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Novel Capping Agents for Nanomaterials

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Abstract: Nanomaterials are of great scientific interest as they bridge the gap between bulk materials and atomic or molecular structures. Capping agents are biological or chemical components naturally restrict the reaction and the particle growth in the nanoparticles synthesis. The understanding of the effect of capping on nanoparticles is one of the most important topics now-a-day. Protein and peptides capping agents have been characterized by FTIR, SDS-PAGE and MALDI-TOF-MS. In this review we are attempting to address main function of capping agents and how this may cause noticeable improvement of efficiency of nanoparticles and materials.

Key words: Capping Agents · FTIR · Nanoparticles

INTRODUCTION

Nanomaterials are of great scientific interest as they bridge the gap between bulk materials and atomic or molecular structures. Scientific research has placed much emphasis on nanomaterials, because their special properties are appealing towards many commercial applications. A wide range of materials can be generated by reducing metal ions in the presence of a capping agent [1]. Metal nanoparticles and other nanostructures have attracted much attention for use in the biomedical field because of their interesting shape dependent and size-dependent physical and chemical properties.

Capping agents are biological or chemical components (Fig. 1) naturally restrict the reaction and the particle growth in the nanoparticles synthesis. This nanostructure like nanoparticles or nanocrystals must be capped appropriately to render biocompatible, functional and stable against aggregation in biological systems. Due to the small size, nanoparticles tend to have a higher surface energy compared to bulk material, which may lead to instability and require capping agents to aid their stabilization. Capping agents follows different mechanisms electrostatic stabilization, steric stabilization, stabilization by hydration forces, depletion stabilization and stabilization by van de Waals forces [2]. Stabilizing agent could prevent agglomeration of the particles due to nanoparticles high surface energy.

Colloidal nanocrystals are synthesized and stabilized in solution with the help of organics or polymers which could bind on the particle surface. Colloidal nanoparticles are typically synthesized in solution by reacting molecular metal precursors with appropriate reducing agents in the presence of capping agents to stabilize the high energy

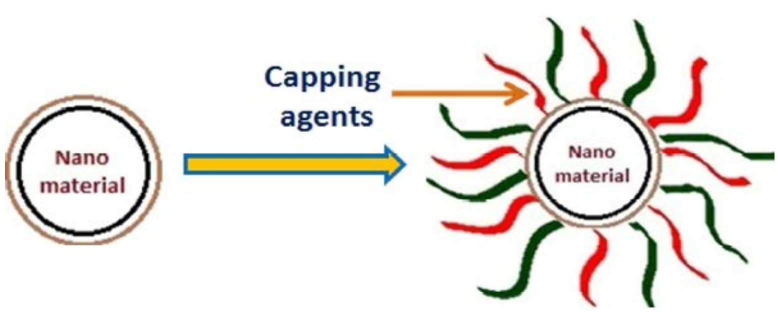

Fig. 1: Capping agents are biological or chemical components around nanomaterial

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surface of the nanoparticles and protect them from aggregation. Nanocrystals synthesized by colloidal methods can be defined as a core-shell structure: a hard inorganic core surrounded by a soft organic shell (i.e., capping agents).

Capping agents often act as ligands to form complexes with original metal precursors and there by affect their reduction kinetics. Another critical role played by capping agents is their selective adsorption on particular crystallographic planes that therefore induces the anisotropic growth of nanocrystals [3-5]. Effect of capping agents on optical properties of nanostructure of ZnS and ZnO were studied [6, 7].

Capping agents act as a physical barrier to restrict the free access of reactants to catalytically active sites on the particle surface. The understanding of the effect of capping on nanoparticles is one of the most important topics now-a-day. Identifying the binding sites of capping agents on the nanoparticles is important in future research. With the aid of computational chemistry, exploring the molecular conformations of capping agents on the metal surface becomes possible.

Effect of capping agent on the particle size and shape for different medium were extensively studied using UV-Vis spectroscopy and transmission electron microscopy (TEM) [8,9]. Capping agents are also used for the stabilization of the nanoparticles and the capped AgNPs exhibit better antibacterial activity than uncapped AgNPs [10-12]. In this review we are attempting to address main function of capping agents and how this may cause noticeable improvement of efficiency of nanoparticles and materials.

