

Detailed Table of Contents

Preface	xxi
----------------------	-----

Chapter 1

Green and Sustainable Manufacturing of Advanced Materials: Progress and Prospects	1
---	---

P. Selvakumar, Nehru Institute of Technology, India

M. Prabakaran, Karpaga Vinayaga College of Engineering and Technology, India

J. Suhashini, GTN Arts College, India

Siva Sankara Babu Chinka, Lakireddy Bali Reddy College of Engineering, Kakinada, India

Santosh Kumar Nathsharma, Stewart Science College, India

Manjunath T. C, Rajarajeswari College of Engineering, India

Green manufacturing represents a pivotal shift in industrial practices, aimed at harmonizing economic growth with environmental stewardship. This chapter delves into the core principles and drivers behind green manufacturing, exploring how they collectively foster a more sustainable industrial ecosystem. At its essence, green manufacturing seeks to minimize the environmental impact of production processes while enhancing resource efficiency. The principles underpinning this approach are grounded in reducing waste, conserving energy, and utilizing environmentally friendly materials. By embedding these principles into the core of manufacturing practices, industries can significantly reduce their carbon footprint and contribute to broader sustainability goals. Central to green manufacturing is the efficient use of resources. This principle emphasizes minimizing the consumption of raw materials, energy, and water throughout the production process. Strategies such as process optimization, material substitution, and closed-loop systems are employed to achieve this goal.

Chapter 2

Advancing Green Manufacturing With Sustainable Solutions for Advanced Materials	29
---	----

G. Boopathy, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, India

V. Srinivasan, Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, India

R. Bhoominathan, Bharath Institute of Higher Education and Research, India

M. Arulmurugan, S.A. Engineering College, India

This chapter touches upon the incorporation of such computational intelligence in the context of sustainable manufacturing of advanced materials from both present context and future prospect. The material creation framework depends on fundamental ideas, tools and techniques for producing sustainable materials and ecologically designed and assessed materials. The computational intelligence is studied and has shown significant importance in optimization of manufacturing process and also improvement of material properties of parts. It empirically provides pragmatic insights about the advantages and hurdle of the success of applications based on empirical studies of the success of the application on many industries. It ends by discussing economic, technologic and regulatory barriers to wide spread delivery and strategies to overcome these barriers and to continue innovation in sustainable manufacturing.

Chapter 3

Emerging Materials for Energy Storage and Environmental Applications	53
--	----

M. Nisha Angeline, Velalar College of Engineering and Technology, India

P. Selvakumar, Science and Humanities, Nehru Institute of Technology, India

Manoj Kumar Gupta, National Institute of Technology, Kurukshetra, India

Naeema Nazar, VISAT Engineering College, India

D. Elumalai, Vels Institute of Science, Technology, and Advanced Studies, India

Sumanta Bhattacharya, Maulana Abul Kalam Azad University of Technology, India

The advent of new materials offers promising solutions for enhancing energy storage systems, improving energy efficiency, and mitigating environmental impacts. These advanced materials are characterized by their unique properties, which enable them to address the limitations of conventional materials and contribute to innovative technologies in various fields. In the realm of renewable energy, emerging materials are transforming photovoltaic technology. Traditional silicon-based solar cells are being complemented by new materials such as perovskite solar cells, organic photovoltaics, and quantum dots. Perovskite materials, known for their exceptional light absorption and charge transport properties, have demonstrated the potential for high-efficiency, low-cost solar cells with ease of fabrication. Organic photovoltaics, which use organic compounds to convert sunlight into electricity, offer flexibility and lightweight characteristics, making them suitable for a range of applications from wearable electronics to building-integrated photovoltaics.

Chapter 4

Bio-Based Materials for Sustainable Energy Applications	73
---	----

Amisha Shaikh, Ajeenkya D.Y. Patil University, India

Susanta Das, Ajeenkya D.Y. Patil University, India

Bio-based materials are those materials which are taken either wholly or partly from bio-based materials, e.g., plants & microorganisms. These materials can be distinguished by their renewability & some measure of carbon capture during their growth. They are gradually becoming famous as a viable option to existing materials because of heightened consciousness about environmental issues. Polymers, coatings, and composites are discussed as an extensive class of bio-based products; these materials possess several characteristics, including biodegradability & non-toxicity. Thus, bio-based materials have been practiced in different industries & areas. Most of these materials substitute fossil-based resources & consequently, processes used in manufacture of these materials contribute to lowering of carbon footprints. Bio-based & biodegradability are two important concepts for waste management & circular economy. In conclusion, applications of bio-based materials can energize sustainable growth, minimize carbon impressions, aid progress, & establish sustainable economies.

