Principles of Nanoscience and Nanotechnology

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Tokeer Ahmad

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Foreword

Nanostructured materials have been fascinating the world of science and technology in the last fifteen years because of their tremendous possibilities in generating novel shapes, structures and the unusual phenomena associated with these materials. Therefore "Principles of Nanoscience and Nanotechnology" is a good book for students and teachers who are entering into this exciting world of Nanoscience. The book emphasizes the need to understand the fabrication of nanomaterials in different shapes and sizes and also discusses some aspects of their fundamental properties and applications. Hence, I strongly recommend it to the students and teachers of Chemistry, Physics, Biology and Engineering who have some interest in understanding Nanoscience.

A.K. Ganguli
IIT Delhi, India

This book will be a useful reference book for graduate students, and is expected to attract a lot of attention, not only from new graduate students, but also from more senior scientists interested in the fascinating area of nanoscience and nanotechnology, and those who are involved in a wide spectrum of disciplines ranging from physics, chemistry, surface science, spectroscopy, materials science, engineering to medicine.

Fahad M. Al-Marzouki
Chairman, Department of Physics
KAAU, Jeddah, Saudi Arabia

This book provides a very detailed and interesting overview of the fundamental principles of nanoscience, discusses the background of several nanoscience experimental techniques, and sheds light on some

of the visionary and important applications in the truly interdisciplinary area of nanotechnology.

A.M. Asiri
Chairman, Department of Chemistry
KAAU, Jeddah, Saudi Arabia

Nanomaterials are being contemplated to play a significant role for the betterment of human life in near future. Already, some of the nanomaterials have shown lots of potential in several technological applications such as drug delivery, catalysis, hydrogen generation and storage, for solar and fuel cells and sensors, just to name a few. The new concept of size and shape dependent functionalities of materials has further enhanced the potential of nanomaterials. I must compliment the authors for bringing out a book on nanomaterials, which includes their preparation, characterization and applications in details. I am sure that this book will be useful to the scientists, specially the young researchers working in the areas of Physics, Chemistry and Materials Science.

A.K. Tyagi
Professor (Chemistry)
BARC Mumbai, India

Preface

A revolution is occurring in science and technology, based on the recently developed ability to measure, manipulate and organize matter on the nanometer scale. At the nanoscale, Physics, Chemistry and Biology, Medical sciences, Materials science and Engineering converge to same principles and tools. As a result progress in nanoscale will have far reaching impact. The next revolution in science and technology will depend on science interdependence.

The properties of nanomaterials are not governed by the same physical laws as larger particles and as such the physical and chemical properties, for example, colour, solubility, strength, chemical reactivity, toxicity, can therefore, be quite different from those of larger particles of the same substance. The altered properties of nanomaterials have created the possibility for many new profitable products and applications. This technology has its roots in the landmark lecture delivered by the famous Nobel Laureate physicist, Richard Feynman, on 29 December 1959 entitled "There's Plenty of Room at the Bottom." By the mid-1980s, it had gained real momentum with the invention of scanning probe microscopes. Today, nanotechnology promises to have a revolutionary impact on the way things are designed and manufactured in the future.

Materials and devices at the nanoscale hold vast promise for innovation in virtually every industry and public endeavour including health, electronics, transportation, environment, and national security and have been heralded as the next industrial revolution. Work on fabrication and processing of nanomaterials started long time ago, and has been drastically intensified in the last decade, resulting in overwhelming literatures in many journals across different disciplines. That makes it impossible for a book of this volume to cover all aspects of the field. An elementary approach to a highly complicated emerging field is the main concern of this book. It was realized that most of students had difficulty in finding a suitable textbook on nanomaterials and this emerging field of science should be introduced at an appropriate level in the curriculum globally. It was a mere coincidence

that both of us were attending an International conference on Nanotechnology organized by King Saud University, Riyadh, where the foundation of this noble project took place. Since this book is planed with a cumulative content, the teacher will profit by following the sequence of the text.

This book has a straightforward aim to acquaint our students with the whole idea of nanoscience and nanotechnology. It is self-contained and unified in presentation. This compact textbook written in a clear and readable style is designed to help readers to acquire a thorough understanding of the main themes in Nanotechnology. It contains the essential information for a knowledge and understanding of the behaviour of materials at the nanoscale. It may be used as a textbook by graduate students and even ambitious undergraduates in engineering and the biological and physical sciences, who already have some familiarity with basic principles of science. It is also suitable for experts in related fields who require an overview of the fundamental topics in nanotechnology. The explanations in the book are detailed enough to capture the interest of the curious reader and complete enough to provide the necessary background material needed to go further into the subject and explore the research literature. This book would also serve as a general introduction to people just entering the field. We also believe that it will cater to the needs of most biologists, who stop their acquaintance with mathematics at school.

The social sciences and humanities have significant roles to play in nanotechnology beyond addressing the issues of public perception and media coverage. Few scientists and engineers have the time, expertise, or resources to survey exhaustively the expanse of societal needs that their research could help address, nor do most scientists and engineers have the broad view needed to construct research programmes that solve some social problems without exacerbating others. Social scientists and humanities scholars do not have all the answers, but they do have information and insights that can help, not just in disseminating the products of nanotechnology, but also in constructing a socially useful nanotech enterprise from the beginning.

To avoid the same public concerns that biotechnology has provoked, nanotech's scientists and policy makers conclude that they must educate

the public on the goals, possibilities, and potential consequences of this emerging field, and that they must listen to the public's apprehensions and needs when shaping their research. Using biotechnology's historical development as an indicator of nanotechnology's future may or may not be justified; scholars disagree. But the comparison has sparked interest in the ways that nanotechnology's development will affect the public's perception and the ways that the public will affect nanotechnology.

