, Cambridge, England", and for inclusion in the list of "2009 edition of Marquis Who's Who in the World". He has been shortlisted by the Ministry of HRD, Government of India for the Commonwealth Scholarship/Fellowship Plan, 2012 offered by the Government of United Kingdom.

His research interests are in the field of Semiconductor Devices, Hybrid Solar Cells, Photonics, Nano-optics and related fields.

Abbreviations

ACSR	Aluminum Conductor Steel Reinforced
AR	Anti Reflective
BCT	Body Centred Tetragonal
BJT	Bipolar Junction Transistor
BMG	Bulk Metallic Glass
CCD	Charge Coupled Device
CIC	Cable-In-Conduit
CNC	Computerized Numerically Controlled
DC	Diamond Cubic
EGS	Electronic Grade Silicon
EHP	Electron-Hole Pair
FCC	Face Centred Cube
FFC	Flexible-Film-Circuit
FPC	Flexible Printed Circuit
GGG	Gadolium Gallium Garnet
GMR	Giant Magneto-Resistance
HCP	Hexagonally Closed Packed
HMM	Hard Magnetic Materials
HTS	High Temperature Superconductor
IGFET	Insulated Gate Field-Effect Transistor
IFF	Ionic Ferrofluid
KDP	Potassium Dihydrogen Phosphate (a piezoelectric material)
LBL	Layer-By-Layer
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LHM	Left-Handed Material
LTS	Low Temperature Superconductor
MBD	Magnetic Bipolar Diode
MBT	Magnetic Bipolar Transistor

MCE	Magneto–Caloric Effect
MEE	Magneto–Electro–Elastic
MGS	Metallurgical Grade Silicon
MHD	Magneto–Hydro-Dynamic
MOSFET	Metallic Oxide Semiconductor Field- effect Transistor
MRAM	Magnetic Random Access Memory
NLO	Non–Linearly Optical
NTC	Negative Temperature Coefficient (Thermistor)
OFHC	Oxygen Free High Conductivity
OMR	Optical Magnetic Reader
PCB	Printed Circuit Board
PLZT	Lead Lanthanum Zirconate Titanate
PTC	Positive Temperature Coefficient (Thermistor)
PZT	Lead Zirconate Titanate
RHM	Right Handed Material
SET	Single Electron Transistor
SFF	Surfated Ferrofluid
SMC	Surface Mounted Device
SOI	Silicon-On-Insulator
SQUID	Superconducting Quantum Interference Device
TEC	Thermo–Electric Cooler
TEE	Thermo–Electric Effect
UPT	Unipolar Transistor
USB	Universal Serial Bus (interface)
VDR	Voltage- Dependent Resistor
VLSI	Very Large Scale Integration
VVR	Voltage–Variable Resistor
WAN	Wide Area Network
WC	Tungsten Carbide
XRD	X-ray Diffraction

Contents