Chapter 5

Biogenic Gold Nanoparticles: Methods, Characterization, and Diverse Applications.....	83
---	----

Amisha Shaikh, Ajeenkya D.Y. Patil University, India

Susanta Das, Ajeenkya D.Y. Patil University, India

Metallic NPs, particularly (AuNPs), have attracted great attention due to their unique characteristics and applications. NPs have unique surface qualities as compared to bulk substances, including diagnostics and medicine administration. Therapeutic plant extracts exhibit stability, making them suitable for various applications as a result of their biocompatibility and flexibility, thereby minimizing their phytochemical

properties. The biogenic NPs were characterized using UV-vis, FTIR, and SEM, demonstrating antibacterial activity and potential for large-scale synthesis. Green synthesis technique adopted ecological acceptable practices and showed the promise of plant-based synthesis in biomedical applications. Phytoextract is cost-effective and eco-friendly method for producing AuNPs, outperforming conventional chemical synthesis methods. Along with providing workable substitute for chemical synthesis in pharmaceutical, medical, and agricultural domains, it also demonstrates the viability of green synthesis for the production of bioactive AuNPs and shows its prospective applications.

Chapter 6

Design, Development, and Testing of Eco-Friendly Natural Fiber-Reinforced Composites for High Temperature Applications: Eco-Friendly Biocomposites 101

Prakash Chandra Gope, College of Technology, G.B. Pant University of Agriculture and Technology, India

In recent years, there has been a growing demand for development of eco-friendly material for long-lasting, lightweight, superior strength and fire retardant. This has drawn the researchers to use various natural fiber as a reinforcing agent in a matrix material. The use of bio-fibers as reinforcement in place of synthetic fibers (carbon and glass fiber) in the creation of polymer matrix composites has garnered a lot of interest in the last few years. Several natural fibers have been exploited as reinforcing materials by researchers in the past. Excellent adhesion to various materials, high strength, toughness, resistance to chemical assault, humidity, and moisture resistance, superior electrical insulating properties, odorlessness, non-toxicity, and minimal shrinking are only a few of the qualities of epoxy resin to be used as a matrix material. Information regarding environmentally acceptable materials that can be used in high-temperature applications is needed by numerous sectors.

Chapter 7

Computational Intelligence (CI) in the Sustainable Manufacturing of Emerging Materials for Energy Storage and Environmental Applications 121

Vijayalaxmi Vishwanath Sonkamble, Indian Institute of Technology, Bombay, India
Vinod Govind Gawai, Tata Motors Pvt. Ltd., India

The demand for sustainable energy storage has driven advancements in material science, where Computational Intelligence (CI) is emerging as a key tool. CI techniques like machine learning and neural networks optimize complex processes, enhancing material properties and manufacturing efficiency. In energy storage, CI accelerates the discovery of materials for advanced batteries, supercapacitors, and hydrogen storage, improving energy density, cycle life, and safety. CI also aids environmental applications, such as water purification and carbon capture, by enhancing material performance. Despite challenges like data availability and computational resources, CI's integration into manufacturing promises a more sustainable future.

Chapter 8

AI-Driven Optimization in Sustainable Manufacturing for Eco-Efficient Manufacturing of Advanced Materials	149
---	-----

R. Jegadeesan, Department of Computer Science and Engineering, Jyothishmathi Institute of Technology & Science, Thimmapur, India

Sonia Maria D'Souza, Department of Artificial Intelligence and Machine Learning, New Horizon College of Engineering, Bengaluru, India

B. Dhanasakkaravarthi, Department of Mechanical Engineering, Agni College of Technology, Chennai, India

S. Ranganathan, AMET University, India

V. Kavitha, Department of Data Science and Business Systems, School of Computing, SRM Institute of Science and Technology, Kattankulathur, India

A. Rajendra Prasad, Department of Mechanical Engineering, Sri Sai Ram Engineering College, Chennai, India

The chapter studies the use of AI-driven optimization to apply methods of sustainable manufacturing based on the scenario of eco-efficient production of advanced materials. It also shows how AI methods could be used, including machine learning and optimization algorithms, to increase the efficiency of manufacturing processing flows while decreasing environmental impact. The chapter covers a scope of AI-based predictive maintenance, process optimization, and resource management strategies that result in a reduction in waste generation, energy use, and gases emitted. These are demonstrated in practice through case studies and examples in the manufacturing of advanced materials, ensuring the transformation of conventional manufacturing practices into more sustainable operations. In fact, the implementation of AI into the practice of manufacturing that recognizes and promotes sustainable manufacturing would massively contribute to the enhancement of full sustainability benefits by encouraging environmental stewardship while fostering innovation in material science.

