ADVANCES IN PHYSICS OF MATERIALS

(Proceedings of VI International Workshop on Physics of Materials, Nov. 23-Dec. 5, 1987)

Editors

Z. H. Zaidi
M. Husain

Organised by
DEPARTMENT OF PHYSICS
JAMIA MILLIA ISLAMIA
Jamianagar New Delhi-110025

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Z. H. ZAIDI
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Department of Physics
Jamia Millia Islamia
Jamianagar, New Delhi-110 025

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PH.D., D SC. (WALES), F.N.A.SC., F.A.SC., F.N.A.
Vice-Chancellor

FOREWORD

The Department of Physics, inspite of limited resources at its disposal, had organised an International Workshop on "Physics of Materials" from 23 November to 5 December, 1987. In this Workshop about 100 scientists from twelve different countries participated. The lectures delivered in this Workshop covered a wide area of Physics dealing with semiconductor, laser, solar energy, dielectric and superconducting materials. Sustained efforts of the organisers has brought these lectures in the form of Proceedings of the Workshop.

The papers contained in the Proceedings are of much interest and include reviews of the current research areas and the results of latest researches.

The lectures included in the Proceedings cover both fundamental and applied aspects of the subjects and these provide an in-depth discussion on some of the underlying principles. I am sure, the Proceedings will prove to be of value to the readers.

I congratulate the participants and the organisers for organising such a successful two-week Workshop; and hope that there will be many more such seminars/workshops in the future.

15 May, 1989

(S.Z. QASIM)
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PREFACE

In Arabic 'Jamia' means University. What distinguishes Jamia Millia Islamia, or popularly known as 'the Jamia' from others is its unique historic association with the very struggle and triumph of nationalism in this country - nationalism that encouraged science and scientific attitude, cherished independence and freedom of thought, and at the same time attached special importance to India's national heritage and culture.

During the Khilafat and non-cooperation movement, in response to Gandhiji's call to boycott all government supported educational institutions, Maulana Mahmud Hasan, Maulana Mohammad Ali, Hakim Ajmal Khan, Dr. Mukhtar Ansari, Dr. Zakir Husain and some others, founded the Jamia at Aligarh in 1920. It moved from Aligarh to Delhi in 1925. Since then it has been continously growing and branching out from time to time to meet new needs. While developing, the Jamia reflects the original feelings of its founders who had deeply felt for the masses and hoped that education based on scientific thinking would liberate the country from poverty, ignorance and backwardness.

The department of Sciences were created in the Jamia Millia Islamia in 1971. Towards the end of VIth Plan Period, UGC permitted creation of a Centre of Physical Sciences and a Centre for Bio-Sciences. The Centre for Physical Sciences was supposed to start a post-graduate course with specialisation in Materials Science. Accordingly the Department of Physics is running a postgraduate course in Physics of Materials since 1985.

Materials science might be defined broadly as the characterisation, understanding and control of the structure of matter at the ultramolecular level and the relating of this structure to properties (mechanical, magnetic, electrical etc.) Materials technology is, of course, thousands of years old and a science of materials, though labelled only recently, has existed for a long while. It has assumed special importance because the present day science and technology requires materials with desired properties. Solid state materials, single crystals, ceramics, glasses, polymers and thin films, which are the building blocks of the modern devices, all should have desired properties. To prepare materials possessing desired properties, material scientists have to understand the relationship between chemical composition, physical perfection and properties of scientific and technological importance.

The emergence and progress of Materials Sciences has marched, and indeed crucially depended on, interdisciplinary interaction of physicists, chemists, metallurgists and other applied scientists. Such interdisciplinary cooperation must continue and flourish if Materials Science is to remain a meaningful and viable superdiscipline. With this objective we thought about organising a workshop of Physics of Materials.

The workshop was a great success as a number of distinguished speakers delivered lectures on different aspects of Physics of Materials. In addition to the resource persons, 63 participants got registered from India and abroad. The participants had been selected from a large number of applicants and represented different regions of the country. The other countries represented during the workshop were USA., UK., France, West Germany, Iran, Afghanistan, Pakistan, Nepal, Bangladesh, Russia and Japan. In fact we wanted participants from more countries particularly SARC countries but lack of funds forced us not to do that.

This volume can be broadly divided into five parts which cover the major fields: (a) Semiconductor materials (b) Laser materials (c) Solar energy material (d) Superconducting materials; and (e) Dielectric materials. The speakers not only took pains to prepare and deliver excellent lectures on topics of great interest but also in preparing articles for the proceedings. At the time of the workshop we were not very sure whether we shall have sufficient number of manuscripts to bring out the proceedings. However, most of the speakers responded to our request for the manuscript and took pains to contribute to the proceedings and we are very grateful to them.

