Chapter 9

Nanocoatings in Medicine:
Revolutionizing Healthcare Through Precision and Potential

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ABSTRACT

The use of nanotechnology in healthcare and medicine is crucial, particularly for nanocoatings. The therapeutic potential of nanocoatings on medical implants and devices is examined in this chapter. It goes into the ingredients, production processes, and health benefits of nanocoatings. Device functionality and biocompatibility can be enhanced by nanocoatings. They are essential in addressing healthcare issues including cardiovascular stents and orthopedic implants. Additionally, nanocoatings are used in medication delivery systems, tissue engineering, and wound healing. This chapter offers important knowledge on the medical applications of nanocoatings to experts and researchers. Nanotechnology has the potential to alter the medical industry, which would be advantageous for patients.

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INTRODUCTION

Research and study on nanotechnology have shown enormous promise for innovative advances in a number of sectors, including healthcare and medicine. One interesting area of research is the use of nanotechnology in the form of nanocoating, which are essentially functionalized thin films of nanomaterials applied to a variety of surfaces. These nanocoating are especially interesting for use in the medical industry because of their special qualities and characteristics. Considering this, the suggested academic book chapter seeks to explore and fully look at the wide range of therapeutic applications linked to nanocoating, with a focus on highlighting their notable benefits to the field of medicine and patient care.

The chapter will begin with an introduction to nanocoating, providing a comprehensive overview of their composition, fabrication methods, and properties that make them suitable for medical applications. It will also discuss the importance of surface modification in biomedical materials and devices, emphasizing the role of nanocoating in enhancing their performance and biocompatibility. One of the key focuses of the chapter will be on the use of nanocoating in medical devices and implants. This section will delve into how nanocoating can improve the mechanical properties of implants, reduce the risk of infections through antimicrobial properties, and promote tissue integration for enhanced biocompatibility. Additionally, we will explore the application of nanocoating in cardiovascular stents, orthopaedic implants, and other medical devices, highlighting their potential to address critical healthcare challenges.

Furthermore, the chapter will discuss the role of nanocoating in drug delivery systems. Nanocoating offer a promising avenue for targeted and controlled drug delivery, increasing the therapeutic efficacy of medications while minimizing side effects. We will examine various strategies for incorporating drugs into nanocoating and their release mechanisms, emphasizing recent advancements and potential future developments in this area. We will discuss the mechanisms behind these effects and highlight case studies highlighting the successful application of nanocoating in wound management and tissue engineering. Another essential aspect that the chapter will cover is the safety and toxicity considerations of nanocoating in medicinal applications. The potential cytotoxicity and biocompatibility challenges of nanocoating will be addressed, along with ongoing research efforts to ensure their safe use in medical settings.

Finally, the planned chapter would give an in-depth examination of the numerous and potential medical applications of nanocoating. Through this investigation, we hope to shed insight on nanotechnology's enormous potential for revolutionising modern medicine and improving patient outcomes. The chapter will be an invaluable resource for researchers, academics, and professionals looking to comprehend the most recent advances in the field and fully realise the promise of nanocoating in therapeutic applications.

BASICS OF NANOCOATING

Nanocoating are thin layers of material with dimensions ranging from 1 to 100 nanometers. At this scale, distinct physical and chemical properties emerge, distinguishing nanocoating from their countless counterparts. Nanocoating have a high surface area-to-volume ratio and precise interactions with biological entities at the nanoscale. Nanocoating have the capacity to alter the surface properties of a wide range of substances, altering factors such as a surface's ability to reject or retain liquids, the degree of adhesion between surfaces, and a surface's compatibility with living organisms. The capacity to functionalize nanocoating with specific molecules or compounds improves their activity and enables more focused applications in medicine.

Nanocoating enable the molecular personalization of medical therapies. This level of precision is critical in the implementation of personalised medicine, which allows therapies to be tailored to the unique needs and characteristics of each patient. The ability to cautiously change drug delivery procedures and medical tools deviates from universal methodologies. The use of nanocoating in medicine is more than just a technological advancement; it has practical implications for therapeutic outcomes. Nanocoating contribute to the decrease of unwanted effects, enhancement of treatment effectiveness, and overall improvement of patient experiences by enabling accurate drug administration and improving the compatibility of medical implants with living tissues. Thin coats of nanomaterials called nanocoating are applied to surfaces to improve their characteristics and protect them from the damaging effects of corrosion. The synthesis of these coatings is often achieved by employing a variety of processes, including as chemical vapor deposition, spin coatings, sputtering, plasma spraying, cold spraying, and electroplating (Parray et al., 2023).

This chapter aims to give a thorough analysis of the role of nanocoating in redefining the present state of modern medicine. From fundamental principles to complex applications, the chapter will investigate several elements, revealing the opportunities, challenges, and potential developments associated with the incorporation of nanocoating into healthcare approaches. As we proceed on the course of this study, the section will take us through the fundamental concepts of nanocoating, their numerous applications in medicine, and the complicated relationship between the fields of precision medicine and nanotechnology. Furthermore, it will rigorously investigate the challenges experienced in the implementation of nanocoating, providing profound understanding into the solutions and advancements that build the framework for a future period in which healthcare is differentiated by exceptional accuracy and potential.

Organic Nanocoating

Organic nanocoating are thin films made of carbon-based compounds that are applied at the nanoscale. They take advantage of the special properties of organic materials to offer certain functions including improved adhesion, flexibility, and compatibility with living things. Organic nanocoating' intrinsic flexibility allows them to adapt to a wide variety of underlying surfaces, making them suitable for a wide range of materials and forms. The innate biocompatibility of many of the organic chemicals employed in these coatings lowers the likelihood of unfavorable reactions occurring when they come into touch with biological systems. Furthermore, organic coatings can be engineered to have their properties customized, which adds versatility for a variety of uses, such as delivering drugs and surface property change.

Organic nanocoating are used in drug delivery applications because of their ability to coat and protect therapeutic molecules, allowing for regulated and targeted release. It can improve the compatibility of medical implants with biological systems, reducing the risk of inflammatory responses and further improving implant integration with surrounding tissues. These coatings are applied to medical devices and surfaces to adjust qualities such as wettability, adhesion, and resistance to microbial settlement, thereby contributing to improved performance and safety. Metallic surfaces can have their level of corrosion protection increased using advanced nanocomposite coatings. When nanofillers are incorporated into organic matrices, key characteristics required for the use of anticorrosive agents are improved (Harb et al., 2020). The impact of the organic coating on the magnetic properties of nanoparticles is thoroughly analyzed in this study. The paper looks at different ways to control the surface chemistry and architecture of assemblies of nanoparticles (Abdolrahimi et al., 2021).