Chapter 9

Integrating Machine Learning and Computational Intelligence for Green Manufacturing Processes	177
---	-----

P. Chitra, Department of Computer Science and Engineering, SRM Institute of Science and Technology, Chennai, India

Rao P. B. V. Raja, Shri Vishnu Engineering College for Women, India

A. Ananthi, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, India

G. Saritha, Sri Sai Ram Institute of Technology, India

A. Balasuadhakar, AMET University, India

Sampath Boopathi, Muthayammal Engineering College, India

The chapter is focused on integrating machine learning and computational intelligence into green manufacturing processes. ML and CI offer data-driven solutions toward industries strive for reduced environmental impacts through resource usage, energy consumption, and waste reduction, among others. This chapter will focus on some very prominent algorithms, such as neural networks, reinforcement learning, and fuzzy logic, and their applications in predictive maintenance, process optimization, and supply chain management for sustainability. The chapter relates the integration of ML and CI in achieving eco-friendly manufacturing goals—reduction of carbon footprint and improvement in operational efficiency—through case studies and practical examples. It discusses the role played by digital twins, IoT

integration, and AI-driven decision-making in enabling adaptive and resilient manufacturing systems. The chapter is concluded by future trends and challenges to implement these technologies on a larger scale for the transformation of industry in a sustainable way.

Chapter 10

Development of Nature-Inspired Algorithms for Intelligent Manufacturing Systems 205

Jatin Soni, Shri Mata Vaishno Devi University, India

Kuntal Bhattacharjee, Nirma University, India

Intelligent manufacturing systems focus on enhancing product quality while reducing production costs through the optimization of process parameters. Researchers have faced various challenges in engineering design and process optimization, prompting the development of two variants of the Artificial Bee Colony (ABC) algorithm. One variant incorporates Differential Evolution (DE) operators into the standard ABC, resulting in the creation of a new algorithm called Artificial Bee Colony-Differential Evolution (ABC-DE). This hybrid algorithm synergizes the strengths of both ABC and DE algorithms, making the optimization process both efficient and effective. The ABC-DE algorithm is versatile and can be applied to any manufacturing process improvement aimed at optimizing process parameters, improving product quality, and reducing costs. Its application in the manufacturing industry holds significant potential, enabling companies to lower product prices while maintaining high-quality standards, which could have a profound impact on industry competitiveness and customer satisfaction.

Chapter 11

Sustainable Machining Process Optimization: Predictive Modeling With Multi-Objective Ant

Colony Algorithms..... 237

*Mahendra Kumar B., Department of MCA, Dayananda Sagar College of Engineering,
Bengaluru, India*

*K. S. Shreenidhi , Department of Biotechnology, Rajalakshmi Engineering College, Chennai,
India*

*Harishchander Anandaram, Department of Artificial Intelligence, Amrita Vishwa
Vidyapeetham, Coimbatore, India*

*Sampath Velpula, Department of Mechanical Engineering, Vignana Bharathi Institute of
Technology(VBIT), Medchal, India*

*R. Gukendran, Department of Mechanical Engineering, Kongu Engineering College, Erode,
India*

Sustainable machining practices are essential for an effective machining process with minimum impact on the environment. In this respect, this chapter puts forward the utilization of multi-objective ACO techniques applied to predictive modeling on sustainable machining processes. In this research, ACO has been utilized to study the conflicting objectives of energy consumption, tool wear, surface quality, and production time to optimize the parameters for machining. Sustainably machining problems are discussed in detail and further go on to describe ACO algorithms: simulating foraging behavior of ants to identify good solutions. Then, case studies are presented, demonstrating how ACO can simultaneously minimize environmental impact while improving machining performance. The results underline potential resource-efficient manufacturing by way of minimization and decision making for waste with ACO-induced sustainable industrial processes.

Chapter 12

Optimization of Abrasive Jet Machining Processes Using Evolutionary Algorithms: A Computational Approach	261
--	-----

T. Kumaresan, Department of Mechanical Engineering, PSG Polytechnic College, Coimbatore, India

Shrikant Joshi, Brahmadevdada Mane Polytechnic, Solapur, India

Nachimuthu Somasundaram, Department of Mechanical Engineering, Rathinam Technical Campus, Coimbatore, India

Shreenidhi K. S., Department of Biotechnology, Rajalakshmi Engineering College, Chennai, India

Harishchander Anandaram, Department of Artificial Intelligence, Amrita Vishwa Vidyapeetham, Coimbatore, India

Abrasive Jet Machining is a non-traditional machining process with the considerable versatility of use, mostly in cutting, cleaning, and deburring hard and brittle materials. In AJM, optimal parameters involve such things as abrasive flow rate, pressure, and standoff distance, all of which are very important for attaining the appropriate performance metrics with respect to material removal rate (MRR) and surface finish. It applies evolutionary algorithms, specifically Genetic Algorithms (GA) and Particle Swarm Optimization (PSO), to the optimization of AJM processes. The evolutionary algorithms may efficiently locate optimal parameter combinations from computer simulations of various machining conditions into significant reductions in energy, wear, and increases in accuracy in machining. The computational approach given below provides a robust framework for achieving precision in AJM, beating traditional optimization techniques. Experimental verification has demonstrated the effectiveness of proposed EA-based models in optimizing efficiency in AJM.

