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Funtionalization of Titanium Metal Oxide Nanoparticles with Synthetic Polymer

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Abstract

Functionalization of titanium dioxide (TiO_2) nanoparticles with synthetic polymers is an important area of research due to the wide range of potential applications in fields such as catalysis, sensors, drug delivery, and photovoltaics. The process involves modifying the surface of TiO_2 nanoparticles with synthetic polymers to improve their stability, dispersibility, and interaction with other materials. This abstract elucidates the rationale behind this dynamic field, encompassing the enhancement of TiO_2 nanoparticle stability, surface modification for tailored reactivity, controlled release mechanisms, and improved photocatalytic properties. With applications spanning from catalysis to drug delivery and photovoltaics, the functionalization of TiO_2 nanoparticles offers transformative potential. Characterization techniques such as Transmission Electron Microscopy, FTIR Spectroscopy analysis are essential for understanding the resulting nanoparticle-polymer hybrid materials structural and physicochemical properties. This process involves modifying the surface characteristics of TiO2 nanoparticles through the integration of synthetic polymers, thereby imparting diverse functionalities and enhancing their utility in a myriad of applications.

Keywords: nanoparticles; titanium metal oxide; synthetic polymers.

1. Introduction

The remarkable mechanical qualities, resistance to corrosion, and biocompatibility of titanium and its alloys have earned them great respect across a wide range of industries, including chemical, aerospace, and biomedical engineering. However, obtaining the best possible functionality and surface qualities is frequently a crucial prerequisite in these applications. One extensively researched method for improving titanium's performance and customizing its surface properties is surface modification. The use of synthetic polymers, such as polyethylene glycol (PEG) and polyvinyl alcohol (PVA), has become apparent as a potential strategy among the various surface modification techniques available[1]. For a number of reasons, the functionalization of TiO_2 surfaces using artificial polymers like PEG and PVA is very interesting. First off, it makes it possible to create surfaces for biomedical implants that are bioactive and fouling-resistant, as well as improve the tribological characteristics of aerospace components[2]. Second, based on the particular application and functionalization method used, these polymers' adaptability enables a broad range of surface attributes to be created. Thirdly, PVA and PEG are both advantageous due to their biocompatibility and simplicity of handling, which makes them ideal for a range of uses[3,4]. This study compares and examines the functionalization of TiO_2 surfaces using

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synthetic polymers, PEG and PVA. Through an examination of the procedures, outcomes, and consequences of these adjustments, we want to clarify the benefits and constraints of every polymer in terms of surface functionalization. This work intends to advance the fields of surface science and material engineering by providing a thorough analysis of how PEG and PVA might be used to optimize titanium surfaces for various engineering and biomedical applications[5].

2. **Materials and Methods:** Ethyl acetate, polyethylene glycol (PEG 6000), poly vinyl alcohol, sodium lauryl sulfate, distilled water, titanium oxide and HCl.

2.1 Equipment and Method: Ultrasonicator (Model: AB-34, Make: Digital pro+) and Solvent Evaporation.

2.2 Parameters varied*:* Temperature (30-80^{0}C)

In this paper, Solvent Evaporation methods are used to form nanoparticles with selective raw materials such as PVA and PEG.

2.3 Formation of TiO_2-NPs via solvent evaporation method

Phase I was prepared as follows: 30 ml water was placed in a beaker, and 2 gm of surfactant was thoroughly mixed in it. Phase II was prepared as follows: 5.5 gm of titanium oxide was dispersed in 25 ml of solvent (HCL). Two phases are prepared that are immiscible. Emulsification and mixing were performed by using an ultrasonicator at 80°C for 90 min. The nanoparticles formed were placed in a desiccator at room temperature for 24 hrs for moisture removal.

2.4 Ultrasonication:

Use an ultrasonicator to further disperse the nanoparticles in the PEG and PVA solution at 80^{0}C for 2 hours. Ultrasonication helps break up any nanoparticle agglomerates and ensures a homogenous dispersion. Ultrasonicate the mixture for a sufficient amount of time, depending on the nanoparticle size and the equipment used.

2.5 Functionalizing titanium oxide nanoparticles with PEG :

Functionalizing TiO_2 nanoparticles with Polyethylene Glycol (PEG) typically involves a series of steps to ensure effective coating and stabilization of the nanoparticles. Below are the general steps for functionalizing TiO_2 nanoparticles with PEG:

Preparation of PEG Solution: PEG is a water-soluble polymer and is available in various molecular weights use (PEG6000). Dissolve 50gm of PEG6000 mol.wt. in 100ml water. A PEG solution is prepared by dissolving PEG in a suitable solvent, such as water to create a stable and homogenous solution.

Mixing Titanium Nanoparticles with PEG Solution: Take 0.5 gm of synthesized TiO_2 nanoparticles are mixed with the PEG solution. The mixing can be achieved through ultrasonication at 80^{0}C for 2 hours to ensure the uniform dispersion of the nanoparticles within the PEG solution.

