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Synthesis of Mixed Metal Oxides CuO–SnO – Composite Nano Material for the Study of Efficiency of Textile Fabrics as UV-Absorbers

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Abstract

In the present study, we report the synthesis and characterization of nanosized copper oxide, tin oxide and composite of copper and tin oxide and their application on cotton fabrics for UV shielding. The CuO–SnO nanocomposite material prepared under different temperatures, e.g., 90°–150°C by using water and 1,2-ethanediol as a solvent. Copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles were then applied to cotton sample to impart sunscreen activity to the treated textiles. SEM (scanning electron microscopy) was used to characterize the surface of cotton sample which was treated with copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles. Physical tests were performed on the fabrics after the treatment with copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles. CuO is covalent in nature. Copper oxide crystallizes in a cubic structure. At high temperature, it is easily reduced by hydrogen and dissociate in acid solution to give copper (II)ions and copper. The chemical compound is quite distinctive due to its black color, a significant variation from the metallic copper it originates from copper (l). SnO is collectively considered as versatile metal oxide mainly because of its variance valence state and because of the existence of vacant oxygen defects.

Keywords: Copper oxide, tin oxide and composite of copper oxide and tin oxide nanoparticle(s), textile, SEM, nanocomposites

INTRODUCTION

The use of nanomaterials, such as zinc oxide (ZnO) and silver nanoparticles in the textile industry, has shown significant improvements in fabric performance, particularly in terms of antibacterial and UV-protective properties. These nanoparticles are highly effective due to their exceptionally large surface area relative to their volume, which enhances their ability to interact with microbial cells and absorb or scatter harmful ultraviolet radiation. ZnO nanoparticles have demonstrated superior UV-blocking capabilities when compared to their bulk counterparts, making them a preferred choice in functional fabric treatments. As a result, textiles treated with these nanomaterials offer enhanced durability, hygiene, and protection, meeting the growing demand for high-performance and multifunctional clothing in both everyday wear and specialized applications [1]. The use of nano materials in the textile industry is mainly due to the large surface area and surface energy for the better affinity of fabrics and high durability for fabrics, as compared to the conventional material, which will impart different properties to fabrics and do not have permanent effects, and easily lose their functions after laundering or wearing [2].

Nano martials cotton fabrics when treated with bulk copper oxide, tin oxide, and composite of

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copper and tin oxide nanoparticles show different physical and mechanical properties. This reflects the improved properties of nano-sized particles with respect to conventional materials [3]. Air permeability of the fabrics is reduced when the coating process is carried out with bulk copper oxide, tin oxide, and composite copper and tin oxide, while it is improved when nano-copper oxide, tin oxide, and composite of copper and tin oxide are used. The present work addresses the synthesis and characterization of copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles obtained through a homogenous phase reaction between copper chloride and sodium hydroxide at high temperature. SEM (scanning electron microscopy) was used to determine the surface area of the cotton with respect to nanoparticles [4].

The nanocomposite material SnO_2–CuO also work as a nano catalyst for effective reduction process of aliphatic as well as aromatic nitro compounds in presence of traditional reducing agents like $LiAlH_4$, $NaBH_4$, etc. The mixed metal composite nano martials have several advantages, benefits as compared to the traditional reducing surface in the organic as well as inorganic reaction mechanisms, including the mixed metal composite, like SnO_2–CuO, SnO–CuO as a catalyst, can enhance the reaction rate by decreasing the activation energy and consequently the reduction process completed within shorter period of time with increasing in the product yield. The reduction reactions of nitro substituted aromatic and heterocyclic compounds effectively takes place over the nano catalyst surface under the milder reaction conditions, reducing the risk of side reactions and improving product selectivity. The nanocomposite catalyst can be reused, making the process more sustainable and cost-effective.

The reduced compounds can be used as a reaction intermediate as well as potential initial starting materials in various organic reactions, such as polymer synthesis, dyes pigment, pharmaceutical, and various chemical synthesis [5].

This work had basically explored the decrease in reduction time by combining two types of metal oxide which helps to reduce time, energy, and resources for effective reduction process.

