Effect of Cu_3N and Cu on the photocatalytic activity of Cu_2O nanoparticles

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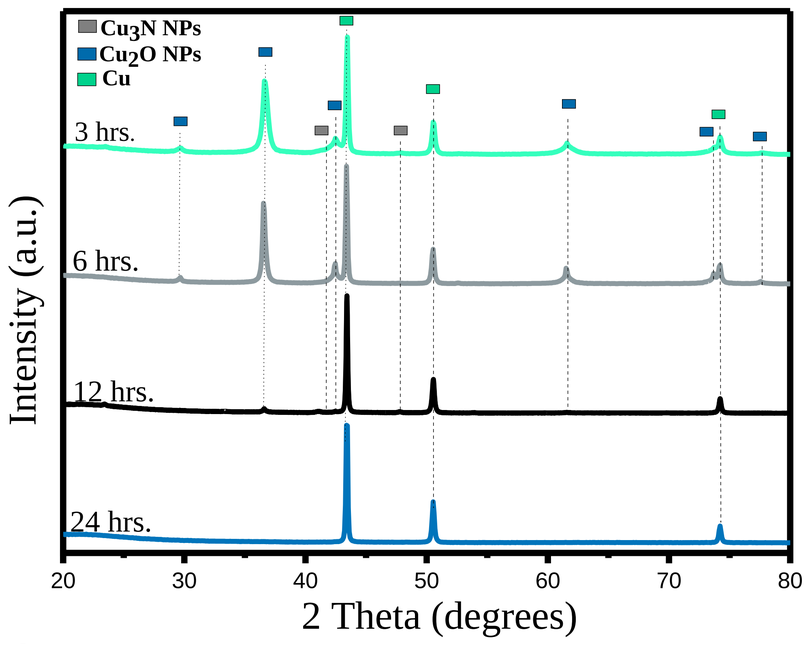
Introduction

In recent years, green photocatalysis has been widely used in environmental remediation using sunlight as an excitation source. Semiconductor-based photocatalysts have attracted much attention in the field because of their low cost and availability. In this work, we synthesized cupric oxide (Cu_2O), copper nitride (Cu_3N) and copper (Cu) nanoparticles using a non-aqueous sol-gel route. We controlled the phase ratios by adjusting the reaction time, and demonstrate that these nanoparticles are efficient catalysts under visible solar radiation.

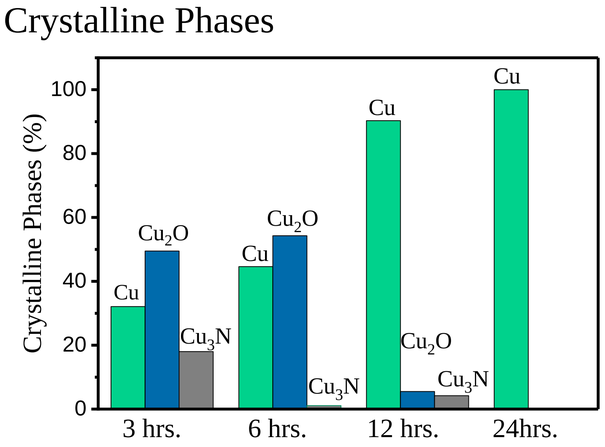
Nanoparticles Synthesis

Cu, Cu_2O and Cu_3N nanoparticles were synthesized using non-aqueous sol-gel methods in a glovebox under controlled N_2 conditions and then transferred into an autoclave. Then the solution was placed in an autoclave and put in an oven at 280°C. The reaction time from 3 to 24 hours in order to optimize the synthesis.

X-ray diffraction (XRD)



Crystalline Phases

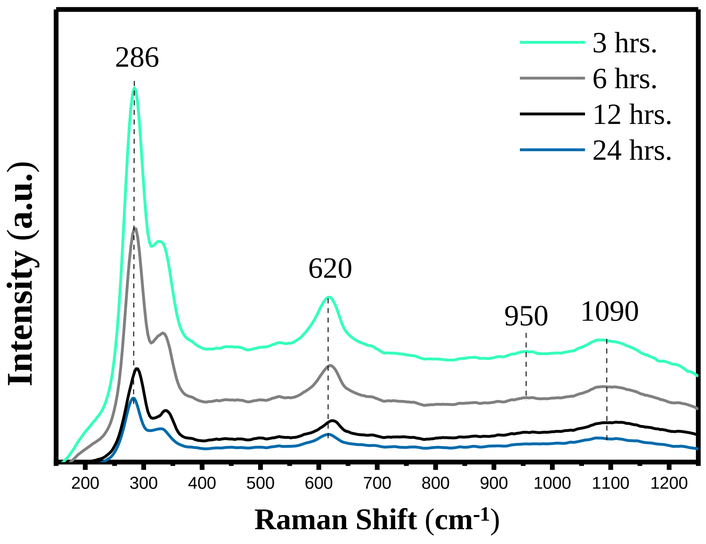


Particle size

Samples	Cu	Cu_2O	Cu_3N
3 hrs.	50	14.8	2.8
6 hrs.	51.7	26.7	27
12 hrs.	54	30	29
24 hrs.	71	-	-

The XRD patterns show the presence of all 3 phases. The quantity of each phase is provided in the table along with the average size of the nanoparticles obtains from Rietveld refinement.