Chapter 13

Multi-Objective Genetic Algorithms for Optimizing Cold Roll Forming of Advanced High Strength Steels	285
--	-----

Dayanand Yesane, Department of Mechanical Engineering, Dr. D.Y. Patil Institute of Technology, Pune, India

Rupesh Bhortake, Department of Mechanical Engineering, Marathwada Mitra Mandal's Institute of Technology, Pune, India

The roll forming of Advanced High Strength Steels (AHSS) is characterized by several challenges, mainly because of their specific mechanical properties: springback, tool wear, material fracture, and lubrication inefficiencies. This chapter presents an optimized manufacturing process using MOGAs, balancing opposing objectives like low springback and tool life by utilizing MOGAs. The study examines the impact of advanced tooling materials, coatings, finite element analysis process simulations, and lubrication techniques on joint effect. Case studies demonstrate successful application of solutions, resulting in higher quality products, reduced costs, and improved operational efficiency. The proposed approach will enhance the durability and strength-to-weight ratio of AHSS, thereby overcoming the limitations of the cold roll forming technique, thereby enabling its wider industrial applications in automotive and construction sectors.

Chapter 14

Advancing Material Property Prediction With AI and Deep Learning Technologies 309

Durga Prasad Garapati, Department of Artificial Intelligence, Shri Vishnu Engineering College for Women, India

S. Iniyan, Department of Computing Technologies, School of Computing, SRM Institute of Science and Technology, Chennai, India

Sultanuddin SJ, Department of Cyber Security, Dhanalakshmi College of Engineering, Chennai, India

R. Manivannan, Department of Electrical and Electronics Engineering, St. Joseph's Institute of Technology, Chennai, India

N. Pragadish, Department of Mechanical Engineering, Rajalakshmi Institute of Technology, Chennai, India

Artificial intelligence and deep learning technologies are driving transformations in material science, particularly in predicting material property through machine learning applications. In this chapter, we are concerned about how materials property prediction can be revolutionized by advances in new state-of-the-art technologies enabling more accurate and efficient predictions in comparison to the traditional methods which incur time-consuming and cost-consuming expense. While both ML and deep learning offer powerful alternatives, they require large datasets and robust algorithms to accurately map complex interplay between the material structure and its properties. In this text you will read about employing deep learning architectures, such as CNNs and RNNs, in predicting properties such as mechanical strength, thermal conductivity and electronic behavior. The chapter discusses successful case studies and predicts future material science research and industry practices integrating AI-driven approaches.

Chapter 15

Mathematical Modeling and Computational Methods in Emerging Engineering Applications: A Study 335

Balveer Saini, Department of Mathematics, Maharani Shri Jaya Govt PG College, Bharatpur, India

S. B. Javheri, Department of Civil Engineering, Walchand Institute of Technology, Solapur, India

P. Sasikala, Department of Computer Science, Lal Bahadur Shastri Government First Grade College, Bangaluru, India

Saurabh Chandra, School of Law, Bennett University, Greater Noida, India

Keshav Kumar K., Department of Humanities and Mathematics, G. Narayanamma Institute of Technology and Science (for Women), Hyderabad, India

Mathematical modeling and computational methods are the critical techniques necessary to meet such complex challenges in the scope of a broad range of emerging engineering fields. This chapter emphasizes how these techniques might be dovetailed for applications of handling real problems within renewable energy, biomedical engineering, autonomous systems, and smart infrastructure. Powerful algorithms, numerical methods, and data-driven models may be used to simulate, predict, and even optimize system behavior under various conditions. The synergy between mathematical theories and computational tools is highlighted: artificial intelligence, machine learning, and high-performance computing, which improve design efficiency and bring innovation. A set of practical benefits presented in case studies of modern engineering applications benefits from these approaches. The chapter puts theories together with practice in giving an all-round overview of how computational methods drive advancement in engineering.

