Chapter 2
Characterization Methods for Nanomaterials

Yogesh K. Kadam
https://orcid.org/0000-0002-3522-4659
Vanita Vishram Women's University, India

Kinjal D. Solanki
Vanita Vishram Women's University, India

Mihar S. Shaikh
Vanita Vishram Women's University, India

Ashwini M. Savle
Vanita Vishram Women's University, India

Naved I. Malek
https://orcid.org/0000-0002-2164-5268
Sardar Vallabhbhai National Institute of Technology, India

Neelam Mishra
https://orcid.org/0000-0003-4698-0166
Sir P.T. Sarvajanik College of Science, India

ABSTRACT

The characterization of nanoparticles is a critical element in nanotechnology, allowing for the exploration and enhancement of their distinct properties for various uses. This chapter elaborates various methods utilized in nanoparticle characterization, emphasizing on the techniques such as electron microscopy (TEM, SEM, and AFM), scattering (DLS), diffraction (XRD), and spectroscopy (UV-Vis, FTIR). Microscopic methods (TEM and SEM) offer detailed information on morphology and size distribution while AFM provides nano scale surface topography. Spectroscopic methods provide insights into chemical composition and surface chemistry. By combining these techniques, a thorough understanding of nanoparticle properties is gained which is crucial for their successful application in fields like medicine, electronics, and environmental science. Each of these techniques offers unique advantages and insights into the properties, structures, and behaviours of materials and biological specimens, contributing to advancements in scientific understanding and technological innovation.

1. INTRODUCTION

Nanoparticles are extremely small particles that typically ranging between 1 to 100 nanometers in at least one dimension. For reference, a nanometer is one billionth of a meter, much smaller than a human hair's width. These particles can be composed of various materials like metals, metal oxides, polymers,

DOI: 10.4018/979-8-3693-6326-3.ch002

ceramics, carbon-based materials such as carbon nanotubes and graphene. Their unique properties, due to their small size and high surface area, lead to distinct physical, chemical, mechanical, optical and electronic characteristics compared to larger particles of the same material. Nanoparticles find applications in diverse fields like medicine (e.g., drug delivery systems, diagnostic imaging agents), electronics (e.g., conductive inks, quantum dots), energy (e.g., solar cells, fuel cells), catalysis (e.g., catalysts for chemical reactions), environmental remediation (e.g., water purification) and consumer products (e.g., sunscreen, cosmetics). Research and technology focusing on nanoparticles have a huge potential for innovation and impact across various industries. Nanoparticles are widely utilized for targeted drug delivery, enhancing drug efficacy while minimizing side effects. They also protect drugs from degradation and improve their solubility and availability in the body. Moreover, for biomedical research, nanoparticles are invaluable for studying cellular processes, drug interactions and disease mechanisms at a molecular level, aiding in understanding biological phenomena and developing therapeutic strategies. In diagnostic imaging, nanoparticles serve as contrast agents for techniques like MRI, CT, and fluorescence imaging, improving visualization for early disease detection. In energy technologies, nanoparticles enhance the efficiency, durability and performance of devices like solar cells, batteries, fuel cells and catalytic converters by improving charge transport, catalytic activity, and surface reactions. Nanoparticles are being more frequently used in various consumer goods like cosmetics, clothing, coatings, and electronics. Nanoparticles have various uses in medical treatments like cancer therapy, gene therapy, and regenerative medicine. They are capable of transporting therapeutic substances like chemotherapy drugs, nucleic acids, proteins and stem cells directly to specific locations, improving the effectiveness of treatment while minimizing side effects in the body. In general, nanoparticles have transformed multiple industries and research sectors by providing creative solutions to difficult problems and pushing progress in science, technology, and healthcare. Their significance is anticipated to expand further as scientists delve into fresh uses and fully harness the capabilities of nanotechnology.