We hope that the proceeding will be useful not only to the participants of the workshop but also to a large number of active research workers working in areas related to the subject matter.

The financial assistance received from the Department of Science & Technology, Govt. of India for meeting a part of the cost of publication of the proceedings is gratefully acknowledged.

Thanks are also due to Prof. D.S. Kothari, Professor Rais Ahmad, Professor F.H. Choudhury (UNESCO), Dr. K.P.P. Nambiar and Dr. G.D. Sootha for constant guidance and help. It will be unfair not to mention here the name of Dr. Krishan Lal who kept our morale high and helped practically for the success of this workshop.

We are grateful to Shri Khurshed Alam Khan, Chancellor, Jamia Millia Islamia for encouragement.

We are also thankful to Professor Ali Ashraf (then Vice-Chancellor), Registrar, Mr. Khwaja M. Shahid, and members of the Department of Physics for the help and cooperation during the workshop.

Editors

Z.H. Zaidi

M. Husain

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INAUGURAL ADDRESS

BY
Shri K.P.P. Nambiar, Secretary
Department of Electronics
Govt. of India
New Delhi.

Mr. Chairman, Prof. Kothari, Mr. Vice-Chancellor, distinguished guests from India and abroad, ladies and gentlemen. It is my pleasure and privilege to inaugurate the VI International Workshop on Physics of Materials in Jamia Millia Islamia, an institution of national importance and repute.

Materials play a very significant role in meeting the needs of society and therefore the ages of mankind's history have appropriately been named after materials prominent during that historical age, for example, the Stone Age, the Bronze Age, the Iron Age. The present age may be described as the Silicon Age if one gives importance to electronics, or Composite Age or Ceramics Age considering the developments taking place in these areas at present.

The innovation in the materials technologies are some of the most important efforts made by humans to improve their living conditions, to meet increasing energy requirements and health needs, to modernise the industrial production and to improve the agricultural output. Materials have played a significant role in achieving strength for the nation in socio-economic, industrial and strategic fields. Materials science and engineering has progressed through development of new materials, new phenomena, new processes etc. which has changed the concept of industrial technology, communication, transport, agriculture etc.

Physics plays an important role in understanding 'materials' and 'phenomenon' and contributes in developing new materials and using them for appropriate applications. I must congratulate the organisers for identifying such an important topics as the central theme of the Workshop. Since the subject of materials is extremely relevant, having experts from different countries come together to discuss these issues is a welcome event.

The present Workshop is dealing with very important segment of modern materials namely, Semi conductor materials, Semiconductors for solar energy conversion, Laser materials, Dielectric materials and Superconducting materials. A cursory glance on the types of materials would indicate that the most important common aspect is the electronic behaviour of these materials. And I see most of the lectures have been devoted on this subject. The list also includes topics related to synthesis and characterisation of materials. Therefore, I would briefly express my thoughts on some of these aspects. I am sure the technical aspects covering theory, synthesis and applications of materials would be covered in detail by experts in the respective fields.

If one looks at the history, the concept prevailing in earlier days regarded materials as inherently linked to the phenomena occurring in nature. However, after the days of Galileo, when the modern physics based on systematic experimentation started taking roots to explain the natural phenomena, a new concept based on materials-independent interaction of basic physical phenomena took shape. This concept developed further thereafter to an essential paradigm of physics. This resulted into development of various new hypothesis of quantum mechanics and so on. Physics thus became the successful science of nature by being able to correlate all materials dependent properties with other branches such as chemistry, mineralogy, metallurgy, etc.

This further developed into a physics of materials as an acceptable branch when the deep and complete understanding of the quantum mechanics of the individual item was established. Modern Material science with its revolutionary consequences, specially in micro-electronics had its scientific foundations in a few basic developments in physics in this century. These advances

clearly brought out the role of perfect crystals, control of specific impurities and their effects on the useful properties leading to a possibility of materials with desired properties by controlling composition and structure of materials.

The whole development changed the semi conductors, the one previously regarded as an example of materials unreliability, suddenly became the example of a completely new type of material with enormous technological implications. Perhaps, the present technological developments in ceramics is likely to change the present dominance of semiconductors. In addition to this, the unknown secrets of nature which are likely to be available in the future generations would bring out various changes to the concept of Materials technology and its application to our society.