EXPERIMENTAL

Synthesis of CuO/SnO Nanoparticles

For $CuCl_2$ (min. 98%), NaOH (pellet min. 99%), 1,2 ethanediol (min. 99.5%), and 2-propanol (min. 99.5%) [6] purified water was used. The nano particles were prepared by adding $CuCl_2$ (5.5 g) in 100 mL of water, about 12–16 mL of 5 M NaOH solution were added dropwise to the copper chloride [6] solution, and the mixture was heated at 90°–95°C in an oil bath. With a constant stirring for 10 min at 90°C CuO particles [7] were precipitated by sedimentation process. The precipitate was washed away five times with distilled water to lower the concentration of NaCl. The complete removal of NaCl from the solution was checked by using $AgNO_3$. The product was peptized with 2-propanol in an ultrasonic bath for 10 min at room temperature. The precipitation was kept for centrifugation at 6,000 rpm for 15 minutes and finally the particles were dried in oven at 250°C for 5 h.

Synthesis of SnO was carried out in the same way but in place of $CuCl_2$, $SnCl_2$ solutions were used. For synthesis of composite copper oxide and Tin oxide nanoparticle, $CuCl_2$ solution was used, and the same procedure was followed.

PREPARATION of SnO–CuO NANOCOMPOSITE

Step 1: Preparation of Molar Solutions

To initiate the synthesis of the *SnO–CuO* nanocomposite, two solutions were prepared:

- *SnO_2 Molar Solution:* 7.299 grams of SnO_2 were dissolved in 100 ml [8] of distilled water to obtain a 0.05 M solution.
- *$CuSO_4$ Molar Solution:* 7.189 grams of $CuSO_4 \cdot 7H_2O$ were dissolved in 100 ml of distilled water to obtain a 0.05 M solution.

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Step 2: Synthesis of SnO_2–ZnO Nanocomposite

The synthesis of the SnO_2–ZnO nanocomposite involved the following steps:

- *Sonication:* 100 mg of SnO_2 were added to 100 ml of the 0.05 M $CuSO_4$ solution, and the mixture was sonicated for 5 minutes.
- *Addition of NaOH:* 125 ml of 0.125 M NaOH solution were added dropwise to the sonicated mixture under magnetic stirring for 3 hours.
- *Precipitation:* The resulting precipitate was allowed to settle at room temperature for 12 hours.

Step 3: Post-Synthesis Treatment

The precipitate was subjected to the following post-synthesis treatments:

- *Filtration:* The precipitate was filtered using a Buchner funnel.
- *Washing:* The filtered precipitate was washed repeatedly with double-distilled water and ethanol to remove impurities.
- *Drying:* The washed precipitate was dried carefully in a hot air oven at 80°C for 4 hours.

Step 4: Obtaining the SnO–CuO Nanocomposite

The resulting dried powder was the *SnO–CuO* nanocomposite, which was obtained through the successful synthesis and post-synthesis treatments.

Fabric Treatments

Cotton fabrics were used as received. The mass per unit surface was 146 g/m^2 for cotton. The fabrics samples were conditioned at constant relative humidity (33%) and temperature (20°C). The fabric samples of size (10 cm × 10 cm) were soaked in a 2-propanol solution of CuO, SnO and composite of CuO and SnO [9] with a constant magnetic stirring for 10 min. After 10 minutes, the sample was squeezed and dried in an oven at 130°C for 15 min. The nanoparticles adhesion properties were evaluated as per the standard method (WGA1420TIN) [10]. The soaked sample was tested after washing using SEM micrographs [6].

SEM (Scanning Electron Microscopy)

A Scanning Electron Microscope is a scientific instrument that bridges the gap between the magnification capabilities of light microscopy and the higher resolving power of the transmission electron microscope. Food and its ingredients have been examined by scanning electron microscopy (SEM) ever since the first instrument was available [8].

RESULT AND DISCUSSION

The surface morphology and elemental composition of the soaked fabric samples has been investigated by using SEM micrographs [7]. The surfaces morphology of synthesized SnO/CuO nano materials and mixed nano composite materials SnO–CuO was studied by using Field Emission Gun Scanning Electron Microscope (FEGSEM) with EDS and WDS (JEOL Japan Model: JSM7600 F. The Jeol field emission scanning electron microscope is a versatile high resolution scanning electron microscope [9]. The application and surface morphology of mixed Cuo–SnO composite nano materials on the cotton fabrics were studied with the help of SEM micro graphs. The findings clearly demonstrate that synthesis conditions play a crucial role in determining the shape and size of nanoparticles produced through various methods. Specifically, when the reaction temperature is increased – from 90°C using water as a medium to 150°C using 1,2-ethanediol – a noticeable reduction in both the size of the nanoparticles and their degree of agglomeration is observed. This reduction in particle size and clustering behavior suggests that higher temperatures, particularly in the presence of organic solvents, like 1,2-ethanediol, promote more uniform and finely dispersed nanoparticles. Such control over particle morphology is essential for tailoring the physical and chemical properties of nanomaterials for specific applications, including drug delivery, catalysis, and textile finishing [10].

$$N=\frac{4}{3}\pi R^3 N_{A\frac{\rho}{M}}$$

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where N_A, R, ρ, and M are the Avogadro number, the radius of the nanoparticles, the density (5.47 10^6 g/m^3) and the molecular weight (81.408 g mol$^{-1)}$ of copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles, respectively.