Chapter 16

Optimizing Composite Material Selection Using the Artificial Bee Colony Algorithm: A Comprehensive Approach..... 361

L. S. Sindhuja, Department of Networking and Mobile Application, PSG College of Arts & Science, Coimbatore, India

K. S. Shreenidhi, Department of Biotechnology, Rajalakshmi Engineering College, Chennai, India

Harishchander Anandaram, Department of Artificial Intelligence, Amrita Vishwa Vidyapeetham, Coimbatore, India

Saurabh Chandra, School of Law, Bennett University, Greater Noida, India

B. S. Hari, Department of Mechanical Engineering, Kongu Engineering College, Erode, India

The selection of optimal materials for composite structures is an important step in engineering design, balancing performance, cost, and weight. In this chapter, the Artificial Bee Colony (ABC) algorithm, a nature-inspired optimization technique, is applied to efficiently identify the best composite material configurations. The ABC algorithm is inspired by the foraging behavior of honeybees, offering robust search capabilities and convergence properties. We discuss the principles underlying the ABC algorithm, its application to material selection, and performance evaluation criteria for composites. We compare it with traditional optimization techniques and make it clear that it outperforms them in solving complicated multidimensional problems. Case studies give an example of how it can be used for obtaining the optimal solution in several engineering applications. This chapter provides a comprehensive guide for researchers and engineers to improve design efficiency and performance by utilizing bio-inspired algorithms in material selection.

Chapter 17

Mastering Friction Stir Welding (FSW) With Machine Learning (ML): A Comprehensive Guide to Algorithms and Applications..... 387

Raheem Al-Sabur, University of Basrah, Iraq

Akshansh Mishra, Politecnico di Milano, Italy

Hassanein I. Khalaf, Univeristy of Basrah, Iraq

This chapter introduces machine learning (ML) in friction stir welding (FSW), a solid-state welding process that has gained significant attention in research and application. The chapter discusses five primary ML methods: artificial neural networks (ANNs), support vector machines (SVM), random forests (RF), particle swarm optimisation (PSO), and convolutional neural networks (CNNs). The chapter emphasizes the successful application of ANNs in optimizing FSW process parameters and predicting tool wear, tensile failure, and fracture positions. CNNs are shown to be effective for microstructure studies and image detection, while SVM is a good tool for FSW process monitoring and temperature control. RF is demonstrated to have good abilities in investigating welding defects and tool monitoring, while PSO is frequently used in FSW welding bead studies. The chapter provides a straightforward methodology for those interested in utilising ML in welding studies, particularly for FSW.

Chapter 18

Machining of Hardened Steel on EDM and Optimization Using Genetic and Particle Swarm

Algorithms 417

Sampath Velpula, Department of Mechanical Engineering, Vignana Bharathi Institute of Technology(VBIT), Medchal, India

K. Eswaraiah, Department of Mechanical Engineering, Kakatiya Institute of Technology and Science, Warangal, India

Sridhar Bheemanaathy, Department of Mechanical Engineering, Vignana Bharathi Institute of Technology(VBIT), Medchal, India

G. Amarendar Rao, Department of Mechanical Engineering, Vignana Bharathi Institute of Technology(VBIT), Medchal, India

Y. V. S. S. V. Prasada Rao, Department of Mechanical Engineering, Vignana Bharathi Institute of Technology (VBIT), Medchal, India

This research focuses on optimizing electrical discharge machining (EDM) parameters to improve performance in producing complex shapes from conductive materials. EDM is a specialized process that requires precise parameter settings for enhanced results. We propose a novel approach using a combination of genetic algorithms and particle swarm optimization to identify optimal machining parameters for OHNS steel using a copper electrode. The objective functions include various performance metrics such as work piece initial and final weights, surface finish quality, current, spark gap, machining time, voltage, rate of material removal, and electrode wear rate. By evaluating these parameters, our method aims to achieve superior machining efficiency and quality. The study's approach provides a comprehensive framework for determining the best SEM settings, contributing to advancements in precision manufacturing and material processing.

Chapter 19

Computational Intelligence-Driven Design and Optimization of Polyurethane Belt-Type Oil

Skimmer for Sustainable Manufacturing Using Solidworks 3D CAD 445

Amandeep Singh Wadhwa, University Institute of Engineering and Technology (UIET), Panjab University, Chandigarh, India

Shalom Akhai, Maharishi Markandeshwar Engineering College, Maharishi Markandeshwar University (Deemed), Mullana, India

Mahapara Abbass, Maharishi Markandeshwar Engineering College, Maharishi Markandeshwar University (Deemed), Mullana, India

Arti Chouksey, Deenbandhu Chhotu Ram University of Science and Technology, Murthal, India

Shailendra Tiwari, Uttaranchal University, Dehradun, India

Tanu Taneja, Baba Farid College of Engineering and Technology, Bathinda, India

This study focuses on developing a belt-type oil skimmer to effectively remove oil from water surfaces, promoting a green industry and reducing global pollution. The skimmer uses a belt mechanism that uses water and oil density differences to remove oil, achieving an efficiency of 62% to 92% depending on the oil type. The study uses SOLIDWORKS to create a detailed 3D model, adhering to industry best practices. The research extends beyond environmental protection to aquatic ecosystems, aligning with eco-friendly industrial practices and showcasing the impact of technical advancements on environmental challenges. This research demonstrates the potential of improving oil-water separation-dependent industrial operations and reducing water pollution.