The need to develop an understanding of this general subject matter for the practicing engineer and scientist of the future cannot be questioned. The teaching of nanotechnology course will soon be required in most engineering and science curricula as it is also generally accepted as one of the key state of the art courses in applied science. The text is divided into seven chapters.

The first chapter of the book briefly introduces the systematic development of materials and its long journey to nanodimensions. The science of nanomaterials has created great excitement and expectations in the last decade and how nano has moved from the world of the future to the world of the present is discussed in detail.

The second chapter of the book emphasises on how the unique properties of nanomaterials have motivated the researchers to develop the simpler and inexpensive techniques to produce nanostructures of technologically important materials. Both, top down approaches which rely on continuous breaking up of the bulk matter and bottom up approaches which build the nanostructures by its constituent units have been discussed briefly.

The third chapter of this book introduces the invention and development of sophisticated equipments which have opened up new possibilities for the characterization, measurement and manipulation of nanomaterials. With the development of some equipment like Scanning Probe Microscopy and High Resolution Transmission Electron Microscopy, it is possible to study the nanomaterials to a great deal even down to atomic scale.

Chapters four and five describe the diffraction and spectroscopy techniques. These techniques are so powerful that every student should be armed with this knowledge so that it can be put to use when the need arises. These chapters aim at providing an understanding of the basic principles involved rather than through knowledge of the theory and practice of techniques.

Chapter six will describe the significant impact on the properties of nanomaterials which may be highly attentive for the research scholars entering to the world of Nanoscience, while Chapter 7 will address the potential applications on all most all industries and all areas of society. At the end of each chapter we have included a list for further reading of books and research papers, which would amplify and extend the contents of each chapter. This list is of course neither exhaustive nor comprehensive.

Last, but not the least, writing this book was a rewarding experience. Editors will be pleased to receive suggestions for improvment, if any.

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M.A. Shah

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Contents

Foreword *v*
Preface *vii*
Acknowledgements *xi*

Chapter 1 Systematic Development of Materials **1**
1.1 Introduction 1
1.2 Solid materials and their strength 3
1.3 Perspective of length 5
1.4 Nanoscience and nanotechnology 7
1.5 Nanostructures in nature 8
1.6 Quantum structures 11
1.7 Quantum confinement 12
1.8 Surface effects of nanomaterials 15
1.9 Prime materials 17
1.10 Carbon nanostructures 18
1.11 Oxides 22
1.11.1 Zinc oxide 23
1.11.2 Magnesium oxide 25
1.11.3 Aluminum oxide 25
1.11.4 Manganese oxides 26
1.11.5 Nickel oxide 27
1.11.6 Cobalt oxide 27
1.11.7 Copper oxide 27
1.11.8 Lanthanum-manganese based oxide 28
1.12 Bright future of nanotechnology 28
Suggested further reading 30
References 30

Chapter 2 Methods of Generation of Nanomaterials **32**
2.1 Introduction 32
2.2 Nanomaterials synthesis 33

2.3 Physical approaches 33
2.3.1 Arc discharge method 35
2.3.2 Laser ablation 36
2.3.3 Aerosol synthesis 37
2.3.4 Inert gas condensation 38
2.3.5 High-energy ball milling (Mechanical alloying method) 39
2.3.6 Chemical vapor deposition 40
2.3.7 Plasma synthesis method 43
2.3.8 Electro-deposition 44
2.4 Chemical approaches 45
2.4.1 Solvothermal synthesis 47
2.4.2 Hydrothermal synthesis 48
2.4.3 Reverse micellar/Micro-emulsion method 49
2.4.4 Sol-gel synthesis 58
2.4.5 Microwave method 60
2.4.6 Sonochemical process 61
2.4.7 Co-precipitation 63
Suggested further reading 65
References 65

Chapter 3 Electron Microscopy **67**
3.1 Introduction 67
3.2 Principles of electron microscopy 68
3.3 Scanning Electron Microscope (SEM) 70
3.4 Strength and limitations of scanning electron microscopy 76
3.5 Energy Dispersive X-ray Analysis (EDX) 77
3.6 Transmission Electron Microscope (TEM) 78
3.7 Scanning Tunneling Microscope (STM) 83
3.8 Atomic Force Microscope (AFM) 85
3.9 Methods of sample preparation 87
3.9.1 Chemical fixation technique 87
3.9.2 Cyro fixation technique 88
3.9.3 Dehydration 89
3.9.4 Embedding biological samples 89
3.9.5 Sectioning 89

3.9.6 Staining 89
3.9.7 Mechanical milling 90
3.9.8 Chemical etching 90
3.9.9 Ion etching 91
3.9.10 Conductive coating 91
Suggested further reading 91
References 92

Chapter 4 X-ray Crystallography **93**
4.1 Introduction 93
4.2 Structure of nanomaterials 94
4.3 X-ray diffraction (XRD) 96
4.4 The Laue method 99
4.5 The rotating crystal method 100
4.6 The powder method 101
4.6.1 Determination of grain size/crystallite size using X-ray line broadening studies (Scherrer's formula) 104
4.6.2 Determination of crystallite size distribution using X-ray line shape analysis 105
4.7 X-ray diffraction pattern and analysis of some commercially important oxides 105
4.8 Small angle X-ray scattering (SAXS) 109
Suggested further reading 109
References 110

Chapter 5 Spectroscopy Techniques **111**
5.1 Introduction 111
5.2 The regions of spectrum 112
5.3 Characterization of electromagnetic radiations 114
5.4 The quantization of energy 115
5.5 Absorption spectroscopy 117
5.6 Photoluminescence 119
5.7 Fourier transform infrared spectroscopy 121
5.8 Raman spectroscopy 123
Suggested further reading 125
References 125