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Tony Blythe and David Bloor
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ELECTRICAL PROPERTIES OF POLYMERS

Second edition

Fully revised and expanded, this new edition of Anthony Blythe's successful title on electrical properties of polymers covers both the fundamental and recent developments in this growing area. The book provides a broad and comprehensive account of the topic, describing underlying physical principles and synthesis through to emerging technologies. The second edition places particular emphasis on the new generation of conductive polymers, describing emerging uses of polymers in industrial applications and covering topics such as light emitting diodes, flexible polymers and soft electronics.

Written in an accessible style, without complicated theory, this book combines key concepts with applications. With the inclusion of further reading material at the end of each chapter for interested readers, this book is an authoritative guide to advanced-level undergraduates and graduates studying polymer materials and physical sciences. It will also be of significant interest to researchers working in this evolving field.

ANTHONY BLYTHE has been active in the area of polymer materials and processing for over 40 years. He has successfully initiated numerous groundbreaking projects in the polymer field, specifically for the wire and cable industry, and his achievements are recognised by the several patents he holds. He has also been an external lecturer to established universities in the UK and has authored more than 40 scientific papers.

DAVID BLOOR is Emeritus Professor of Physics at the University of Durham. Since his retirement in 2002 he has continued his research in

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the area of optical materials and conductive materials, with particular interest in the developing areas of liquid crystalline materials and display devices. He holds a number of patents and has authored over 300 scientific papers.

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Preface

The predecessor to this book was published in the Cambridge Solid State Sciences Series in 1979 following a series of lectures given to graduate students in the Polymer Physics Group at Leeds University. It was written as an introductory text on electrical aspects of polymeric materials, principally electrically insulating polymers, but with a description of work on electrically conductive organic materials up to the mid-1970s. Since that time intrinsically conductive polymers have progressed from laboratory curiosities with either poor chemical and physical stability frequently, indeterminate composition, to widely explored materials that have demonstrated new physics and use in diverse commercial applications. An account of these developments has displaced most of the content on organic conductors from the original volume.

Emphasis is mainly laid on the description and explanation, in molecular and electronic terms, of the observed phenomena, so as to give a basic understanding of the electrical behaviour of polymers. Principles of measurement methods are also stressed, since a sound framework of experimental techniques and data is so essential for proper scientific development of such a subject. The choice of subject matter was made with the aim of being educative and stimulating rather than exhaustive and exhausting. It is hoped that the book will be of most help to those venturing into research in polymer science, or to those joining the industrial sectors that utilise both insulating and conductive plastics, who want an insight into the somewhat specialised area of electrical properties. Only a general knowledge of physics and chemistry is assumed, and for this reason an introduction to polymer structure is included.

The electrical properties of polymers are a subject which is inherently interdisciplinary in nature. The development of intrinsically conductive polymers has benefited immensely from the contributions of synthetic chemists.

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Electrical properties are closely allied with the mechanical properties of polymers studied by both physicists and engineers. Established models of the semiconductive properties of inorganic substances and metals provide a starting point for understanding similar properties of polymers, although subsequent critical input from across the disciplines eventually led to the view that the underlying physics is distinctly different. A primary objective, therefore, was to collate the relevant aspects of these contingent subjects to form a more unified treatment than is generally available.

Since the early days of plastics technology, when such materials were regarded electrically as simply good insulators, observations of subtleties in electrical response have shed a great deal of light on the underlying microscopic structure and molecular dynamics. This has contributed to polymer science in a general way, and has, at the same time, enabled the development of materials which meet exacting electrical engineering requirements. This process has continued in the development of intrinsically conductive polymers over the last 25 years of the twentieth century. The book encompasses both this well-established area of dielectric science and the modern frontiers concerned with non-linear optical and electrically conductive plastics. Research along these lines has demonstrated the feasibility of obtaining materials with entirely novel sets of properties, that have opened up new areas of application for polymers.

The bibliography has been considerably expanded, partly due to the inclusion of new topics, e.g. linear and non-linear optical properties, and partly reflecting the steady and sizeable flow of papers on intrinsically conductive polymers. The authors have made extensive use of the literature in the preparation of this book. The selection of papers included in the bibliography is meant to be indicative of this literature since it cannot possibly include more than a small fraction of the published output. The final choice is not intended as any indication of the quality of work that is not included.

SI units have been used throughout the book.

Special thanks are due to Professor I. M. Ward for encouraging us to update the earlier book and for reading and commenting on the whole of the draft manuscript. We should also like to thank Dr G. H. Cross and Dr G. R. Davies for constructive criticism on much of the manuscript, and Professors J. S. Dugdale and A. P Monkman for suggestions on Chapters 4 and 9 respectively. ARB is grateful for the invaluable help and advice from colleagues at BICCGeneral, and DB for similar assistance from colleagues at the University of Durham. Valuable inputs were received from Professor D. Baeriswyl, Professor A. Kaiser, Professor W. R. Salaneck, Professor G. Weiser, Dr D. de Leeuw and Dr S. Roth. Dr Mile H. Bertein, Mr W. Reddish, Dr D. J. Groves and Mr J. Billing kindly supplied photographs.

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