Chapter 20

Design and Strategies Related to Smart Manufacturing System Development Using IoT 465

Lakshya Pandey, VIT Bhopal University, India

Spandan Agrawal, VIT Bhopal University, India

D. Lakshmi, VIT Bhopal University, India

The realm of manufacturing is shifting towards intelligent manufacturing systems, emphasizing Industry 4.0, and integrating digital and physical environments using IoT, cloud systems, data analysis, and Machine Learning (ML). Smart devices and sensors gather data for various applications, which are then transmitted to the cloud for analysis. Cloud systems, powered by AI and ML, provide valuable insights. The latest inventory management technology uses automation and robotics for real-time monitoring, while MEMS are miniature sensors that detect changes. The text below discusses the diverse applications of IoT sensors such as accelerometers, microphones, gyroscopes, inkjet printer heads, and blood pressure sensors. The text discusses how IoT has revolutionized healthcare, agriculture, smart cities, manufacturing, retail, logistics, and energy. It highlights the role of IoT sensors in real-time monitoring, disease management, crop yield maximization, and enhanced safety measures. When integrated with intelligent manufacturing, it improves efficiency, safety, and sustainability.

Chapter 21

Integrating Machine Learning With Industrial Automation for Enhanced Predictive Maintenance . 487

Archana Kedar Chaudhari, Vishwakarma Institute of Technology, India

The integration of machine learning with industrial automation is transforming the landscape of predictive maintenance, a critical aspect of modern manufacturing and industrial operations. This research explores the synergies between machine learning algorithms and industrial automation systems. Predictive maintenance leverages data-driven insights to anticipate equipment failures, thereby reducing downtime, optimizing maintenance schedules, and enhancing operational efficiency. The core of the research focuses on the application of machine learning techniques to predictive maintenance. The paper outlines the processes of data collection, feature extraction, model training, and validation, highlighting the challenges and solutions associated with each step. The work discusses industrial applications based on machine learning for predictive maintenance. Issues like data integration, scalability and security are discussed along with strategies to overcome the challenges.

Chapter 22

Innovations in Device-to-Device Communication for Mechanical Tool Optimization 511

P. Sreenivas, Department of Mechanical Engineering, K.S.R.M. College of Engineering, Kadapa, India

Divakar Harekal, Department of Information Science and Engineering, Jyothy Institute of Technology, Bengaluru, India

T. K. S. Rathish Babu, Department of Computer Science and Engineering, SRM Institute of Science and Technology, Ramapuram, India

Sudheer Kumar Battula, Department of Mechanical Engineering, Lakireddy Balireddy College of Engineering, Krishna District, India

J. Ramya, Easwari Engineering College, Chennai, India

This chapter explores the emerging innovations in Device-to-Device (D2D) communication aimed at optimizing the performance and efficiency of mechanical tools. D2D communication allows mechanical

tools and devices to directly exchange data without relying on centralized networks, enabling faster, more reliable interactions. The chapter delves into various technologies such as 5G, Internet of Things (IoT), and edge computing, highlighting their role in enhancing real-time communication, predictive maintenance, and autonomous tool operations. Additionally, it examines the challenges and solutions related to data security, energy efficiency, and interoperability in D2D networks. Case studies and applications in industries such as manufacturing, automotive, and construction are presented to illustrate the practical benefits of these innovations. The chapter concludes by discussing future trends, including the integration of artificial intelligence and machine learning in D2D systems, which promises to further revolutionize mechanical tool optimization.

Chapter 23

The Role of Computational Approaches in Additive Manufacturing for Medical Applications 533

*Jayashri Narayanan Nair, Department of Mechanical Engineering, VNR Vignana Jyothi
Institute of Engineering and Technology, Sanga Reddy, India*

*Annapoorna M. S., Department of Mathematics, BMS Institute of Technology and
Management, Bengaluru, India*

*Madhu P., Department of Mechanical Engineering, Malnad College of Engineering, Hassan,
India*

*Shreenidhi K. S., Department of Biotechnology, Rajalakshmi Engineering College, Chennai,
India*

*Harishchander Anandaram, Department of Artificial Intelligence, Amrita Vishwa
Vidyapeetham, Coimbatore, India*

This chapter presents the major role of computational methods in driving additive manufacturing (AM) toward medical applications. Additive manufacturing technology for instance, through 3D printing, has seen the medical application evolve into creating personalized implants, prosthetics, and surgical guides. Computational methods like CAD, FEA, and optimization algorithms are crucial in designing complex medical devices and simulating their performance. Computational techniques are used to enhance the accuracy, functionality, and customization of medical products, enabling material selection, mechanical performance prediction, and process improvement in the manufacturing process. The chapter discusses the transformative impact of technologies like implants, bioprinting, and personalized medicine, highlighting the potential of computational approaches and additive manufacturing in shaping future healthcare innovation.