The characterization of nanoparticles is a critical element in nanotechnology, allowing for the exploration and enhancement of their distinct properties for various uses (Joudeh, N., & Linke, D. 2022). This chapter elaborates various methods utilized in nanoparticle characterization, emphasizing on the techniques such as electron microscopy i.e. Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM), scattering i.e. Dynamic Light Scattering (DLS), diffraction i.e. X-ray Diffraction (XRD) and spectroscopy (UV-Vis, FTIR). This chapter also shed light on other methods like Thermo Gravimetric Analysis (TGA), Zeta Potential Analysis (ZPE), Cryo-Electron Microscopy (Cryo-EM), Correlative Light and Electron Microscopy (CLEM), Super-Resolution Microscopy Techniques (SRMT) and Atomic Probe Tomography (APT). TEM and SEM offer detailed information on morphology and size distribution while AFM provides nano scale surface topography (Modena, et al.2019). Dynamic Light Scattering (DLS) is employed to measure size and distribution in colloidal solutions (Abel, et al.2011). X-ray Diffraction (XRD) assists in identifying crystalline structures. Spectroscopic methods provide insights into chemical composition and surface chemistry (Yoganandam, K et al. 2021), (Saka, A et al. 2022). By combining these techniques, a thorough understanding of nanoparticle properties is gained which is crucial for their successful application in fields of medicine, electronics, and environmental science (James, R. 2014), (Stefanos Mourdikoudis, Roger M. Pallares and Nguyen T. K. Thanh.2018).. The chapter ends by addressing the progress made in methods for characterizing materials and how these advancements will influence future studies and advancements in the field of nanotechnology (Mitchell, M. J., Billingsley, M. M., Haley, et al. 2020). Each of these techniques offers unique advantages and insights into the properties, structures and behaviors

Related Content

NanoMaterial: Fortifying Civil and Infrastructure With Next-Gen Corrosion Inhibition - A Review
Nidhya Rathinavel, Arun Murugesanand Abdul Aleem Mohamed Ismail (2024). *Sustainability, Safety, and Applications of Nanomaterials-Based Corrosion Inhibitors (pp. 51-65).*
www.irma-international.org/chapter/nanomaterial/350974

Nanotechnology for Soil Remediation and Land Restoration
Muhammad Majeed, Wajeeha Noor, Arshad Rasool, Muhammad Saleem, Iqra Bashir, Rabia Fatima, Allah Bakhsh Gulshan, Dwaipayan Sinha, Satarupa Nath, Shumaila Hassan, Zehra Batool, Shahid Abbasand Arslan Rafique (2024). *Harnessing NanoOmics and Nanozymes for Sustainable Agriculture (pp. 60-77).*
www.irma-international.org/chapter/nanotechnology-for-soil-remediation-and-land-restoration/346022

Study of the Structure and Properties of Nanoparticles Cynara scolymus L. Encapsulated With Sodium Carboxymethyl Cellulose Polysaccharide
Muborak A. Tulyasheva, Sobitjan Y. Inagamovand Gafur I. Mukhamedov (2021). *International Journal of Applied Nanotechnology Research (pp. 1-10).*
www.irma-international.org/article/study-of-the-structure-and-properties-of-nanoparticles-cynara-scolymus-l-encapsulated-with-sodium-carboxymethyl-cellulose-polysaccharide/287586

Spectral Atomic Selection and Pumping
(2014). *Quantum and Optical Dynamics of Matter for Nanotechnology (pp. 329-347).*
www.irma-international.org/chapter/spectral-atomic-selection-and-pumping/92595

Spin Relaxation Mechanisms in the Organic Semiconductor Alq3
Sridhar Patibandla, Bhargava Kanchibotla, Sandipan Pramanik, Supriyo Bandyopadhyayand Marc Cahay (2009). *International Journal of Nanotechnology and Molecular Computation (pp. 20-38).*
www.irma-international.org/article/spin-relaxation-mechanisms-organic-semiconductor/40363