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Short Biography. Vesselin Shanov is a Professor with the Chemical Engineering program at the Department of Chemical and Environmental Engineering at the University of Cincinnati (UC), and the co-founder and co-director of the teaching and research facility Nanoworld Lab. He has over 35 years of academic and industrial experience in research and development related to technologies and facilities for processing of advanced materials and thin films. Dr. Shanov has been a tenured associate professor at the University of Chemical Technology and Metallurgy, Sofia, Bulgaria, where he also served as an advisor to over 30 graduate students. He has taught 8 courses at the University of Chemical Technology and Metallurgy, Sofia, Bulgaria and 17 courses at the University of Cincinnati. His recent research focuses on synthesis, characterization, processing, and application of nanostructured materials with emphasis on carbon nanotubes, graphene, as well as on biodegradable Mg for medical implants. Applications of his research are in the areas of energy storage, wearable electronics, sensors, aerospace, and nanomedicine. Dr. Shanov has more than 300 scientific publications, including 20 issued patents, 32 provisional patents & patent applications, and 6 books, cited in about 10,000 different references, which earned him an H-index of 46.

SELECTED LECTURES ON NANOSCALE SCIENCE AND TECHNOLOGY

This course is offered to be given once a week with a duration of 90 minutes
Nanoscale science is an emerging area that has positively impacted multiple engineering technologies and medicine. The leading semiconductor manufacturers around the world have already started fabricating chips with feature size below 10 nanometers thus putting billions of transistors on space less than a human fingernail. The vision of the “nanoscience community” worldwide is a future in which the ability to understand and control matter at the nanoscale leads to ongoing revolutions in technology and industry that benefit society.

This course will address important topics concerning nanostructured materials and devices that are closely related to their science and engineering. Zero-, one-, and two-dimensional nanostructures will be introduced, in conjunction with their fabrication, characterization and application. The delivered knowledge will include state-of-the-art Chemical Vapor Deposition (CVD), Physical Vapor Deposition (PVD), Plasma processing reactors, and thin film characterization techniques such as Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Four-probe measurements, Atomic Force Microscopy (AFM), Thermogravimetric Analysis (TGA), Raman and UV-VIS spectroscopy, etc. Breakthrough areas of research at the UC Nanoworld Lab will be highlighted as well.

LECTURES:

Nanotechnology, Small world with a Big Future
This lecture delivers knowledge about the scope of nanoscale science and defines nanomaterials thus setting the stage for the entire module. You will learn how to define a nanomaterial and why by shrinking the size of the nanoparticles their physical and chemical properties change. Information on the basic approaches to making nanoparticles such as bottom-up and top-down

will be discussed and illustrated with appropriate examples. Multiple slides related to this part are available to the enrolled students for their study.

Scanning Electron Microscopy. Main Components and Principle of Operation
This lecture provides knowledge about the operating principles of Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) including their different performance modes. You will become familiar with the main components of SEM and TEM along with the science behind the formation of the images using these instruments. You will also understand the interaction of the electron beam with the studied substance and the generation of secondary and backscattered electrons responsible for the formation of the contrast on the image. In addition, information on Energy Dispersive Spectroscopy (EDS) as a non-destructive analytical technique for qualitative elemental analysis will be provided. Various slides illustrating this part are available to the enrolled students for their study.

Zero-Dimensional Nanomaterials, Quantum Dots
This lecture delivers learning about the 0-dimentional nanomaterials called quantum dots. Quantum dots are a “hot topic” in technologies related to electronics, medicine, sensing, etc. This part will equip you with knowledge about their synthesis, characterization, and applications. Approaches to tailor the properties of quantum dots will be presented and explained based on the quantum confinement of their charge carrier. A set of slides illustrating the core information of the quantum dots related to this part is available to the enrolled students for their study.

One-Dimensional Nanomaterials. Carbon Nanotubes, Synthesis and Characterization
This lecture provides knowledge about the 1-dimentional nanomaterials called carbon nanotubes. The major synthesis approaches to growing these nanoparticles will be presented with emphasis on the most popular one- Chemical Vapor Deposition (CVD). Characterization of CNT with advanced analytical techniques such as scanning electron microscopy (SEM), Raman spectroscopy, thermogravimetric analysis (TGA), and 4-probe measurement will be presented. Discussion on the role of the catalyst in the synthesis of CNTs is included in this part along with a comprehensive collection of slides which are available to the enrolled students for their study.