Chapter 24

Biomaterials in Medicine: A Review 559

Swaralee Prabahwalkar, Ajeenkya D.Y. Patil University, India

Sanjana Pandey, Ajeenkya D.Y. Patil University, India

Ebaa Mubarak, Ajeenkya D.Y. Patil University, India

Susanta Das, Ajeenkya D.Y. Patil University, India

Nishakant Ojha, Ajeenkya D.Y. Patil University, India

Material science is essential to medical applications. Biomaterials are a class of materials studied under material science for healthcare. The initial known application of biomaterials was the use of animal intestines to suture wounds, wood as a missing limb in an amputation and glass as a substitution for an eye. Biomaterials impact a variety of applications like tissue engineering, implants, dentistry, drug delivery, etc. They are chosen based on their properties like biocompatibility, thermal conductivity,

resistance to compression and corrosion, chemical stability, strength etc. This review broadly discusses biomaterials, their classification into ceramics, metals and polymers, their characteristics, current applications, properties which are vital for in-vivo material action prediction. A bibliometric analysis was done which identified information gaps like prolonged in-vivo studies, extensive interdisciplinary research and highlighted the future scope of biomaterials in healthcare and medicine for development of composite materials, bioprinting, AI and personalized medicine.

Chapter 25

Theoretical Framework of Novel Oxide Compounds for Visible Range Light-Emitting Devices 589

Sudipta Koley, Amity University, Kolkata, India

Composite oxides have been proved to be valuable materials in optoelectronic applications. The combination of indium oxide and gallium oxide and other oxides can lead to enhanced optical and electronic properties, making them suitable for a variety of optoelectronic devices. A favorable energy band gap is needed in the visible region of the spectrum, indicating the applicability in optoelectronic devices such as LEDs and solar cells. Overall band gap engineering and tuning the radiative recombination is a challenge for new age semiconductors. Artificial Intelligence and Machine Learning have become powerful tools in the theoretical study and discovery of oxide materials for LEDs. By analyzing vast datasets, models can predict material properties, optimize synthesis parameters, and even generate new compounds with desired characteristics. This data-driven approach accelerates the material discovery process and enhances the precision of theoretical predictions, allowing researchers to explore a broader chemical space and identify optimal candidates for visible range light emission.


About the Contributors 619

Index..... 629

Chapter 3


Emerging Materials for Energy Storage and Environmental Applications

M. Nisha Angeline

 <https://orcid.org/0000-0002-7439-4191>

*Velalar College of Engineering and Technology,
India*

P. Selvakumar

 <https://orcid.org/0000-0002-3650-4548>

*Science and Humanities, Nehru Institute of
Technology, India*

Manoj Kumar Gupta

 <https://orcid.org/0000-0001-9311-2674>

*National Institute of Technology, Kurukshetra,
India*

Naeema Nazar

 <https://orcid.org/0009-0007-6768-2842>


VISAT Engineering College, India

D. Elumalai

 <https://orcid.org/0000-0003-3881-0124>

*Vels Institute of Science, Technology, and
Advanced Studies, India*

Sumanta Bhattacharya

 <https://orcid.org/0000-0003-2563-2787>

*Maulana Abul Kalam Azad University of
Technology, India*

ABSTRACT

The advent of new materials offers promising solutions for enhancing energy storage systems, improving energy efficiency, and mitigating environmental impacts. These advanced materials are characterized by their unique properties, which enable them to address the limitations of conventional materials and contribute to innovative technologies in various fields. In the realm of renewable energy, emerging materials are transforming photovoltaic technology. Traditional silicon-based solar cells are being complemented by new materials such as perovskite solar cells, organic photovoltaics, and quantum dots. Perovskite materials, known for their exceptional light absorption and charge transport properties, have demonstrated the potential for high-efficiency, low-cost solar cells with ease of fabrication. Organic photovoltaics, which use organic compounds to convert sunlight into electricity, offer flexibility and lightweight characteristics, making them suitable for a range of applications from wearable electronics to building-integrated photovoltaics.

