

Applications of Cu₂O Nanoparticles Prepared via Various Techniques: A Review Paper

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ABSTRACT

This manuscript aims to illustrate some of the current industrial and biological applications of copper oxide (Cu₂O) nanoparticles, where nanoparticles are of particular interest because of their multiple applications, as well as antibacterial and antiviral. In addition to the industrial applications such as ink permeability, sensing and carriers in solar cells, the obvious properties of finely processed Cu₂O is discussed along with different preparation methods through which Cu₂O nanoparticles are obtained. It is widely accepted that pulsed laser ablation is one of the most successful Cu₂O fabrication techniques. , where this study focus on preparation and characterization copper nanoparticles doped Silver nanoparticles (Cu₂O@Ag) for optoelectronics, and bio-applications I can't understand this sentence, please revise it.

Keywords: Copper Oxide; Pulsed laser ablation; Cu₂O; Nanostructure; biological applications.

1. INTRODUCTION

Nanoscience and nanotechnology has reached a status which is considered as one of the most pronounced research findings, as researchers develop a deep understanding of the distinctive characteristics of molecular and atomic assemblages built at the nano-scale [1-4]. Copper oxide (Cu₂O) is a p-type semiconductor with relatively low optical bang gap ranging from 1.8 to 2.5 eV and a reddish brown color [5-8].

The entitled material has wide range of applications as well as some outstanding physical and chemical characteristics [9-11]. Herein, several techniques have been proposed throughout the last few years for the production of Cu₂O nanoparticles with size smaller than 100 nm [12-15]; for instance, thermal oxidation, potentiostatic placement microemulsion, microwave, reactive evaporation triggered, pulsed laser ablation, etc. [16-19]. Due to the fact that the majority of Cu₂O nanoparticles preparation methods involve the utilization of toxic chemicals, the search for environmentally friendly approach is of great importance [20-23].

Pulsed laser ablation is widely known method for the production of Cu₂O with an approximate nanoparticle diameter of 29 nm, at room temperature [24-26]. Pulsed laser ablation is also observed to provide Cu₂O nanoparticles with polycrystalline structure caused by localized high pressure using liquid copper sault as a target [27-30]. It is widely accepted that pulsed laser ablation is one of the most successful techniques [31-33]. It involves the use of Nd:YAG laser at different wavelengths [33-35]. Pulsed laser ablation is a very effective process for the production of Cu₂O nanoparticles that is often free of toxic substances [36-38].

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Another method so-called microemulsion (ME) is well-established for the production of well-crystallized Cu₂O nanoparticles [39-42]. In particular, the starting material for this procedure is copper acetate (Cu (CH₃COO)₂) along with an appropriate chelating agent; wherein such a technique is usually carried out in water for hydrolysis process at room temperature (benzylamine or n-propylamine) [43-46].

The resultant Cu₂O nanoparticles, using the addressed method, is attained in a transparent yellowish solution known as ME-Cu₂O suspension [47-49]. Nanocrystals Cu₂O were also successfully prepared using hydrothermal method using sodium hydroxide (NaOH) as reducing agent while copper chloride and ascorbic acid are utilized as the precursors [50-53]. Cu₂O thin film can also be produced using RF sputtering technique [54-56].

This report presented a mini review of data for copper oxides and their deposition methods, fabrications, characterization, and applications.

2. CU₂O NANOPARTICLES APPLICATIONS

2.1. Industrial Electronic Applications

Cu₂O thin-films are used as a hole-transport layer in planar perovskite solar cells. The Cu₂O layer was produced using a process known as sequential ionic layer adsorption and reaction (SILAR). The direct structure (pin) has been formed with methylammonium lead triiodide (MAPbI₃), in which the perovskite layer is sandwiched between a layer of p-type Cu₂O and another layer of n-type PCBM (phenyl-C61-butyric acid methyl ester), which served as a hole- and electron-transport materials, respectively. The band-edges have determined the materials in relation to their Fermi energy by recording scanning tunneling spectroscopy that corresponds to their density of states (DOS). Upon illumination, the energy levels of the materials form type II band-alignment at each of the two interfaces (pi and in), allowing for charge separation and uninterrupted carrier transit. Charge-transfer from MAPbI₃ was facilitated by such band-alignment, as indicated by the suppression of its photoluminescence emission when the perovskite was in contact with either the hole- or electron-transport layer. The planar perovskite solar cell (Cu₂O/MAPbI₃/PCBM) produced an energy conversion efficiency (η) of 8.23% under 1 Sun light using the direct pion structure with acceptable energy levels for carrier separation [57-59].

CuO was also used for memory applications, particularly ferroelectric memory, magnetic memory, phase change memory, and resistive switching memory for various random access memory (RAM) alternatives to flash memory [60, 61]. This in turn was accomplished through sandwich technique of Cu/Cu_xO/Pt [62, 63]. Moreover, in the production of ink, copper oxide nanoparticles were also demonstrated a great deal for inkjet printer application [64-66]. Various approaches were used to regulate the decorating of copper, cuprous oxide, and cupric oxide nanocrystals in multiwalled carbon nanotubes (MWCNTs) using infrared (IR) irradiation [67, 68]. A scaling-up of the Cu₂O nanocrystal manufacturing was demonstrated for potential electro catalysis, photovoltaics, electronics, and optics application [69, 70].