Study presents an inquiry into the hydrophobic and thermal stability of composite nanocoating made of both organic and inorganic components. These nanocoating make use of several silane alkyl chain groups. For the films made using Si/ITMS and Si/ETMS, the water contact angle attained by the glass substrate was measured to be $154 \pm 2°$ anD $150.4 \pm 2°$, respectively. It was found that the superhydrophobic coatings were remarkably resistant to high temperatures, retaining their stability up to 200°C (Syafiq et al., 2018). The reduced size of nanomaterials causes them to exhibit unique properties. The density of states and electronic energy spectrum of nanoparticles change. The effect of organic and inorganic coatings on magnetic nanoparticles is investigated in this article. An extensive overview of theories explaining the unanticipated magnetism caused by nanoscale phenomena is discussed (Crespo et al., 2013).

At lower levels of nanoparticle loading, the properties of nanocomposite coatings are improved. Ion exchange or covalent reactions are the processes that transform clay. Several organic groups are used to modify anisotropic nanoparticles, or sepiolite. The evaluation of the general effectiveness and surface characteristics of nanocomposite coatings is carried out (Wouters et al., 2010). Achieving the endurance and firmness of organic nanocoating in living tissues can be a tough challenge, necessitating ongoing research aimed at improving their long-term stability. Scholars work to improve the efficiency of organic coatings for specific reasons such as customising treatment discharge behaviour or enhancing the impact of surface changes.

Inorganic Nanocoating

Inorganic nanocoating are thin layers of inorganic compounds that are deposited uniformly on a nanoscale. These coatings take advantage of the unique properties of inorganic compounds to achieve specialised functionality such as increased lifetime, conductivity, or exclusive optical properties. Inorganic nanocoating are frequently recognised for their outstanding hardness and endurance, making them suitable for applications requiring abrasion resistance and environmental concerns. Inorganic substances have the ability to exhibit different properties such as electrical conductivity, magnetic susceptibility, or optical transparency, which imparts tremendous value in a variety of technological applications. Many inorganic nanocoating have high thermal stability, making them appropriate for use in situations with extreme temperatures.

In the field of medical imaging techniques, inorganic nanocoating are crucial in the development of contrast agents. When used in imaging modalities such as MRI or CT scans, these coatings serve to increase the visibility of specific tissues or structures. Furthermore, medical implants benefit from the use of inorganic coatings such as hydroxyapatite, which not only improves biocompatibility but also allows for smooth integration with adjacent tissues. Furthermore, the use of inorganic nanocoating adds considerably to the creation of diagnostic tools with increased sensitivity, allowing for the early detection of diseases or specific diagnostics.

Bionic nanocoating based on metalized retinin have strong antiviral and bactericidal properties. Composites based on silver nanoparticles show stronger bactericidal effects, while composites based on copper nanoparticles show stronger antiviral effects. Scientists used cutting-edge instruments like scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) to understand nanomaterials. They looked into the effects on human cells and found that nanocoating can both kill bacteria and provide viral protection. Surfaces with the ability to repair and think are a fascinating prospect because to this combination of biomolecule and metal (Kryuchkov et al., 2022). The combination of stearic acid and SiO_2 nanoparticles that were improved by oleic acid, according to the data, had the highest water contact angle—158.6°—and excellent sliding properties. These findings suggest the existence of both superhydrophobicity and self-cleaning properties. The combination of SiO_2 aerogel and stearic acid also showed a similar water contact angle, but with better durability. Conversely, the combination with intact SiO_2 nanoparticles showed superhydrophobicity but lacked durability and self-cleaning capabilities, while stearic acid alone showed hydrophobicity (Fallah et al., 2018).

The assurance of biocompatibility of inorganic nanocoating is critical for their effective use in medical contexts, and current research focuses on this specific aspect. Researchers working to promote the widespread use of inorganic nanocoating in medical applications have been concentrating on the problems of developing reliable synthesis procedures and ensuring production scalability.

Hybrid Nanocoating

Hybrid nanocoating are thin layers that combine organic and inorganic components on the nanoscale. The goal of hybrid coatings is to synergistically enhance specific features or capabilities by combining the benefits of both material categories. Hybrid nanocoating exhibit versatility by combining the pliability and customizability of organic materials with the rigidity and robustness of inorganic materials. The combination of organic and inorganic constituents allows for the creation of coatings with customised qualities such as increased mechanical strength, improved compatibility with living organisms, or advanced optical capabilities. The mutual interaction of organic and inorganic materials frequently results in coatings that outperform the capabilities of their individual constituents, providing a multifaceted approach to meet a wide range of applications.

The process of combining hybrid organic/inorganic molecules with integrated organic ligands and an amorphous oxide covering is discussed. The goal of these mixed coatings is to provide long-lasting CO_2 electro reduction catalysts. Coatings with hybrid oxides strengthen copper catalysts for the electroreduction of CO_2. As a result, the copper surface is effectively contained by these coatings in a state that is resistant to reduction (Albertini et al., 2023). This paper investigates the combination of hybrid nanocoating with silver nanoparticle (AgNP)-adorned self-assembled antimicrobial peptide (AMP) amphiphiles to prevent implant infections. The use of antimicrobial coatings has enormous promise for preventing implant infections. The enhanced antibacterial activity of hybrid nanocoating made of self-assembling organic-inorganic amphiphiles has been demonstrated (Ye et al., 2022).

In order to combine the stability and targeting abilities of inorganic materials with the qualities of controlled release demonstrated by organic materials, hybrid nanocoating are used in drug delivery systems. In the context of medical implants, hybrid coatings have the potential to improve both mechanical strength or durability, attained through the insertion of inorganic components, and biocompatibility, attained through the introduction of organic components. Biomolecules can be included into hybrid coatings to provide surfaces that interact well with biological systems for applications in tissue engineering and diagnostics. An ongoing task is to maintain stability and functionality while achieving the ideal balance between organic and inorganic ingredients to maximise synergistic effects. Research and development must prioritise ensuring the biocompatibility and security of hybrid nanocoating in medical facilities.

The investigation of the characteristics that make nanocoating very desirable for various applications as shown in Table 1 represents the study of the optimal nanocoating properties.

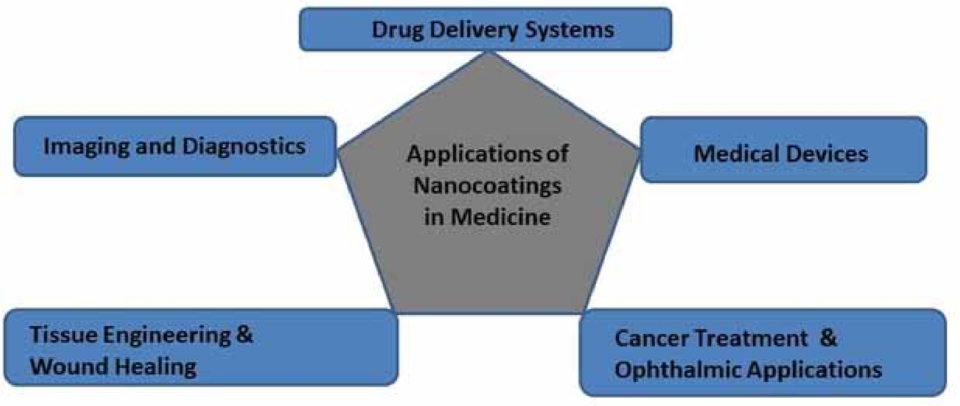
Table 1. Properties of ideal nanocoating