DOI: 10.4018/979-8-3693-7974-5.ch003

INTRODUCTION TO EMERGING MATERIALS FOR ENERGY STORAGE AND ENVIRONMENTAL APPLICATIONS

The advent of new materials offers promising solutions for enhancing energy storage systems, improving energy efficiency, and mitigating environmental impacts. These advanced materials are characterized by their unique properties, which enable them to address the limitations of conventional materials and contribute to innovative technologies in various fields. In the realm of renewable energy, emerging materials are transforming photovoltaic technology. Traditional silicon-based solar cells are being complemented by new materials such as perovskite solar cells, organic photovoltaics, and quantum dots. Perovskite materials, known for their exceptional light absorption and charge transport properties, have demonstrated the potential for high-efficiency, low-cost solar cells with ease of fabrication. Organic photovoltaics, which use organic compounds to convert sunlight into electricity, offer flexibility and lightweight characteristics, making them suitable for a range of applications from wearable electronics to building-integrated photovoltaics. Quantum dots, with their tunable bandgaps, enable the development of highly efficient solar cells that can capture a broader spectrum of sunlight. The pursuit of sustainable energy solutions has also spurred innovation in energy harvesting materials. These materials are designed to capture and convert ambient energy sources—such as solar, wind, thermal, and mechanical energy—into usable electrical power. Emerging materials for energy harvesting include thermoelectric materials, piezoelectric materials, and triboelectric nanogenerators. Thermoelectric materials, which convert temperature differences into electrical voltage, are being improved with materials like skutterudites and half-Heusler alloys to enhance efficiency. Piezoelectric materials, such as certain ceramics and polymers, generate electricity from mechanical stress and are used in applications ranging from self-powered sensors to energy-harvesting devices. Triboelectric nanogenerators exploit the contact electrification effect to convert mechanical energy into electrical energy, with applications in wearable devices and low-power electronics.

Environmental Remediation Materials: In addressing environmental challenges, emerging materials play a crucial role in pollution control and environmental remediation. Nanomaterials, including nanocapsules, nanofibers, and nanoparticles, are being utilized for their high surface area-to-volume ratio and reactivity to target and remove contaminants from air, water, and soil. For instance, magnetic nanoparticles are employed in water treatment processes to remove heavy metals and organic pollutants through magnetic separation (Kumar, R., et al., 2024). Photocatalytic materials, such as titanium dioxide and graphitic carbon nitride, can degrade organic pollutants under light irradiation, offering an effective method for water purification and air purification. Additionally, advanced sorbents, including biochar and engineered activated carbon, are used to capture and immobilize pollutants, enhancing the efficiency of soil and water remediation efforts.

Smart Materials for Environmental Monitoring: Emerging smart materials with sensing and responsive capabilities are enhancing environmental monitoring and management. These materials include responsive polymers, nanosensors, and smart coatings that can detect and react to environmental changes such as pollution levels, temperature variations, and humidity. Responsive polymers change their properties in response to environmental stimuli, providing real-time feedback on pollution levels or hazardous conditions. Nanosensors offer high sensitivity and specificity for detecting trace contaminants and environmental pollutants. Smart coatings, which can change color or exhibit other visual indicators in response to environmental changes, are being used for monitoring infrastructure health and environmental conditions.

18 more pages are available in the full version of this document, which may be purchased using the "Add to Cart" button on the product's webpage:
www.igi-global.com/chapter/emerging-materials-for-energy-storage-and-environmental-applications/376689?camid=4v1

Related Content

Application of Machine Learning Techniques in Additive Manufacturing: A Review

Amithkumar Gajakosh, R. Suresh Kumar, V. Mohanavel, Ragavanantham Shanmugam and Monsuru Ramoni (2022). *Applications of Artificial Intelligence in Additive Manufacturing* (pp. 1-24).

www.igi-global.com/chapter/application-of-machine-learning-techniques-in-additive-manufacturing-a-review/294046?camid=4v1a

Design, Development, and Testing of Eco-Friendly Natural Fiber-Reinforced Composites for High Temperature Applications: Eco-Friendly Biocomposites

Prakash Chandra Gope (2025). *Using Computational Intelligence for Sustainable Manufacturing of Advanced Materials* (pp. 101-120).

www.igi-global.com/chapter/design-development-and-testing-of-eco-friendly-natural-fiber-reinforced-composites-for-high-temperature-applications/376692?camid=4v1a

Developing New Japan Marketing Management Model for Customer Creation

(2022). *Examining a New Automobile Global Manufacturing System* (pp. 336-357).

www.igi-global.com/chapter/developing-new-japan-marketing-management-model-for-customer-creation/303358?camid=4v1a

Recent Developments in Conventional Machining for Metals and Composite Materials

Soundarrajan Madesh, Clement Christy Deepak Charles and Sathishkumar D. (2022). *Advanced Manufacturing Techniques for Engineering and Engineered Materials* (pp. 82-102).

www.igi-global.com/chapter/recent-developments-in-conventional-machining-for-metals-and-composite-materials/297271?camid=4v1a