2019

Investigation of Electrical and Optical Properties of Novel ZnO Nano Structures

Islam Uddin

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by

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Published by
AIJR Publisher, Dhaurahra, Balrampur, India 271604

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About this Monograph
This monograph is the part of a thesis of the author approved by the Department of Applied Sciences & Humanities, Faculty of Engineering and Technology, Jamia Millia Islamia, New Delhi, India as a partial fulfilment for Ph.D. Degree in Physics in 2010. The original thesis title was " Investigation of Electrical and Optical Properties of Novel ZnO Nano Structures" written under the guidance of following supervisors-

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ISBN: 978-81-942709-0-4 (eBook)
DOI: 10.21467/thesis.78

Series
AIJR Thesis

Published
23 August 2019

Number of Pages
94

Imprint
AIJR Books

Published by
AIJR Publisher, Dhaurahra, Balrampur, India 271604

Dedicated

to

My Parents

Table of Contents

Preface

Nano is a familiar prefix used everywhere these days as public interest in nano materials has grown rapidly. The last forty years people have seen a number of crucial technical developments in field. These developments have initiated changes in human life of an unprecedented kind. This period has simultaneously witnessed other landmark developments. The construction of point contact transistor in 1947 rapidly led to intensive research which ultimately led crystallized in the concept and subsequent realization of the information technology (IT) era. In the 1970's, the information age per se started. We saw stepwise appearance of quartz optical fiber, III-V compound semiconductors and gallium arsenide (GaAs) lasers. During the evaluation of the information age, silicon (Si) occupied a dominant place in the commercial market, as it was used to fabricate the discrete devices and integrated circuits needs of for computing, data storage and communication.

Zinc oxide (ZnO) is a II–VI compound semiconductor with a wide direct band-gap of3.3 eV and a hexagonal structure. ZnO is often used in the paint, paper, rubber, food and drug industries. It is also a promising material in nanotechnology applications, for example in nano-electronics and nano-robotic technology. With its wide band-gap, high exciton binding energy and high breakdown strength, ZnO can be utilized for electronic and photonic devices, as well as for high-frequency applications. One-dimensional ZnO nanostructures have great potential applications in the fields of optoelectronic and sensor devices. Therefore, it is really important to realize the growth of ZnO nanostructures and investigate their properties. A physical vapor condensation method is used to synthesize the nanostructures of ZnO. These nanostructures are fabricated by resistive heating of Zn powder at a temperature of 400^{o}C in the presence of oxygen and argon gases under a vacuum of order of 10^{-6} mbar. The transmission electron microscope (TEM) images suggest that these nanostructures have some mixed morphology. They contain nanorods as well as nanoparticles. The typical diameter of these nanorods is in the range of 80-150 nm and the length is of the order of several micrometers, whereas the size of the nanoparticles vary from 50-80 nm. Temperature dependence of dc conductivity of these ZnO nanostructures is also studied in the temperature range (303-573K). It is found that the experimental data gives a good fit for thermally activated process. Therefore, it is suggested that thermally activated process is responsible for the transport in these nanostructures.

The main objective for this book to successfully synthesis of ZnO nanostructures with investigation of the electrical and optical properties in detail by the methods of Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Field Emission Scanning Electron Microscope (FESEM) etc. The entire book has been divided into six chapters, each of which is a self-contained unit in itself.

Chapter 1 begins with some basic introduction to nanotechnology and provides a comprehensive introduction to ZnO nanostructures It also provides some historical background and a brief summary of some basic subject matter and definitions.

Chapter 2 presents an extensive review of the subject. This chapter provides some historical connection between the nanotechnology and ZnO nanostructures. It gives an access to most of the basic material on the structure, synthesis, general properties with electrical and optical properties production, growth mechanisms and applications of ZnO nanostructures. Many references are provided from which the reader can obtain more detailed information further.

Chapter 3 deals with techniques of synthesis and characterization of ZnO nanostructures begins with experimental details and the description of the method used to prepare the ZnO nanostructures. This includes synthesis of ZnO nanostructures by physical vapor deposition. It further provides the brief information about the characterization of ZnO nanostructures. Different characterization techniques like SEM, TEM and FESEM adopted for the characterization of ZnO nanostructures are duly incorporated in details and results are given in chapter 4, chapter 5 and chapter 6

Chapter 4 presents results and discussion on the Electrical Transport Properties of ZnO nanostructures. The growth and characterization of ZnO nanostructures are also discussed along with their results.

Chapter 5 includes optical and electrical characterization of ZnO thin film. It presents results and discussion on the optical and electrical properties of ZnO thin film. The growth and characterization of ZnO nanostructures are also discussed along with their results.

Chapter 6 gives an overview of nanoparticles. It elaborates ways to produce ZnO nanoparticles with characterization including result and discussion.

Dr. Islam Uddin

List of Symbols and Acronyms

Symbols:

μm	Micrometer
A	Ampere
Ar	Argon
Cu	Copper
E	Young's Modulus
Fe	Iron
GHz	Giga Hertz
GPa	Giga Pascal
H_2	Hydrogen
H_2O_2	Hydrogen Peroxide
H_2SO_4	Sulphuric Acid
He	Helium
K	Kelvin
Li	Lithium
mA	Milli-ampere
MgO	Magnesium Oxide
Mo	Molybdenum
NH_3	Ammonia
Ni	Nickel
nm	Nanometer
O_2	Oxygen
Pd	Palladium
Pt	Platinum
Si	Silicon
TPa	Tera Pascal
V	Volt
V_S	Group Velocity
W	Watt
W	Wein
°C	Degree Celsius
$\varkappa$	Thermal Conductivity

Acronyms:

0D	Zero-Dimensional
1D	One-Dimensional
2D	Two-Dimensional
3D	Three-Dimensional
AC	Alternating Current
APCVD	Atmospheric Pressure Chemical Vapour Deposition
CVD	Chemical Vapour Deposition
DC	Direct Current
FET	Field-Effect Transistor
HRTEM	High Resolution Transmission Electron Microscopy
LPCVD	Low Pressure Chemical Vapour Deposition
MFC	Mass Flow Controller
MOCVD	Metallo-Organic Chemical Vapour Deposition
MOSFET	Metal-Oxide-Semiconductor Field Effect Transistor
MPCVD	Microwave Plasma Chemical Vapour Deposition
MWNTs	Multi-walled Carbon Nanotubes
NT	Nanotechnology
PECVD	Plasma Enhanced Chemical Vapour Deposition
RF	Radio Frequency
SEM	Scanning Electron Microscopy
STM	Scanning Tunneling Microscopy
SWNTs	Single-walled Carbon Nanotubes
TEM	Transmission Electron Microscopy
UHVCVD	Ultra High Vacuum Chemical Vapour Deposition
VLS	Vapour-Liquid-Solid
XRD	X-Ray Diffraction

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