2.2 Industrial Biological Applications

In the antimicrobial field, CuO was also applied [71-73]. In details, CuO was prepared using eco-friendly reflux condensation method wherein non-surfactants pathway was utilized [74, 75].

Copper nanoparticles (Cu-NPs) have recently sparked interest due to their low cost and antibacterial capabilities, and they may be one of the most important alternatives to silver NPs.

Colloidal oxide copper (Cu₂O and CuO NPs) NPs are synthesized by pulsed laser ablation of a solid target (copper) in liquid media. These copper NP oxides were synthesized utilizing Nd: YAG laser light to maintain a 1064 nm wavelength of 40 mJ/pulse.

During the production of colloidal NPs, identical factors such as optimum equipment settings, laser intensity, and laser exposure period (1 h ablation) were used. Advanced methods such as UV-visible, X-ray diffraction, transmission electron microscopy, and attenuated total reflection Fourier transform infrared spectroscopy were used to analyze these copper oxide NPs. Antibacterial properties of synthetic materials were also shown to be significant. Using disc diffusion methods, the cuprous oxide NPs demonstrated a significant antibacterial effect. The lowest inhibitory and bactericidal concentrations of produced Cu₂O NPs were 120 and 140 g/L, respectively, against *Staphylococcus aureus*, the positive control. As a result of the current study's findings, Cu₂O NPs can be used as stable antibacterial agents for a variety of applications [76]. In terms of sensor application, Cu₂O was also introduced. However, a nanocomposite containing rGO- Cu₂O mesocrystal with a peculiar octahedral shape was employed as an ultrasensitive environmental sensor [77].

In terms of antibacterial as well as nanocoloring wool fibers, green-assembled cupric oxide nanoparticles, exhibited a great deal of importance, This was proposed for the purpose of toxic chemicals replacement considering the current issues with the economy and environment, cupric oxide nanoparticles were found to be highly efficient as UV protection [78].

Copper acetate in conjunction with graphite oxide, as the precursor, was utilized for biosensor application for diethylene glycol detection. It was found that the proposed biosensor geometry has a broad linear range, a low detection limit of 0.1 M, good sensitivity, and durability, and is simple to construct, making it indicating the potential for non-enzymatic glucose sensors in the future. This was achieved upon attaining evenly distributed cuprous oxide nanoparticles over reduced graphene oxide (RGO) sheets [79]. Cupric oxide was also tested to prevent the surface infection of SARS-CoV-2 (COVID-19) through door handles and handrails. The fabrication, design, and examination of a cupric oxide as an anti-SARS-CoV-2 covering was reported this was acquired as the fact that cupric oxide allows fast aqueous solutions infiltration into the covering wherein a diffusion distance to the cupric oxide surface is small while the related surface area is relatively outsized The infection rate of SARS-CoV-2 from cupric oxide was decreased to 99.8% within 30 minutes as well as 99.9% after 1 hour in comparison to that made out of glass [80]. The Cu₂O photo-excited charge separation was reported to be enhanced through the utilization of Persulfate (PS). Besides, the mentioned process also promotes the persulfate heterogeneous PS activation process, which in turn was responsible for the generation of free radicals that are active. This research not only presents a simple and effective photocatalytic method for eliminating pollutants, but it also sheds light on the intricate principles of PS photocatalytic activation using semiconductors [81], table for the mentioned applications.

Table 1 The summary of the applications

Industrial Electronic Applications	Industrial Biological Applications
<p>a- Cu₂O thin-films are used as a hole-transport layer in planar perovskite solar cells.</p> <p>b- Cu₂O was also used for memory application.</p> <p>c- The production of ink.</p> <p>d- For organizing decorating copper, cuprous oxide and cupric oxide nanocrystals in multiwalled carbon nanotubes.</p> <p>Further scaling up the fabrication of Cu₂O nanocrystals for potential electrocatalysis, photovoltaics, electronics, and optics application.</p>	<p>a- Antimicrobial field.</p> <p>b- Sensor application, Cu₂O was also introduced.</p> <p>c- In term of antibacterial as well as nanocoloring wool fibers, green-assembled cupric oxide nanoparticles, exhibited a great deal of importance.</p> <p>d- Copper acetate in conjunction with graphite oxide, as precursor, was utilized for biosensor application for diethylene glycol detection.</p> <p>e- Cupric oxide was also tested to prevent the surface infection of SARS-CoV-2 (COVID-19) through door handles and handrails The fabrication, design.</p> <p>In enhancing the charge separation of Cu₂O by photo using persulfate (PS).</p>

3. CONCLUSION AND FUTURE OUTLOOK

Cu₂O is well-established semiconductor materials by which a sound optoelectronic characteristic could be delivered which in turn make Cu₂O widely used in;

1. Perovskite solar cells.
2. Additionally, Cu₂O nanoparticles have the potential to be used in the gas sensor application due to its photocatalytic properties.
3. Antibacterial action against bacteria, fungus, algae, and viruses.

These characteristics detection and sensing applications are depending on the composition and structure of the Cu₂O nanoparticles. The addressed nanoparticles properties make it a perfect candidate for the well-known current application as well as a potential material for foreseeable application and scientific development.

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