S. No.	Property	Description
1	**Thickness and Uniformity**	Nanocoating are incredibly small, particularly when viewed at the nanoscale. In order to preserve the substrate's original characteristics, these coatings are thin. For stable operation, a homogeneous coating on the surface is essential.
2	**Adhesion**	Strong adherence to the substrate material is a necessary quality of ideal nanocoating for longevity and durability. Delamination and separation are avoided via efficient intermolecular interactions.
3	**Chemical and Mechanical Stability**	Nanocoating should remain stable in a variety of environments and uses. Mechanical stresses must be tolerated by the coating without causing it to lose its integrity.
4	**Biocompatibility**	For medical uses, nanocoating should be biocompatible to reduce negative reactions with living tissues.
5	**Tailorability**	The capacity to design and tailor nanocoating for particular uses is a crucial characteristic. This involves modifying the thickness, composition, and surface functionalities.
6	**Optical Transparency**	In certain applications, nanocoating that are ideal for optical coatings or coatings for electronic displays will retain optical transparency, which enables clear visibility and minimal interference.
7	**Electrical Conductivity or Insulation**	Nanocoating can conduct or insulate electricity, depending on the application. The best coatings have precise control over electrical characteristics.
8	**Anti-Microbial Properties**	In some cases, nanocoating with anti-microbial properties help reduce microbial settlement and improve safety and hygiene.
9	**Environmental Friendliness**	Ideal nanocoating prioritize eco-friendly practices, reduce harmful substances, and promote sustainability.
10	**Ease of Application**	Nanocoating should be easily applied with appropriate methods, ensuring efficiency and cost-effectiveness in large-scale manufacturing.

APPLICATIONS OF NANOCOATING IN MEDICINE

The use of nanocoating in diagnosis, treatment, and patient care has completely changed medicine. They facilitate accurate medication administration, advance medical implants, and improve diagnostic equipment. In addition to supporting tissue engineering, nanocoating collaborate well with cutting-edge technologies to provide personalized treatment. The primary uses for nanocoating are depicted in Figure 1.

Figure 1. Medical applications of nanocoatings



Drug Delivery Systems

The precise and controlled delivery of medicinal compounds made possible by the use of nanocoating in drug delivery systems has revolutionized the field of medicine. These novel technologies offer solutions to the problems associated with conventional drug delivery techniques, such as non-specific targeting and systemic side effects. In the field of medication distribution, two salient features stand out as being important:

1. Targeted Drug Delivery
2. Controlled Release

Targeted Drug Delivery

Targeted drug delivery refers to the precise distribution of pharmaceuticals to particular biological entities, anatomical structures, or organs in order to reduce exposure to non-targeted areas. The mechanism of action as follows:

- **Surface Modification**: Pharmaceutical compounds are specifically included into nanocoating so that they can be released in response to specific stimuli or conditions.
- **Active Targeting**: Surface-based functionalities of nanocoating have the capacity to deliberately target particular biomolecules or receptors linked to diseased cells with their actions.
- **Passive Targeting**: The enhanced permeability and retention (EPR) effect allows nanoparticles to collect within aberrant tissues, which is made possible by the nanoscale size.

By delivering medications directly to the desired site, targeted drug delivery reduces exposure to healthy tissues and, consequently, the possibility of undesirable reactions. This results in a decrease in side effects. Additionally, the concentration of therapeutic substances at the targeted site minimizes the required dosage while improving treatment effectiveness and efficacy of therapy.

Controlled Release

Controlled release, also known as sustained release, is the slow, controlled release of medicinal agents over a prolonged period of time. The mechanism of action as follows:

- **Encapsulation:** Pharmaceutical drugs can be encapsulated by nanocoating, creating a protective covering that controls the release kinetics.
- **Responsive Release:** The rate of release can be precisely adjusted in response to external stimuli like magnetic fields and light, as well as environmental variables like pH, temperature, and the presence of enzymes.

Reducing fluctuations and improving treatment outcomes are achieved by keeping medication concentrations in the bloodstream at steady levels. By reducing the frequency of drug dosage, the use of controlled release devices frequently improves patient adherence to treatment plans.

In the field of anti-inflammatory treatments, nanoparticle-mediated drug delivery platforms have found use, showing promise in enhancing anti-inflammatory outcomes while concurrently minimising undesirable effects (Wang et al., 2021). In the field of medicine, nanocoating have been used to create drug delivery systems that can selectively localise to specific areas, increase the effectiveness of therapy, and simultaneously reduce any negative side effects (Su et al., 2020). Drug administration and diagnostic procedures are both facilitated by nanomedicine. Additionally, there have been developments in the area of intelligent medication delivery devices that may react to outside stimuli (Aiacoboae et al., 2017). Due to their small size, compatibility with living things, and capacity to successfully maintain lipophilic pharmaceutical chemicals inside their core region, nanomicelles have shown promise as nanocarriers for the transportation of pharmacological drugs (Tawfik et al., 2020). Due to their small size, biological compatibility, and ability to safely contain liquid medicines within their nucleus, nanomicelles have shown promise as nanocarriers for the administration of pharmaceuticals. To measure nanoparticle size, TEM and SEM are used (Mirza et al., 2014).

Medical Devices

Nanocoating enhance the surface properties of medical devices, such as implants and prosthetics, reducing friction and obstructing microbial adherence while also improving biocompatibility. Nanocoating with antimicrobial properties help to prevent infections linked to medical devices, which lowers the risk of complications. Here are some key points regarding the use of nanocoating in medical devices:

- Medical equipment using nanocoating can have less friction. This enhances the longevity and functionality of mobile devices, which makes it significant.
- Antimicrobial qualities of nanocoating can stop infections. As an added layer of defence, they prevent microorganisms from adhering to device surfaces.
- Medical equipment with nanocoating have increased biocompatibility. By doing this, the possibility of negative reactions or immune system rejection is decreased.
- For continuous or focused drug release, some nanocoating improve drug delivery. For targeted therapy, these coatings can be included onto the surfaces of medical devices.
- Precise surface alterations are made possible by nanocoating, and this is essential for improved device integration with surrounding tissues, particularly for implants that need to be stable and functioning.
- Medical equipment that has nanocoating on it is more resilient to wear and tear, extending its lifespan and lowering the need for regular updates or replacements.
- Medical device surfaces that have certain nanocoating applied to them are less likely to create biofilm, which makes cleaning them easier and lowers the possibility of problems from microbial infection.