Capping Agents

Natural (Protein or Peptides) Capping Agents: Biosynthesis of nanoparticles as an emerging highlight in nanotechnology has received increased attention due to growing need to develop low toxic and ecofriendly technologies in material synthesis [13]. Most of nanoparticles are coated with proteins and peptides when we use naturally biological sources like bacteria, algae, fungus, or plant extracts for synthesis. Peptides which are different from proteins on the basis of size and number of amino acids and their folding, are well known to be involved in molecular recognition events. These natural materials such as peptides are biocompatible, well-characterized, nonimmunogenic, biodegradable and multifunctional [14]. The preparation of peptide-capped nanoparticles is rapid, simple and amenable to high-throughput approaches. Peptide-capped nanomaterials have many applications like biosensors, cell imaging and many possibilities for the design and preparation of the advanced functional nanomaterials of the future. Protein and peptides capping agents have been characterized by FTIR, SDS-PAGE and MALDI-TOF-MS and studied by various researchers [15-19]. Peptide-coated gold nanoparticles have also been evaluated for *in vivo* applications [20, 21]. Peptide capped NPs have many applications like artificial enzymes [22].

Chemical Capping Agents: The shape-controlled synthesis of metallic nanostructures (One-dimensional (1D) -wires, rods and tubes and Two-dimensional (2D) and three-dimensional (3D) nanostructures like nanoplates, nanodisks, nanocubes, nanospheres) has become a hot topic in the synthetic field and they has a great effect on their properties and chemical and physical performances [23].

The development of materials with the ability to inhibit bacterial growth have been of great interest in recent years due to their potential use in everyday products like paints, kitchenware, school and hospital utensils, etc. Inorganic antibacterial materials have several advantages over traditionally used organic agents, like chemical stability, thermal resistance, safety to the user, long-lasting action period. Guili Yang *et al*. [24] investigated the antibacterial activity silver nanoparticles against *Escherichia coli, Staphylococcus aureus, Staphylococcus epidermidis, Pseudomonas aeruginosa,* and *Klebsiella pneumonia* and how their activity was enhanced with dextran acts as capping agent.

The gold nanoparticles and nanorods were successfully synthesized from aqueous and non-aqueous medium with CTAB (Cetyl trimethyl ammonium bromide) and PVP as a capping agent by simple chemical route. To control the growth of the nanoparticles, organic stabilizers (polymers) e.g. polyethylene oxide (PEO), poly(N-vinyl-2 Pyrrolidone, PVP), Citrate, polyvinyl carbazole (PVK) are added during the wet-chemical synthesis for capping the surface of the particles.

Citrate: Arnim Henglein [25] explained how citrate concentration effects as capping agent NPs synthesis and stabilization. Ángela *et al*. [26] used capillary electrophoresis for the analysis of citrate-capped gold and silver nanoparticles

Poly (N-vinyl-2 Pyrrolidone (PVP): PVP is a water soluble polymer made from monomer - *N*-vinyl pyrrolidone. It contain a highly polar amide group that confers hydrophilic and polar-attracting properties and non-polar methylene groups confer hydrophobic properties [27]. There have been numerous types of stabilizers that have been used as capping agent for stabilizing nanoparticles but few are successful agents like PVP. Currently nanomaterials based on AgNPs are applied in electronic, optic, chemical, textile industries, as well as in pharmacy, cosmetology, medicine, food production and packing the effective concentration of AgNPs was investigated by Dagmara malina *et al.* [28]. Zeng *et al.* [29] and Liang *et al*. [30] found that silver nanoparticles could be selectively obtained by introducing PVP, as the capping agent. Xin-Ling Tang *et al*. [31] produced gold nanoparticles using PVP as capping agent.

Polyethylene Glycol-g-polyvinyl Alcohol (PEG-g-PVA): PEG-g-PVA is commercially available, highly water soluble and biocompatible. Tyagi *et al.* [32] and Alaaldin M. Alkilany *et al.* [33] successfully produced gold Nanoparticles and Manoj Sharma *et al.* [34] and Dasari Ayodhya *et al.* [35] produced ZnS nanoparticles using PEG-g-PVA as capping and stabilizing agent.

Polyvinyl Carbazole (PVK): It is organic semi conducting polymer used as capping agent for nanomaterials synthesis [36].

CONCLUSIONS

Capping agents are biological or chemical components and identifying the binding sites of capping agents on the nanoparticles and materials are important in future research. We have still more questions like why few peptides opted for binding on nanoparticles and how should we quantify them. We need more sophisticated technologies to understand the interaction between nanomaterials and capping agents.

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