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COPPER NANOPARTICLES AND ITS APPLICATIONS

Poonam Rani
Department of Chemistry
Guru Jambheshwar University of Science & Technology
Hisar-125001, Haryana, India
Email: poonamritu087@gmail.com

Abstract

Copper nanoparticles are copper based particles 1 to 100 nm in size. Like many other forms of nanoparticles, copper nanoparticles can be formed by natural processes or through chemical synthesis. These nanoparticles are of particular interest due to their historical application as coloring agents and their modern-day biomedical ones. Nanomaterials are being applied in more and more fields within engineering and technology. The present paper will focus mainly on the applications of copper nanoparticles in various fields.

Keywords *1,2,3-triazoles, applications, Copper-Catalyzed, Huisgen cycloaddition*

Introduction

Copper nanoparticles are copper based particles 1 to 100 nm in size.[1] Copper nanoparticles can be formed by natural processes or through chemical synthesis.[2] These nanoparticles are of particular attention due to their historical application as coloring agents and their modern-day biomedical ones.

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Nanomaterials are being applied in more and more fields within engineering and technology. One of the key benefits of nanomaterials is that their properties vary from bulk material of the same composition. The properties of nanoparticles can be easily altered by varying their size, shape, and chemical environment.

Copper is a Block D, Period 4 element. It is a ductile metal with very high thermal and electrical conductivity. The morphology of copper nanoparticles is round, and they appear as a brown to black powder. Copper is found to be too soft for some applications, and for this reason it is often combined with other metals to form numerous alloys such as brass, which is a copper-zinc alloy. Copper nanoparticles are found as highly flammable solids; therefore they must be stored away from sources of explosion. They are also known to be extremely poisonous to marine life.

Historical Uses

One of the earliest uses of copper nanoparticles was to color glass and ceramics for the period of the ninth century in Mesopotamia.[1] This was done by creating a glaze with copper and silver salts and applying it to clay pottery. When the pottery was baked at high temperatures in reducing conditions, the metal ions migrated to the outer part of the glaze and were reduced to metals.[1] The end result was a double layer of metal nanoparticles with a small amount of glaze in between them. When the finished pottery was exposed to light, the light would penetrate and reflect off the first layer. The light penetrating the first layer would reflect off the second layer of nanoparticles and cause interference effects with light reflecting off the first layer, producing a luster effect that results from both constructive and destructive interference.[2]

Manufacturing Process

An assortment of methods has been described to chemically synthesize copper nanoparticles. An older way involves the reduction of copper hydrazine carboxylate in an aqueous solution using

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reflux or by heating through ultrasound under an inert argon atmosphere.[3] This results in a combination of copper oxide and pure copper nanoparticle clusters, depending on the method used. A more modern synthesis utilizes copper chloride in a room temperature reaction with sodium citrate or myristic acid in an aqueous solution containing sodium formaldehyde sulfoxylate (SFS) to obtain a pure copper nanoparticle powder.[4] While these syntheses generate fairly consistent copper nanoparticles, the possibility of controlling the sizes and shapes of copper nanoparticles has also been reported. The reduction of copper(II) acetylacetonate in organic solvent with oleyl amine and oleic acid causes the formation of rod and cube-shaped nanoparticles while changes in reaction temperature influence the size of the synthesized particles.[5]

Copper nanoparticles can also be synthesized using green chemistry to reduce the environmental impact of the reaction. Copper chloride can be reduced using only L-ascorbic acid in a heated aqueous solution to produce stable copper nanoparticles.[6]

The electrodeposition technique is well thought-out by many as one of the most suitable and easiest. The electrolyte used for the process is an acidified aqueous solution of copper sulfate with definite additives. A spongy layer of copper particles is deposited on the cathode surface when the input DC voltage is varied with a constant current. The particles are typically characterized and assessed by XRD and UV-Vis. The surface morphological characterization is done using scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

Damp reunion tends to affect the dispersion performance and usable properties of copper nanoparticles; hence this material has to be sealed under vacuum and stored in a cool and dry room. It should not be exposed to air, and should not be under stress.

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Characteristics

Copper nanoparticles exhibit unique characteristics including catalytic and antifungal/antibacterial activities that are not observed in commercial copper. First of all, copper nanoparticles demonstrate a very strong catalytic activity, a property that can be credited to their large catalytic surface area. With the small size and great porosity, the nanoparticles are able to attain a high reaction yield and a shorter reaction time when utilized as reagents in organic and organometallic synthesis.[7] In fact, copper nanoparticles that are used in a condensation reaction of iodobenzene attained about 88% conversion to biphenyl, while the commercial copper exhibited only a conversion of 43%.[7]

Copper nanoparticles that are very small and have a high surface to volume ratio can also serve as antifungal/antibacterial agents.[8] The antimicrobial activity is induced by their close interaction with microbial membranes and their metal ions released in solutions.[8] As the nanoparticles oxidize slowly in solutions, cupric ions are released from them and they can create toxic hydroxyl free radicals when the lipid membrane is nearby. Then, the free radicals disassemble lipids in cell membranes through oxidation to degenerate the membranes. As a result, the intracellular substances seep out of cells through the destructed membranes; the cells are no longer able to sustain fundamental biochemical processes.[9] In the end, all these alterations inside of the cell caused by the free radicals lead to cell death.[9]

Applications

Copper nanoparticles with large catalytic activities can be applied to biosensors and electrochemical sensors. Redox reactions utilized in those sensors are generally irreversible and also require high overpotentials (more energy) to run. In fact, the nanoparticles have the ability to make the redox reactions reversible and to lower the overpotentials when applied to the sensors.[10]

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One of the examples is a glucose sensor. With the use of copper nanoparticles, the sensor does not need any enzyme and consequently has no need to deal with enzyme degradation and denaturation.[12] In fact, the nanoparticles allow the sensor to be extra stable at high temperatures and varying pH, and further anti to toxic chemicals. In addition, using nanoparticles, native amino acids can be detected.[12] A copper nanoparticle-plated screen-printed carbon electrode functions as a stable and effective sensing system for all 20 amino acid detection.[13]

Some applications of copper nanoparticles are listed below:

1. Acts as an anti-biotic, anti-microbial, and anti-fungal agent when added to plastics, coatings, and textiles
2. Copper diet supplements with efficient delivery characteristics
3. High strength metals and alloys
4. EMI shielding
5. Heat sinks and highly thermal conductive materials
6. Efficient catalyst for chemical reactions and for the synthesis of methanol and glycol
7. As sintering additives and capacitor materials
8. Conductive inks and pastes containing Cu nanoparticles can be used as a substitute for very expensive noble metals used in printed electronics, displays, and transmissive conductive thin film applications
9. Superficial conductive coating processing of metal and non-ferrous metal
10. Production of MLCC internal electrode and other electronic components in electronic slurry for the miniaturization of microelectronic devices;
11. As nanometal lubricant additives

Conclusion

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