Carbon Nanotubes, Post-Processing and Advanced Applications
This lecture offers information about post-processing of carbon nanotubes. You will learn about the formation of the advanced CNT assemblages called sheets and fibers. Their properties will be discussed in detail along with the bond between the tubes in them. Advanced applications of CNT sheets and fibers will be illustrated by focusing on their use for water purification, sensors, antennas, low voltage heaters, and medicine. Multiple slides related to this part are available to the enrolled students for their study.

Nanowires, Synthesis and Characterization
This lecture offers learning about the synthesis of 1-dimentional nanoparticles called nanowires. Information about the synthesis of nanowires by template and non-template assisted growth, and the related growth mechanisms is provided here. Examples of growing metallic and semiconducting nanowires are also presented. You will also become familiar with the nanowire characterization, as well as with the measurement and manipulation of their properties. A comprehensive set of slides illustrating this part are available to the enrolled students for their study.

Nanowires, Advanced Applications.
This lecture delivers knowledge about formation of nanowires with different natures. The presented examples include formation of p-n junctions for fabricating nano-electronic devices. Characterization of the created semiconducting structures is illustrated by advanced analytical techniques including scanning TEM elemental mapping and X-ray Photoelectron Spectroscopy (XPS). Nanowire applications, focusing on optoelectronic and semiconducting devices such as Light Emitting Diodes (LED) and Field Effect Transistors (FET) are discussed. Numerous slides linked to this part are available to the enrolled students for their study.

Two-Dimensional Nanomaterials. Graphene, Synthesis and Characterization
This lecture provides knowledge about the 2-dimentional nanomaterial called graphene. The extraordinary properties of graphene are explained based on its structure and bonding between the carbon atoms in it. Comprehensive information about fabrication of graphene is presented including the frequently practiced physical and chemical synthetic routes. You will learn about the characterization of this nanomaterial by scanning electron microscopy, Raman spectroscopy, and thermogravimetric analysis. Numerous slides explaining this part are available to the enrolled students for their study.

Three-Dimensional Graphene. Synthesis, Processing and Advanced Applications
This lecture teaches about post-processing of graphene, including formation of 3-dimentional (3D) graphene. Synthesis of this nanomaterial will be illustrated by CVD with the use of the most effective catalyst- nickel. Techniques like knife casting and 3D printing will be presented as scale up options for 3D graphene fabrication. You will learn about the unique properties of 3D graphene, their tailoring during the synthesis or post-fabrication via cold rolling, along with their characterization. Advanced applications in Electromagnetic Interference Shielding (EMI), energy storage, and nanomedicine will be discussed. Plurality of slides related to this part are available

At the end of this course participants will be able to:
- Learn about the nature and properties of nanostructured materials
- Understand the relationship between dimensions and properties of nanostructured materials
- Obtain comprehensive knowledge about the main synthetic routes for fabricating nanostructured materials, including top down and bottom-up approaches
- Understand the principles of operations of main analytical tools used in nanoscale science and technology such as SEM, TEM, STM, TGA, Raman
- Gain knowledge about the major applications of nanostructured materials, particularly in nanoelectronics, sensors, energy generation and storage, nanomedicine
- Become aware of the safety regulations when handling nanostructured materials

Textbooks
1. Guozhong Cao and Ying Wang, “Nanostructures and Nanomaterials: Synthesis. Properties & Applications”, (World Scientific), 2nd Edition, 2016, Optional.
2. Book: “NANOTUBE SUPERFIBER MATERIALS, Science, Manufacturing, Commercialization”; Edited by Mark Schulz, Vesselin Shanov, Zhangzhang Yin, Marc Cahay, (Elsevier Science). 2019, Optional.
3. Book: NANOMEDICINE: Design of Particles, Sensors, Motors, Implants, Robots & Devices, with Solutions Manual”, Edited by Mark J. Schulz, Vesselin N. Shanov, Yun YeoHeung, (Artech House Publishers, "Engineering in Medicine & Biology" book series), 2009, Optional.