Currently, nanostructures are being created with the intention of using them in biomedical applications. Furthermore, biological components are being incorporated into biomedical technologies as they advance (Shaik et al., 2021). In the field of medicine, nanocoating have a wide range of uses, including the improvement of performance, the reduction of infection rates, and the support of biocompatibility on medical devices. Their use encompasses pharmaceutical administration, therapies, imaging, and therapeutics (Damodharan, 2021). Various processes are used in the field, including vapour deposition, plasma-assisted ion-beam-assisted techniques, chemical reduction, grafting, pulsed laser deposition (PLD), sputtering, extrusion, self-assembly, layer-by-layer (LbL) coating, dip coating, sol-gel coating, solution casting, and electrospinning. For nanoscale coating, the electrostatic LbL self-assembly method is used (Yilmaz et al., 2019). Medical devices such as dental implants, stents, and hip prosthesis have benefited from the application of nanocoating in order to improve operational effectiveness and reduce the spread of bacterial development. Both top-down and bottom-up approaches are used in the manufacturing of nanotechnology. Additionally, efforts have been made to incorporate silver nanoparticles into titanium nanotubes (Ahmed et al., 2016). In order to address issues with restenosis and thrombosis, nanocoating are now used in the creation of coatings for implantable medical devices (Arsiwala et al., 2013).

Imaging and Diagnostics

By improving the synthesis of contrast agents used in medical imaging modalities, inorganic nanocoating significantly improve the ability to distinguish between tissues and structures in procedures like MRI and CT scans. Nanocoating are utilised to create incredibly responsive biosensors that are used to locate biomarkers, enabling the early detection of diseases. The following are some main ways that inorganic nanocoating improve diagnostics and imaging in medicine:

- For medical imaging, inorganic nanocoating improve the production of contrast agents. They enhance the contrast between tissue and structure in imaging modalities.
- Highly sensitive biosensors for identifying illness biomarkers are made possible by nanocoating. This makes diagnosis easier and allows for prompt treatment.
- Biosensors with nanocoating can identify diseases early by focusing on particular biomarkers. Early identification lessens the effect of the disease and enhances treatment success.
- Personalized diagnostic procedures are made possible in precision medicine by nanocoating. They support the discovery of biomarkers for specialized cancer therapies.

- Nanocoating lessen negative effects and increase imaging accuracy. By using fewer contrast chemicals or radiation, they reduce the possibility of adverse consequences for patients.
- Different imaging applications can be catered for with nanocoating. Under some circumstances, they can permit imaging or react to influences.
- Combining nanotechnology with integration creates opportunities for multimodal imaging. Comprehensive diagnostics can be achieved by combining several approaches.

Numerous opportunities exist in the realm of nanotechnology for the application of clinical imaging techniques. In addition to acting as carriers for pharmacological compounds used in the treatment of cancer, nanoparticles can be used as effective contrast agents during imaging techniques. However, due to their intrinsic toxicity, the introduction of nanoparticles also brings a number of challenges (Prathna et al., 2021). Due to their optical properties and compatibility with living things, gold nanoparticles, also known as AuNMs, have bright futures in the field of biomedical imaging and diagnostics. To test the toxicity of these nanomaterials, in vitro cell culture techniques can be used. Additionally, Surface-enhanced Raman spectroscopy (SERS) can be used to improve molecular imaging. Additionally, research into the possible uses of gold nanoparticles in the fields of biological diagnostics and therapies is necessary. Further research must be done in order to determine the materials' long-term safety and to create effective plans for changing their surfaces (Sasidharan et al., 2015).

Nanotechnology increases the accuracy and precision of diagnostic techniques while lowering their cost. Nanomaterials make it possible to designate and portray desired cells and tissues intracellularly (Savaliya et al., 2015). There are several potential uses for nanocoating in the medical industry, particularly in the areas of imaging and diagnostics. This involves the use of nano diagnostics, which aims to improve sensitivity and make disease detection easier and early. Additionally, there are magnetic nanobeads that have been DNA-labeled and can recognise proteins and nucleic acids. Pathogens can also be measured using bioassays based on bioconjugate nanoparticles (Alharbi et al., 2014). In the field of diagnosing infectious diseases, nano diagnostic technologies have seen great success. The development of extremely complex and cutting-edge point-of-care nano diagnostics calls for coordinated and interdisciplinary efforts. With a specific focus on point-of-care nano diagnostics, recent trends in nano diagnostics for infectious disorders deserve special consideration. (Wang et al., 2017).

Tissue Engineering and Wound Healing

Nanocoating significantly contribute to the development of biomimetic scaffolds used in tissue engineering applications because they create an environment that is conducive to cellular growth and tissue regeneration. The replication of the inherent properties of the biological extracellular matrix is made possible by the manipulation of nanocoating, promoting advantageous cellular interactions. The creation of wound dressings intended to prevent infections and hasten the healing process of wounds benefits from the use of nanocoating containing antimicrobial agents. Responsive nanocoating can intelligently release therapeutic ingredients to effectively enhance and optimize the entire healing process by reacting to the unique conditions of the wound. The following are some salient features emphasizing their contributions:

- Nanocoating facilitate the use of biomimetic scaffolds in tissue engineering. It promote tissue regeneration and cell proliferation by imitating the extracellular matrix found in nature. The characteristics of biological tissues are replicated by nanocoating to promote advantageous cellular interactions.
- Nanoscale coatings encourage the continued growth of cells, which is crucial for tissue engineering. Regenerating healthy, functional tissues is the aim. Enhancing cell adhesion, growth, and differentiation all essential for effective tissue regeneration can be achieved by nanocoating.
- The use of nanocoating in wound healing is crucial. They encourage quicker healing and protect against infections.
- Certain nanocoating release therapeutic chemicals in response to wound situations. This treats the dynamic nature of wounds and improves the healing process.
- Anti-inflammatory nanocoating can speed up the healing of wounds. By controlling the inflammatory response, they aid in a faster and more effective healing process.
- Nanocoating can reduce the production of scar tissue by altering cellular activity. For tissue engineering applications that seek to minimize scarring, this is crucial.
- For particular tissue engineering and wound healing applications, nanocoating can be tailored. This makes it possible to create coverings that are tailored to the particular needs of various tissues and wounds.

To make drug delivery and cellular regeneration easier, nanocoating are useful in the field of tissue engineering, which includes diverse fields like bone, heart, brain, and skin tissue engineering (Ahmad et al., 2021). Exploration is being done into the creation of three-dimensional scaffolds that mimic the natural properties of the extracellular matrix. Additionally, researchers are looking into how to use nanomaterials to control cell adhesion and aid in the development of tissues. Nanomaterials' potential for use in tissue engineering is also being acknowledged. Additionally, damaged tissues can be replaced or restored using nanomaterials (Singla et al., 2019). The characteristics of tissue engineering scaffolds may be improved via nanotechnology. Substances have the ability to effectively restore a variety of organs at the nanoscale level (Abdollahiyan et al., 2021). Collagen films are created using the Langmuir-Blodgett process, while they are transferred using the Langmuir-Schaefer deposition method (Pastorino et al., 2014).