The understanding of the existing materials for better use to the society and developing new materials to meet the needs of the new society made the humans to look for various alternatives. The Natural interest in understanding the environment and the curiosity for acquiring systematic knowledge of physical world, which are important attributes of human race, brought about growth in science. While the technology emerged,as man learnt how the nature can be used to meet his needs by way of producing the commodities required by the society itself, increased through such technological developments, requiring further progress of science. Thus science led to the development of technology and the technology in turn helped the progress of science. In the history of accelerating partnership of science and technology, the materials always played a central role.

The activities related to materials developments, can be grouped into 4 segments which are interlinked. These include -

(i) 'Science of materials' i.e.studies related to physics, chemistry etc. of materials;

(ii) 'Materials science' which relates to activities concerning identifying and meeting technical needs of the materials, for example, high temperature, high strength requirements, controllable semi-conducting properties etc. This requires inter-disciplinary work;

(iii) 'Materials engineering' which relates to activities concerning the use of specific material. These activities essentially needed cooperation between development and production engineers.

(iv) 'Materials supply' activity is also playing dominant role recently. This involves acquiring strength in national resources position and capability of processing and supplying the materials in the local as well as in the world market.

Electronics industry has achieved astonishing break-through within its relatively short history in terms of improved performance and lowering of cost of components, equipments and systems. Inventions and innovations covering devices and manufacturing techniques, not only have changed the basic concept of components and equipment design, but also have improved reliability of the complex electronic systems and have set pace for an ever increasing demand for improved performance, reduced size and lower cost. This was possible essentially through utilisation of useful properties of existing materials and developing new materials or improving the existing materials to meet the new challenges by way of discovering new phenomena, better utilisation of appropriate material properties and increasing the control of manufacturing processes to increase the yield and performance. This necessitates acquiring deeper understanding of intimate relationship between science and technology of materials on one hand and the properties and applications of devices on the other. This calls for a larger interactive coupling between various basic science and engineering disciplines.

Because of the increasing interactive coupling mentioned above, better control over the physical properties of the various materials used in the fabrication process needs to be achieved. Also, newer and more refined techniques/technologies to exploit and control their electronic properties have to be developed to meet the needs. To develop better understanding of the

correlation between the properties of material and its use in specific application in device, has become an important aspect of materials development and therefore characterisation of materials with its broader sense is receiving greater emphasis in this context. This compositional aspects of the characterisation demands knowledge of the nature and concentration of impurities while information on their distribution and chemical state completes this aspect. Indepth knowledge of these, together with their impact on functional properties of the end devices provides an insight to improve the quality of materials to perform a specific function.

Materials are important to society. With the science and technology of materials changing through new concepts, and new phenomenon, need for newer materials is increasing every day. Therefore, various segments of the society responsible for materials development have a definite role to play, for example, the technical needs are identified by Government and industry while laboratories and academic institutions should develop concepts of new products and applications within the economic constraints prevailing in the country. The R&D and Academic institutions have very important role to play with respect to these developments. The feed back interaction is an important linkage leading to overall development in this area.

Man's achievement in the area of new materials is an example of phenomenal progress of technology. However, it must be recognised that all the efforts must be aimed at preserving the earth's valuable resources and the materials that nature unfolds are used for the benefit of our people.

Ladies and Gentlemen, I hope that this workshop will be a great success and the delegate from India and abroad will discuss various important aspects of their respective fields. I am sure that all those who are participating will be benefitted. Finally, I thank the Vice-Chancellor and the Organising Committee for providing an opportunity to the Jamia and to inaugurate the workshop.

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RECENT DEVELOPMENTS IN SEMICONDUCTOR PHYSICS

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ABSTRACT:

Recent developments in semiconductor physics research are discussed. Two areas which have seen the most intense activity in the recent years have been selected for an overview. These include developments in Quantum-Wells, Superlattices and the 2-dimensional Electron Gas. The other major topic dealt with here is the rapidly developing field of Scanning Tunneling Microscopy which has found interesting applications in the diagnosis and modification of semiconductor maerials.

This talk is aimed at presenting an overview of the recent exciting developments in the Physics of Semiconductor Materials. In view of the limitations of time two areas will be selected for detailed discussion although there are a couple of other sub-fields which have witnessed intense research activity in semiconductor physics besides these. The focus of this talk will be the recent developments in

a.Quantum wells, superlattices and 2-dimensional electron gas

and b.Scanning tunnelling microscopy.

The interest generated by these developments can be gauged by the fact that work in these subfields earned the Physics Nobel Prize of 1985 and 1986,