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Functional Coordination Polymers and Gold Nanoparticles form Hybrid Nanostructures: Applications in Biomedicine, Chemistry, Physics, Catalysis and Magnetism

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Abstract

The scientific community has developed an interest in hybrid nanomaterials over the past ten years, particularly those that combine gold nanoparticles with a second functional component. In this unique circumstance, coordination polymers are materials that have possible benefits over regular inorganic nanomaterials and natural mixtures, for example, synthetic flexibility, simple processability, high unambiguous region, low harmfulness, biodegradability and electronic and attractive functionalities to give some examples. By carefully combining Au nanoparticles with coordination polymers in a variety of nanostructures, it has been possible to overcome some of the limitations of Au nanoparticles for particular applications and broaden the range of properties and applications of these systems. As a result, the various hybrid nanostructures that has been reported and is based on the integration of colloidal Au nanoparticles with coordination polymers exhibit either of the relevant physical properties in this review or chemical properties. We have focused primarily on the enhanced properties and potential synergistic effects of this association. Along this front, because of their improved or potentially clever properties, these crossover materials have become promising nanostructures for a few applications, particularly in biomedicine, catalysis, attraction and detecting.

Keywords: Gold nanoparticles • Colloidal chemistry • Coordination chemistry • Prussian blue

Introduction

The creation of hybrid nanoparticles by combining a metallic NP, particularly gold ones, with other types that bring an additional physical or chemical function is an appealing possibility in materials chemistry. The common communication between the two parts of the nanostructure may prompt the development of novel capabilities originating from synergetic impacts past the simple blend of the physic-compound properties of the two parts. In this unique situation, colloidal science is a strong methodology that offers benefits over different techniques for the improvement of crossover nanostructures, for example, high molecule soundness, a huge uncovered surface region and an exact compound control of the molecule size, shape, organization, design, and crystallinity. The potential applications for these hybrid nanomaterials can be expanded when colloidal NPs and other functional nanomaterials are incorporated into advanced materials with specific physical and/or chemical properties. As a result, the majority of research has been devoted to the combination of Au NPs with metal oxides or organic compounds. However, a growing area of research in inorganic chemistry and materials science is the use of coordination polymers as a functional material for these hybrid nanostructures.

Literature Review

Functional coordination polymers and gold nanoparticles have garnered significant attention in recent years due to their unique properties and versatile applications. The hybridization of CPs and AuNPs has emerged as a promising strategy to develop novel nanostructures with enhanced functionalities for a wide range of fields, including biomedicine, chemistry, physics, catalysis, and magnetism. This literature review aims to explore the recent advancements and applications of functional CP-AuNP hybrid nanostructures in these disciplines. Synthesis and Characterization of CP-AuNP Hybrid Nanostructures: The synthesis of CP-AuNP hybrid nanostructures involves the incorporation of AuNPs within the CP matrix either during or after the CP formation. Various synthetic strategies, such as in situ growth, post-synthetic modification, and self-assembly, have been employed to achieve well-defined hybrid nanostructures with controlled size, shape, and composition. Characterization techniques including transmission electron microscopy, scanning electron microscopy , X-ray diffraction, Fourier-transform infrared spectroscopy , and UV-Vis spectroscopy are commonly utilized to assess the morphology, structure, and optical properties of these hybrid materials.

Discussion

The number of publications per year has increased to 5000 by 2021, indicating the current level of scientific interest in hybrid NPs. A substantial portion about Hybrid materials containing Au NPs account for 15% of the total number of publications published in the last five years, of which 30% contain CPs as a functional molecular component. As a result, the most current area of interest is the creation of multifunctional hybrid NPs made from Au and CPs. Since 1990, the number of publications using the terms "gold coordination polymers nanoparticles," "hybrid gold nanoparticles," "hybrid nanoparticles" and "gold nanoparticles" [1].

Hence, this survey means to cover the new advances performed on Au NPs-CPs mixture nanostructures displaying either actual properties of interest or properties of chemicals. The potential synergistic effects of this association will receive special attention. These hybrid nanostructures were selected for their chemical and structural adaptability, ease of processing, large specific area, high solubility, low toxicity, and biodegradability. Prussian Blue Analogues, Spin Crossover Materials, and Metal-Organic Frameworks are the three kinds of coordination polymers that will be the focus of this section. The first two are examples of materials that are both magnetic and electro active, which is important for electro catalysis and magnetism. The third one lets porosity be added to the hybrid nanostructure [2].

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In 1857, Michael Faraday explored a "lovely ruby liquid" got from the development of a dark red-hued colloidal Au by the decrease of a watery arrangement of gold chloride. Faraday realized that the small size of the Au particles was the only reason for the color. He was right when he said that the colloids' metallic particles should be very small because the best microscopes couldn't see them. He additionally noticed that their tones went from ruby, green, violet and blue contingent upon the synthesis of the metallic molecule. Roughly a century after the fact, the more limited frequencies produced in electron magnifying lens confirmed that Faraday's Au colloids had widths from 3 to 30 nm. Then, at the turn of the twentieth century, Gustav Mie developed a comprehensive theory for the scattering and absorption of light by spherical metallic particles by utilizing Maxwell's electromagnetic theory [3].

In 1912, Richard Gams summed up Mie's outcome to ellipsoidal particles of any perspective proportion in the little molecule estimation. In addition, the development of imaging techniques for transmission electron microscopy has brought about resurgence in the study of metal colloids' structure and morphology, making it possible to investigate and profit from their properties. The hybrid nanostructures that combine gold nanoparticles with functional coordination polymers have been the focus of this review. Due to their unique physical properties and the possibility of using colloidal chemistry routes to design the appropriate hybrid nanostructures targeting specific functions, gold nanoparticles have been utilized extensively [4].

The structural and chemical versatility, easy process ability, high specific area, good solubility, low toxicity, biodegradability, and electronic and magnetic functionalities of coordination polymers, on the other hand, are potential advantages of coordination polymers over conventional inorganic nanomaterial and organic compounds. As a result, some of the limitations of Au NPs for particular applications have been overcome by wisely integrating Au NPs into CPs in various kinds of nanostructures, thereby broadening the range of properties and applications of this CPs. In such manner, these crossover materials have become promising nanostructures for applications in biomedicine, catalysis, attraction and detecting [5].

Functional CP-AuNP hybrid nanostructures have shown great potential in biomedical applications. Their unique physicochemical properties, surface functionalization capabilities, and biocompatibility make them ideal candidates for drug delivery systems, theranostics, bioimaging and biosensing. The controlled release of therapeutics, targeted drug delivery, and the combination of diagnostic and therapeutic modalities can be achieved through the integration of CPs and AuNPs, providing enhanced efficacy, improved selectivity, and reduced side effects in the treatment of various diseases [6].

Conclusion

The core shell nanostructure, which consists of an Au core and a functional CP shell, has been the focus of this review because it encourages the appearance of synergistic effects by maximizing interaction between the two nanosystems. Due to their simplicity, versatility, and ease of preparation, decorated NPs are also quite common nanostructures. For the other conceivable nanostructures, the field is considerably less investigated. Despite their recent significant interest, few Janus and elaborated core shell nanostructures, like the yolk shell ones, have been reported so far. In addition, only the most well-known CPs have been considered, such as spin-crossover complexes, bimetallic cyanide complexes of the Prussian Blue family, and some classic MOFs. To be sure, there is still a lot of room accessible to foster new manufactured conventions, to consolidate other more uncommon CPs to create novel crossover nanomaterial and to investigate different physic-synthetic properties coinciding or arising in these brilliant and multifunctional nanostructures.

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Conflict of Interest

None.

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