Potential uses for nanocoating exist in the field of wound healing. These coatings have the power to speed up and improve the healing process while also overcoming problems like infections, persistent wounds that won't heal, and the need to restore both cosmetic and functional qualities (Wang et al., 2021). The development of strong, high-functioning self-repairing coatings, the use of polymers with reversible covalent bonds, and the insertion of micro/nanocapsule containing curative agents are all extremely encouraging for future research applications in the automobile sector (Trentin et al., 2022). The application of therapeutic agents, the facilitation of wound closure, and the prevention of infection are three areas where nanocoating have the potential to be used in the field of wound healing (Mihai et al., 2019). Comparing them to common microorganisms, nanoparticles show special properties. Regulation of nanoparticles is possible by modification of protein and ion composition (Rajendran et al., 2018).

Cancer Treatment and Ophthalmic Applications

Nanocoating have the ability to enable the targeted delivery of chemotherapeutic drugs to tumour cells, thereby minimizing the harm done to healthy tissues. Theragnostic techniques are further supported by the incorporation of nanocoating with imaging agents, enabling the simultaneous diagnosis and therapy of cancer. The addition of nanocoating to contact lenses improves the comfort of the wearer, increases the amount of oxygen that can pass through the lenses, and reduces the possibility of bacterial adhesion. Ophthalmic implants with nanocoating allow for the controlled release of drugs for illnesses including glaucoma. Here are some key points highlighting their contributions:

- With the use of nanocoating, chemotherapeutic medications can be delivered to cancer cells specifically, minimizing harm to healthy tissues and lowering the negative effects of conventional chemotherapy.

- Drugs are delivered to tumour cells directly by nanocoating, minimizing damage to surrounding tissues, increasing the effectiveness of cancer treatments, and lowering systemic side effects.
- Imaging agents are incorporated into nanocoating to facilitate simultaneous diagnosis and therapy, give real-time data on treatment efficacy, and allow for necessary modifications.
- Because contact lenses cause less friction and discomfort, comfort has increased. Additionally, they have higher oxygen permeability to protect and preserve the health of the retina. Antimicrobial nanocoating reduce the chance of contact lens-related visual infections.
- Pharmaceuticals can be released gradually and under control through nanocoating on ophthalmic implants. This is essential for controlling intraocular pressure in glaucoma and related disorders.
- Ophthalmic equipment using antimicrobial nanocoating reduce the chance of infection, irritation, and problems.
- Ophthalmic device performance is increased, adverse response rates are reduced, and biocompatibility is enhanced by nanocoating.

Through the focused delivery of therapeutics to cancerous cells, nanomedicines, which also include nanocoating, demonstrate promising possibilities in the field of cancer treatment by reducing the negative consequences that may result from off-target toxicity (Tracey et al., 2021). Mechanisms generated from nanotechnology, such as carbon nanotubes, semiconductor nanocrystals, and nanostructured shells, have applications in the treatment of cancer (Taleuzzaman et al., 2021). In the areas of cancer theragnostic, nanovaccines, and gene therapy delivery platforms, it is common to see the use of nanoparticles that have achieved clinical approval. Additionally, it is conceivable to develop multifunctional nanomachines and nanorobots for targeted therapy by fusing individual nanoparticles with biomolecules. Rarely does the medication distribution to the tumour exceed 10% of the injected amount. Drug delivery systems that react to stimuli are currently beginning to appear (Loukanov et al., 2019).

Nanomaterials have the capacity to act as carriers for eye-specific medicinal drugs, improving their absorption and bioavailability and aiding in the diagnosis of disorders of the eye (Liu et al., 2021). In comparison to conventional treatment modalities, nanocarriers offer the potential for longer drug release and increased effectiveness in therapy, as demonstrated by the significant research done for the aim of ocular medication delivery (Singh et al., 2019). In the field of ophthalmology, the research investigates the potential use of nanoparticles in the treatment of anterior and posterior eye problems. Innovative diagnostic techniques and nanomedical equipment are used (Kamaleddin et al., 2017). In order to prevent bacterial infections, nanocoating have been applied to prosthetic eyes and silicone scleral buckles used in optical devices. Silver-containing antibacterial coatings created by RF co-sputtering have been used. These coatings are made of silver nanoclusters embedded in a silica matrix (Baino et al., 2017).

FUTURE PERSPECTIVES AND CHALLENGES

Emerging Trends

Examine the potential for modifying nanocoating to fit the unique characteristics of patients, resulting in the development of specialized and more effective therapeutic techniques. Think carefully about how nanocoating might be used with cutting-edge medical technology, such as robotics, 3D printing and artificial intelligence.

It is possible for nanocoating to improve the compatibility and functionality of robotic medical devices. As an example, coating robotic surgical instruments with nanomaterials can improve biocompatibility, reduce friction, and increase precision when doing surgery. The utilisation of robotic systems facilitates the methodical application of nanocoating, ensuring consistency and accuracy in implants and medical equipment. The application of nanocoating in the medical domain has the potential to augment the biocompatibility of 3D-printed objects. The performance and utility of 3D-printed tissues, organs, or implants may be improved by adding nanoparticles to coating solutions. The combination of nanocoating with 3D printing has the potential to create customized medical structures and devices for each patient while maximizing their biological and physical attributes.

Employing equipment like an MRI or PET-CT scan to diagnose at the nanoscale level. Using methods including chemotherapy, radiation, and photodynamic therapy, treatment at the nanoscale. Early illness diagnosis is made possible by nanotheranostics. Nanoscale therapy is offered by nanotheranostics (Suhag et al., 2020). The chapter looks at how nanobiotechnology is being used to treat cancer, neurological disorders, and cardiovascular diseases on an individual basis (Jain et al., 2011). Precipitation techniques used to create iron oxide nanoparticles. To create nanoparticles of solid pharmaceuticals, a milling procedure is used (McDonald et al., 2015).

Ethical and Regulatory Considerations

Examine the ethical issues associated with cutting-edge medical technologies and emphasize the importance of maintaining a delicate balance between ground-breaking innovations and the wellbeing of patients. Analyze the existing and evolving regulatory frameworks that govern the use of nanocoating in the medical field, and consider any potential adjustments that might be necessary to keep up with new discoveries.

Modern medical technologies like artificial intelligence and nanocoating require the collection and analysis of large amounts of patient data. Ensuring patient confidentiality and obtaining informed consent are critical to the use of personal health information. Maintaining patient autonomy and trust is essential to the moral application of these developments. Accurate information exchange about the use of data and the possible outcomes of customized treatments is crucial for securing informed consent.

Availability of advanced medical technologies can lead to disparities in healthcare. Ensuring that a diverse variety of people can benefit from novel treatments including nanocoating is a matter of ethical significance. It is possible to prevent the growing severity of already-existing healthcare disparities by addressing issues with affordability and accessibility. To serve a variety of patient populations, ethical considerations should direct the development and adoption of such technology.

Concerns about patient autonomy are raised by the growing use of artificial intelligence (AI) in the field of medical decision-making. When complex algorithms are used in decision-making, patients may find it difficult to understand and this could hinder their ability to make decisions about their care. Respecting patient autonomy requires that open lines of communication be established on the use of AI in medical decision making. It is the responsibility of healthcare providers to ensure that patients continue to be active partners in their care.