SEM images (Figures 1 and 2) confirm that the large agglomerates are removed from the textile surface after washing. Instead, although the nanoparticles are not covalently grafted to the fabric materials. Preliminary gravimetric essays show more than 50% of their initial amount remains bound to the fibers surface after washing [11].

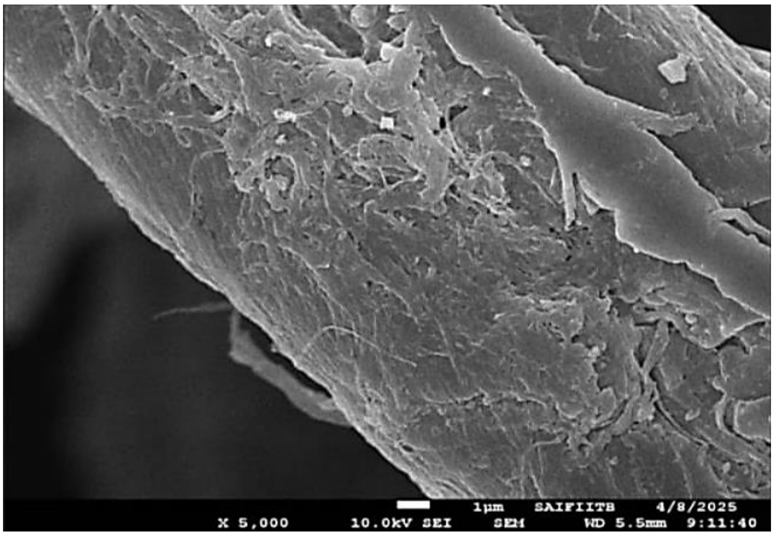

Figure 1. SEM images of composite copper and tin oxide nanoparticle on cotton after washing using water synthesis.

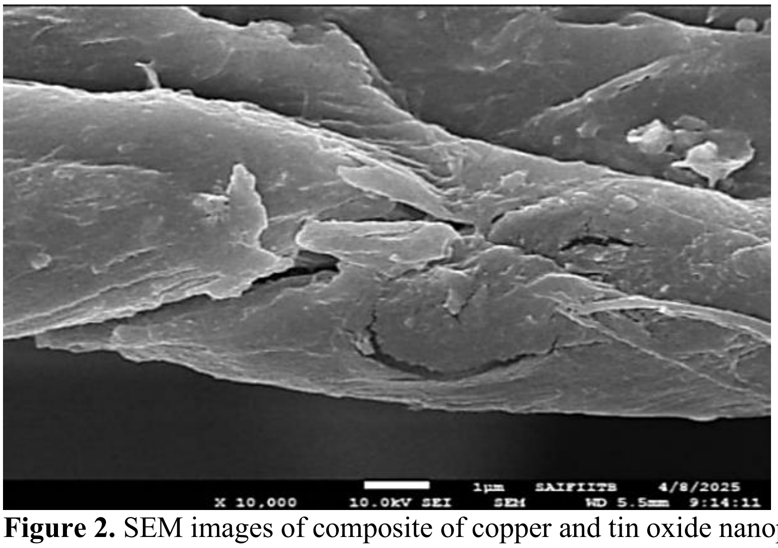

Figure 2. SEM images of composite of copper and tin oxide nanoparticle on cotton after washing with using 1,2-ethaanediol.

CONCLUSIONS

We report the synthesis of copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles through a homogenous phase reaction starting from copper chloride and sodium hydroxide at high temperature, in water or in 1,2-ethane diol. The reaction in 1,2-ethanediol at 150°C results in the formation of smaller nanoparticles with respect to the reaction carried out in water at 90°C. In both cases, the nanoparticles appear to be nearly spherical and with a quite narrow size range. Nanoparticles were analyzed through electron microscopy. The homogeneous phase reaction processes

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offer a valid alternative for industrial-scale production of copper oxide, tin oxide, and composite of copper and tin oxide nanoparticles for many applications.

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