Surface Adsorption or Ligand Exchange: The functionalization of TiO_2 nanoparticles with PEG can occur through surface adsorption or ligand exchange leave the solution for 24 hours. In surface adsorption, PEG molecules adsorb onto the surface of the TiO_2 nanoparticles, forming a protective coating. In ligand exchange, existing surface ligands on the nanoparticles are replaced by PEG molecules.

Reaction and Coating Formation: The mixture of TiO_2 nanoparticles and PEG solution is allowed to react under controlled conditions, which may involve heating or other specific parameters. During this process, the PEG

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molecules bind to the surface of the nanoparticles, forming a stable and uniform coating.

Removal of Excess PEG: After functionalization, any excess PEG that has not bound to the TiO_2 nanoparticles needs to be removed. This is typically done through purification step i.e precipitation. Purification ensures that only PEG-functionalized TiO_2 nanoparticles are retained.

2.6 Functionalizing titanium oxide nanoparticles with PVA:

Functionalizing TiO_2 nanoparticles with a polyvinyl alcohol (PVA) solution is a common method to improve their dispersion and stability in various applications, such as in nanocomposite materials or coatings. Here's a general guide on how to functionalize TiO_2 nanoparticles with a PVA solution:

Preparation the PVA Solution: Dissolve 50gm the PVA powder in 100 ml of distilled water to create a PVA solution. The concentration of PVA can vary, but a concentration of 1-5% PVA in water is typically suitable for functionalization. Use a container and stir the solution until the PVA is fully dissolved.

Mixing of PVA Solution and titanium oxide Nanoparticles: Add the prepared PVA solution to the 0.5gm of TiO_2 nanoparticles. The amount of PVA should be carefully chosen based on the desired functionalization and dispersion level. Stir the mixture to ensure even coating of the nanoparticles.

Drying of Functionalized Nanoparticles from the PEG and PVA solutions: functionalized TiO_2 nanoparticles from the PEG and PVA solution. Allow them to air-dry at room temperature. Rinse the functionalized nanoparticles with deionized water to remove any residual PEG and PVA solution.

3. Characterization of TiO_2 Nanoparticles:

The functionalized TiO_2 nanoparticles can be characterized to confirm the successful functionalization. Characterization techniques such as transmission electron microscopy (TEM), scanning electron microscopy (SEM), dynamic light scattering (DLS), and Fourier-transform infrared spectroscopy (FTIR) can be used to analyze the size, structure, and presence of PEG on the nanoparticle surface.

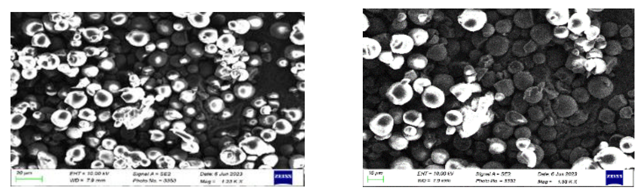

Figure. 1 FESEM images of Functionalized TiO2 NPs with PEG

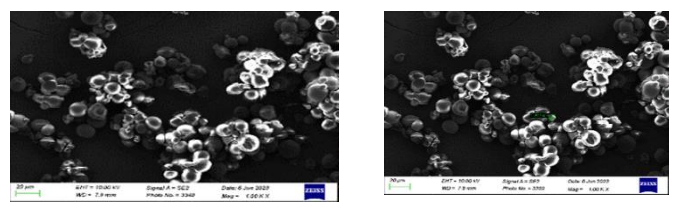

Figure. 2 FESEM images of Functionalized TiO2 NPs with PVA

Stability Testing: The stability of the PEG-functionalized TiO_2 nanoparticles is assessed under various conditions to ensure their long-term stability and dispersibility. Stability testing provides valuable insights into how PVA-functionalized TiO_2 nanoparticles perform under various conditions and can help ensure the nanoparticles' suitability for your intended use.

4. Results

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The functionalization of TiO_2 nanoparticles with PEG shown in (Figure 1) improves their stability, biocompatibility, and dispersibility in both aqueous and non-aqueous environments. PEG-functionalized TiO_2 nanoparticles find applications in various fields, including drug delivery, imaging, and biomedical research. The specific parameters and conditions for functionalization may vary based on the desired properties and applications of the functionalized TiO_2 nanoparticles. Optimization of the process is crucial to achieve the desired results.

The functionalization of TiO_2 nanoparticles with PVA (Figure 2) improves their film formation, biodegradability, film thickness supports ecofriendly. PVA have their unique advantages and are suitable for various applications. The choice between them will depend on the specific characteristics. If you need a stable film, controllable film thickness, or biodegradability, PVA could be the better choice.

5. Conclusion

Studies on the functionalization of TiO_2 with PVA and PEG on the utilization of solvent evaporation technique for the demonstrated their potential in advancing the field of automotive and biomedical applications. Both offer distinct advantages and can be tailored to achieve functionalization of TiO_2 however, the functionalization of titanium metal oxide nanoparticles with polyethylene glycol (PEG) and polyvinyl alcohol (PVA) polymers represents a significant advancement in the field of nanomaterials and materials science. This research has demonstrated the successful modification of titanium metal oxide nanoparticles with these biocompatible polymers, which has opened up a wide range of potential applications in various fields.

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