Unintended consequences arise from the initial lack of thorough understanding regarding the long-term implications of nanocoating and their interactions with the human body. The existence of ethical issues is apparent when questions about possible unexpected implications arise up. To successfully recognize and reduce any unexpected consequences that may result from the use of nanocoating on patients, it is necessary that frequent monitoring be carried out, continuous research attempts be sustained, and ethical responsibility be observed. Maintaining and sustaining trust requires honest and forthcoming communication about uncertainties.

As indicated by the existence of multiple nanomedicines now on the market and the continuing clinical trials for numerous of others, the use of nanotechnology in the domains of medicine and pharmaceutics has resulted in a new era in therapeutic techniques. (Santhini et al., 2020)It has been noted that the ethical issue, which is frequently disregarded, is a crucial concern for any fresh improvements. Additionally, if these technological advances are used improperly, illegally, or unethically, they could represent a risk (Wiwanitkit et al., 2017). The ethical and legal implications of nanomedicine are very important. Currently, the Food and Drug Administration (FDA) is working to create specific criteria for goods utilizing nanobiotechnology (Jain et al., 2017). Concerns about societal, legal, and ethical issues are raised by regenerative nanomedicine. The definitions, applications, dangers, laws, and availability must all be taken into consideration by healthcare professionals and researchers (Glenn et al., 2012).

Nanomaterials have particular qualities that make them suited for use in the medical industry. The use of nanomaterials has fascinating future applications in a number of fields, including imaging, therapy, drug delivery, and tissue engineering. Additionally, the combination of ultrasonic therapy with TiO_2 nanoparticles and the use of magnetic hyperthermia in the elimination of cancer cells present new research opportunities (Chen et al., 2013). The protection and wellbeing of people taking part in clinical trials including the study of nanoproducts in human beings is the main goal of the draft guidelines for nanomedicine (Marshall et al., 2011).

INNOVATIONS IN NANOCOATING DESIGN

Significant progress is being made in the design of smart nanocoating which will indicate in a new era of intelligent medical devices. These cutting-edge coatings have the ability to react dynamically to changing physiological conditions within the human body, maximizing the effectiveness of therapeutic interventions. The idea behind smart nanocoating involves a degree of adaptability that permits in-the-moment modifications, providing a promising path toward individualized and accurate medicinal treatments. A crucial part of this evolution is the investigation of multifunctional platforms inside nanocoating. A novel method for integrating healthcare technologies is the potential for nanocoating to serve two or more functions, such as acting as carriers for drug delivery and diagnostic tools at the same time. This confluence is a key step towards the future of nanotechnology in medicine since it not only streamlines medical operations but also holds the prospect of improved patient outcomes through a more clear and synergistic medical approach.

The creation of high-entropy nanocoating on the hard metal T12A is investigated in the study. It illustrates the possibility of avoiding intermetallic compound formation in these coatings (Popov et al., 2020). Nanocoating provide strength and protect against corrosion. The controlled synthesis of ceramic powders is made easier by the hydrothermal process (Singh et al., 2018). The top-down methodology includes the machining of microstructures in its scope. In order to introduce a nonsolvent, a solvent-mediated approach is used, which causes the coating of the dissolved substance (Bommana et al., 2019). Polymer nanocomposite coating design and production must be sustainable, according to experts in the industry. For the aim of optimization, the use of multiscale modelling and simulation techniques is essential (Xiao et al., 2011). The efficiency and security of nanomedicines are improved by nanotechnology. International harmonization is required for safety evaluation (Grewal et al., 2018).

CONCLUSION

This chapter offers a thorough examination of the revolutionary effects of nanocoating in the medical industry. The exposition begins with a perceptive introduction that lays the groundwork for understanding the rest of the narrative. The key components of nanocoating are thoroughly discussed, including their definitions, characteristics, types and fabrication methods. The chapter then proceeds to a full analysis of the various medical uses for nanocoating. Each application is extensively examined, demonstrating the attention to detail and adaptability that nanocoating offer to medical treatments. These applications range from drug delivery systems to medical equipment, from imaging and diagnostics to tissue engineering and wound healing. Notable portions focus on the use of nanocoating in ophthalmology and cancer treatment, highlighting their potential influence on important medical domains. The chapter offers a glimpse into the future by describing forthcoming trends, ethical and regulatory implications, and the ongoing advancements in nanocoating design. It acts as a guide for navigating the opportunities and difficulties of utilizing nanotechnology for revolutionary advances in healthcare.

REFERENCES

Abdollahiyan, P., Oroojalian, F., & Mokhtarzadeh, A. (2021). The triad of nanotechnology, cell signalling, and scaffold implantation for the successful repair of damaged organs: An overview on soft-tissue engineering. *Journal of Controlled Release*, *332*, 460–492. doi:10.1016/j.jconrel.2021.02.036 PMID:33675876

Abdolrahimi, M., Vasilakaki, M., Slimani, S., Ntallis, N., Varvaro, G., Laureti, S., Meneghini, C., Trohidou, K. N., Fiorani, D., & Peddis, D. (2021). Magnetism of nanoparticles: Effect of the organic coating. *Nanomaterials (Basel, Switzerland)*, *11*(7), 1787. doi:10.3390/nano11071787 PMID:34361173

Ahmad, A., Younas, M., Santulli, C., Kiyani, M. Z., Ali, R., Habbiba, O., & Zubair, M. (2021). Nanomedicine and tissue engineering. In *Nanomedicine Manufacturing and Applications* (pp. 261–277). Elsevier. doi:10.1016/B978-0-12-820773-4.00020-2

Ahmed, W., AlHannan, M., Yusuf, S., & Jackson, M. J. (2016). Nanocoating for medical devices. *Surgical Tools and Medical Devices*, 519-543.

Aiacoboae, A., Gheorghe, T., Lungu, I. I., Curutiu, C., Chifiriuc, M. C., Grumezescu, A. M., & Holban, A. M. (2017). Applications of nanoscale drugs carriers in the treatment of chronic diseases. In *Nanostructures for Novel Therapy* (pp. 37–55). Elsevier. doi:10.1016/B978-0-323-46142-9.00002-5

Albertini, P., Newton, M., Wang, M., Lecina, O. S., Green, P., Stoian, D., & Buonsanti, R. (2023). Hybrid Oxide Coatings Generate Stable Cu. *Catalysts*, CO2.

Alharbi, K. K., & Al-Sheikh, Y. A. (2014). Role and implications of nanodiagnostics in the changing trends of clinical diagnosis. *Saudi Journal of Biological Sciences*, *21*(2), 109–117. doi:10.1016/j.sjbs.2013.11.001 PMID:24600302

Arsiwala, A. M., Raval, A. J., & Patravale, V. B. (2013). Nanocoating on implantable medical devices. *Pharmaceutical Patent Analyst*, *2*(4), 499–512. doi:10.4155/ppa.13.30 PMID:24237126

Baino, F., Perero, S., Miola, M., & Ferraris, M. (2017). Antibacterial nanocoating for ocular applications. *Advances in Science and Technology (Owerri, Nigeria)*, *102*, 24–28. doi:10.4028/www.scientific.net/AST.102.24

Bommana, M. M., Kirthivasan, B., Gupta, S. S., Shikhar, A., & Shah, A. (2019). Nanostructures in pharma: elixir to oral medicine. In *Nanoparticles in Pharmacotherapy* (pp. 23–44). William Andrew Publishing. doi:10.1016/B978-0-12-816504-1.00001-6

Chen, S., Zhang, Q., Hou, Y., Zhang, J., & Liang, X. J. (2013). Nanomaterials in medicine and pharmaceuticals: Nanoscale materials developed with less toxicity and more efficacy. *European Journal of Nanomedicine*, *5*(2), 61–79. doi:10.1515/ejnm-2013-0003

Crespo, P., De la Presa, P., Marin, P., Multigner, M., Alonso, J. M., Rivero, G., ... Hernando, A. (2013). Magnetism in nanoparticles: Tuning properties with coatings. *Journal of Physics Condensed Matter*, *25*(48), 484006. doi:10.1088/0953-8984/25/48/484006 PMID:24201075

Damodharan, J. (2021). Nanomaterials in medicine–An overview. *Materials Today: Proceedings*, *37*, 383–385. doi:10.1016/j.matpr.2020.05.380

Fallah, M., Ghashghaee, M., Rabiee, A., & Ershad-Langroudi, A. (2018). Spray-deposition of an organic/inorganic blend for fabrication of a superhydrophobic surface: Effect of admixing with silica aerogel and modified silica nanoparticles. *Protection of Metals and Physical Chemistry of Surfaces*, *54*(5), 909–916. doi:10.1134/S2070205118050064

Glenn, L. M., & Boyce, J. S. (2012). Regenerative nanomedicine: ethical, legal, and social issues. *Nanotechnology in Regenerative Medicine: Methods and Protocols*, 303-316.

Grewal, A. S., Lather, V., Sharma, N., Singh, S., Narang, R. S., Narang, J. K., & Pandita, D. (2018). Recent updates on nanomedicine based products: Current scenario and future opportunities. *Applied Clinical Research, Clinical Trials and Regulatory Affairs*, *5*(2), 132–144. doi:10.2174/2213476X05666180611115135

Harb, S. V., Trentin, A., Uvida, M. C., & Hammer, P. (2020). Advanced organic nanocomposite coatings for effective corrosion protection. In *Corrosion Protection at the Nanoscale* (pp. 315–343). Elsevier. doi:10.1016/B978-0-12-819359-4.00017-9

Jain, K. K. (2011). Nanobiotechnology and personalized medicine. *Progress in Molecular Biology and Translational Science*, *104*, 325–354. doi:10.1016/B978-0-12-416020-0.00008-5 PMID:22093223

Jain, K. K., & Jain, K. K. (2017). Ethical and Regulatory Aspects of Nanomedicine. The Handbook of Nanomedicine, 605-620. doi:10.1007/978-1-4939-6966-1_18

Kamaleddin, M. A. (2017). Nano-ophthalmology: Applications and considerations. *Nanomedicine; Nanotechnology, Biology, and Medicine*, *13*(4), 1459–1472. doi:10.1016/j.nano.2017.02.007 PMID:28232288

Kryuchkov, M., Adamcik, J., & Katanaev, V. L. (2022). Bactericidal and Antiviral Bionic Metalized Nanocoating. *Nanomaterials (Basel, Switzerland)*, *12*(11), 1868. doi:10.3390/nano12111868 PMID:35683724

Liu, N., Wu, Q., Liu, Y., Li, J., Ji, P., & Fu, G. (2021). Application of Nanomaterials in the Treatment and Diagnosis of Ophthalmology Diseases. *Current Stem Cell Research & Therapy*, *16*(1), 95–103. doi:10.2174/1574888X15666200210104449 PMID:32039688

Loukanov, A., Nikolova, S., Filipov, C., & Nakabayashi, S. (2019). Nanomaterials for cancer medication: From individual nanoparticles toward nanomachines and nanorobots. *Pharmacia*, *66*(3), 147–156. doi:10.3897/pharmacia.66.e37739

Marshall, J. (2011). Draft guidelines for nanomedicine unveiled. *NATNews*.

McDonald, T. O., Siccardi, M., Moss, D., Liptrott, N., Giardiello, M., Rannard, S., & Owen, A. (2015). The application of nanotechnology to drug delivery in medicine. In *Nanoengineering* (pp. 173–223). Elsevier. doi:10.1016/B978-0-444-62747-6.00007-5

Mihai, M. M., Dima, M. B., Dima, B., & Holban, A. M. (2019). Nanomaterials for wound healing and infection control. *Materials (Basel)*, *12*(13), 2176. doi:10.3390/ma12132176 PMID:31284587

Mirza, A. Z., & Siddiqui, F. A. (2014). Nanomedicine and drug delivery: A mini review. *International Nano Letters*, *4*(1), 1–7. doi:10.1007/s40089-014-0094-7

Parray, M. R., Kumar, H., Singh, A., Tomar, B., & Shiva, S. (2023). Synthesis of nanomaterial coatings for various applications. In *Nanomaterials for Sustainable Tribology* (pp. 167–190). CRC Press. doi:10.1201/9781003306276-11

Pastorino, L., Dellacasa, E., Scaglione, S., Giulianelli, M., Sbrana, F., Vassalli, M., & Ruggiero, C. (2014). Oriented collagen nanocoating for tissue engineering. *Colloids and Surfaces. B, Biointerfaces*, *114*, 372–378. doi:10.1016/j.colsurfb.2013.10.026 PMID:24246194

Popov, V., Kostyuk, G., Tymofyeyev, O., Kostyk, K., & Naboka, O. (2020). Design of new nanocoating based on hard alloy. In *Design, Simulation, Manufacturing: The Innovation Exchange* (pp. 522–531). Springer International Publishing. doi:10.1007/978-3-030-50794-7_51

Prathna, T. C. (2021). Nanotechnology in Imaging Applications: An Overview. *Nanotechnology in Medicine*, 75-86.

Rajendran, N. K., Kumar, S. S. D., Houreld, N. N., & Abrahamse, H. (2018). A review on nanoparticle based treatment for wound healing. *Journal of Drug Delivery Science and Technology*, *44*, 421–430. doi:10.1016/j.jddst.2018.01.009

Santhini, O. E., & Kirupha, S. D. (2020). Nanomaterials and ethical issues. *Applications of nanomaterials in human health*, 275-286.

Sasidharan, A., & Monteiro-Riviere, N. A. (2015). Biomedical applications of gold nanomaterials: Opportunities and challenges. *Wiley Interdisciplinary Reviews. Nanomedicine and Nanobiotechnology*, *7*(6), 779–796. doi:10.1002/wnan.1341 PMID:25808787

Savaliya, R., Shah, D., Singh, R., Kumar, A., Shanker, R., Dhawan, A., & Singh, S. (2015). Nanotechnology in disease diagnostic techniques. *Current Drug Metabolism*, *16*(8), 645–661. doi:10.2174/1389200216666150625121546 PMID:26560320

Shaik, J., & Kumar, A. C. (2021). Nanostructures for biomedical devices. In *Nanoscale Processing* (pp. 299–326). Elsevier. doi:10.1016/B978-0-12-820569-3.00011-6

Singh, A., Dogra, T. S., Mandal, U. K., & Narang, R. K. (2019). Novel approaches for ocular drug delivery: A review. Int. J. Bio-. *Pharmaceutical Research*, *8*, 2722–2732.

Singh, A., Mittal, S., Mudgal, D., & Gupta, P. (2018). Design, development and application of nanocoating. *Nanomaterials and Their Applications*, 191-207.

Singla, R., Abidi, S. M., Dar, A. I., & Acharya, A. (2019). Nanomaterials as potential and versatile platform for next generation tissue engineering applications. *Journal of Biomedical Materials Research. Part B, Applied Biomaterials*, *107*(7), 2433–2449. doi:10.1002/jbm.b.34327 PMID:30690870

Su, S., & Kang, M, P. (. (2020). Recent advances in nanocarrier-assisted therapeutics delivery systems. *Pharmaceutics*, *12*(9), 837. doi:10.3390/pharmaceutics12090837 PMID:32882875

Suhag, D., Chauhan, M., Shakeel, A., & Das, S. (2020). Emerging trends in nanotheranostics. *Nanobiomedicine*, 335–368.

Syafiq, A., Pandey, A. K., Balakrishnan, V., Shahabuddin, S., & Abd Rahim, N. (2018). Organic-inorganic composite nanocoating with superhydrophobicity and thermal stability. *Pigment & Resin Technology*.

Taleuzzaman, M., Gupta, D. K., Kala, C., Gilani, S. J., & Beg, S. (2021). Nanotechnology-assisted medical devices in cancer treatment. In *Nanoformulation Strategies for Cancer Treatment* (pp. 195–205). Elsevier. doi:10.1016/B978-0-12-821095-6.00010-0

Tawfik, S. M., Azizov, S., Elmasry, M. R., Sharipov, M., & Lee, Y. I. (2020). Recent advances in nanomicelles delivery systems. *Nanomaterials (Basel, Switzerland)*, *11*(1), 70. doi:10.3390/nano11010070 PMID:33396938

Tracey, S. R., Smyth, P., Barelle, C. J., & Scott, C. J. (2021). Development of next generation nanomedicine-based approaches for the treatment of cancer: We've barely scratched the surface. *Biochemical Society Transactions*, *49*(5), 2253–2269. doi:10.1042/BST20210343 PMID:34709394

Trentin, A., Uvida, M. C., de Araújo Almeida, A., de Souza, T. A. C., & Hammer, P. (2022). Self-healing nanocoating. In *Nanotechnology in the Automotive Industry* (pp. 371–401). Elsevier. doi:10.1016/B978-0-323-90524-4.00018-9

Wang, H., Zhou, Y., Sun, Q., Zhou, C., Hu, S., Lenahan, C., Xu, W., Deng, Y., Li, G., & Tao, S. (2021). Update on nanoparticle-based drug delivery system for anti-inflammatory treatment. *Frontiers in Bioengineering and Biotechnology*, *9*, 630352. doi:10.3389/fbioe.2021.630352 PMID:33681167

Wang, M., Huang, X., Zheng, H., Tang, Y., Zeng, K., Shao, L., & Li, L. (2021). Nanomaterials applied in wound healing: Mechanisms, limitations and perspectives. *Journal of Controlled Release*, *337*, 236–247. doi:10.1016/j.jconrel.2021.07.017 PMID:34273419

Wang, Y., Yu, L., Kong, X., & Sun, L. (2017). Application of nanodiagnostics in point-of-care tests for infectious diseases. *International Journal of Nanomedicine*, *12*, 4789–4803. doi:10.2147/IJN.S137338 PMID:28740385

Wiwanitkit, V. (2017). Ethics in Nanomedicine: A Concern on New Nanotechnology. *Med One*, *2*(5).

Wouters, M., Rentrop, C., & Willemsen, P. (2010). Surface structuring and coating performance: Novel biocidefree nanocomposite coatings with anti-fouling and fouling-release properties. *Progress in Organic Coatings*, *68*(1-2), 4–11. doi:10.1016/j.porgcoat.2009.10.005

Xiao, J., & Huang, Y. (2011). Design of sustainable multifunctional nanocoating: A goal-driven multiscale systems approach. *Chinese Journal of Chemical Engineering*, *19*(4), 666–673. doi:10.1016/S1004-9541(11)60039-6

Ye, Z., Sang, T., Li, K., Fischer, N. G., Mutreja, I., Echeverría, C., & Aparicio, C. (2022). Hybrid nanocoating of self-assembled organic-inorganic amphiphiles for prevention of implant infections. *Acta Biomaterialia*, *140*, 338–349. doi:10.1016/j.actbio.2021.12.008 PMID:34896631

Yilmaz, O., & Yorgancioglu, A. (2019). Nanocoating: preparation, properties, and biomedical applications. In Polymeric Nanomaterials In Nanotherapeutics (pp. 299-331). Elsevier.

ADDITIONAL READING

Alghamdi, M. D., Nazreen, S., Ali, N. M., & Amna, T. (2022). ZnO Nanocomposites of Juniperus procera and Dodonaea viscosa Extracts as Antiproliferative and Antimicrobial Agents. *Nanomaterials (Basel, Switzerland)*, *12*(4), 664. doi:10.3390/nano12040664 PMID:35214995

Amna, T., Hassan, M. S., Yang, J., Khil, M. S., Song, K. D., Oh, J. D., & Hwang, I. (2014). Virgin olive oil blended polyurethane micro/nanofibers ornamented with copper oxide nanocrystals for biomedical applications. *International Journal of Nanomedicine*, *9*, 891–898. doi:10.2147/IJN.S54113 PMID:24611006

Hassan, M. S., Amna, T., Mishra, A., Yun, S. I., Kim, H. C., Kim, H. Y., & Khil, M. S. (2012). Fabrication, characterization and antibacterial effect of novel electrospun TiO_2 nanorods on a panel of pathogenic bacteria. *Journal of Biomedical Nanotechnology*, *8*(3), 394–404. doi:10.1166/jbn.2012.1393 PMID:22764408

Nguyen, L. T., Chau, J. K., Perry, N. A., de Boer, L., Zaat, S. A. J., & Vogel, H. J. (2010). Serum stabilities of short tryptophan- and arginine-rich antimicrobial peptide analogs. *PLoS One*, *5*(9), e12684. doi:10.1371/journal.pone.0012684 PMID:20844765

Walch, E. B. T., & Roos, C. (2020). Measurement of the mechanical properties of silver and enamel thick films using nanoindentation. *International Journal of Applied Glass Science*, *11*(1), 195–206. doi:10.1111/ijag.13875