Raman Spectroscopy

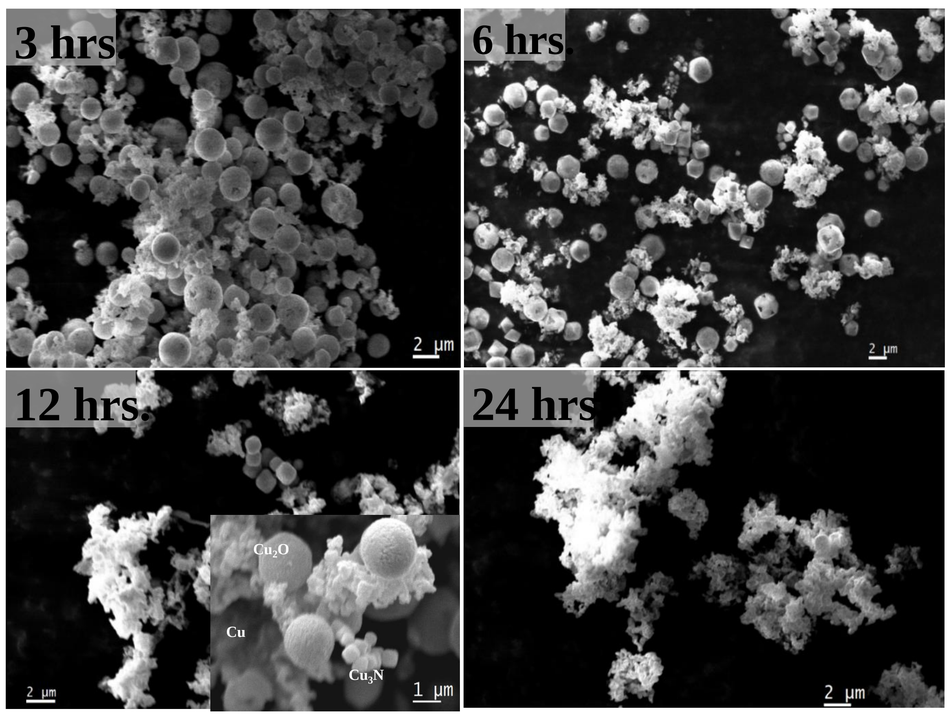


Raman spectra of prepared nanoparticles revel the characteristics vibrational modes of Cu, Cu_2O and Cu_3N phases. The peak around 620 cm^{-1} corresponds to the characteristic vibrations modes of the chemical bonds of Cu-N and Cu-O.

Conclusion

Successful catalytic activity was obtained from the nanoparticles. The samples with 18 % of Cu_3N shows the best catalytic performance with a dye degradation rate of 95% after 4 hours.

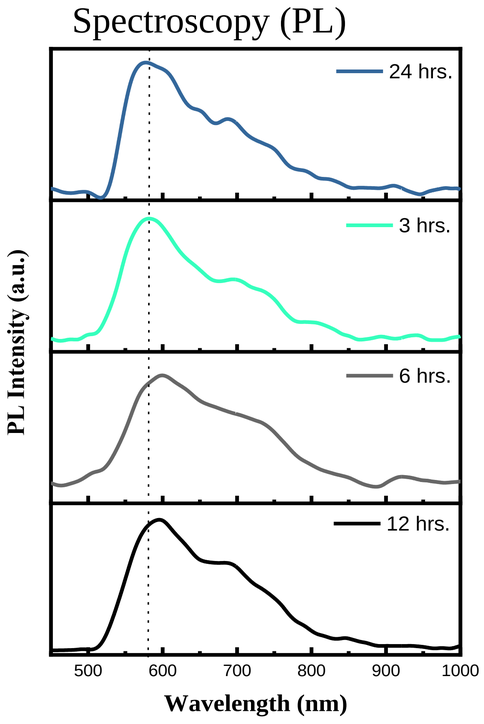
Scanning Electron Microscopy (SEM)



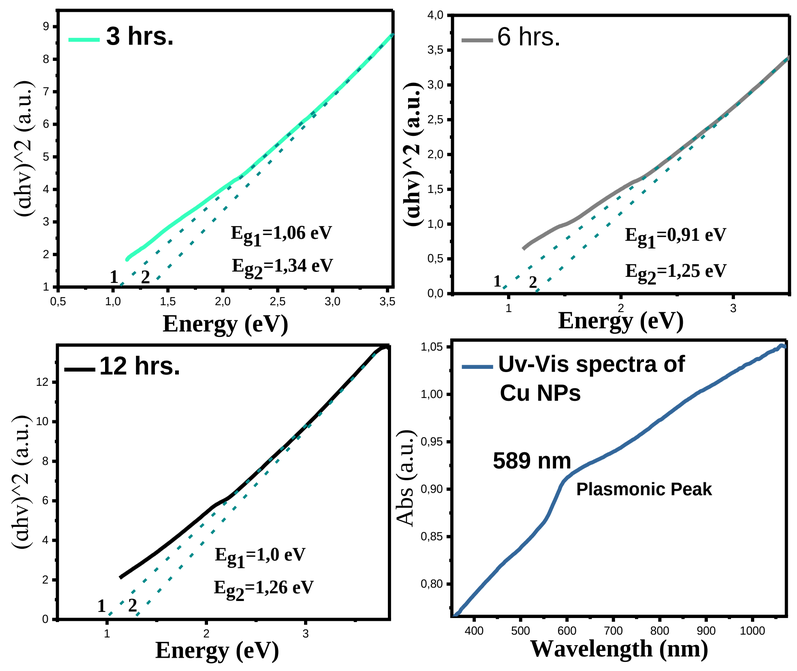
The SEM micrographs reveal the morphology of the various nanoparticle phases. Spherical, cubic and powder features corresponding to Cu_2O, Cu_3N and Cu respectively, were found.

Optical Properties

Photoluminescence Spectroscopy (PL)



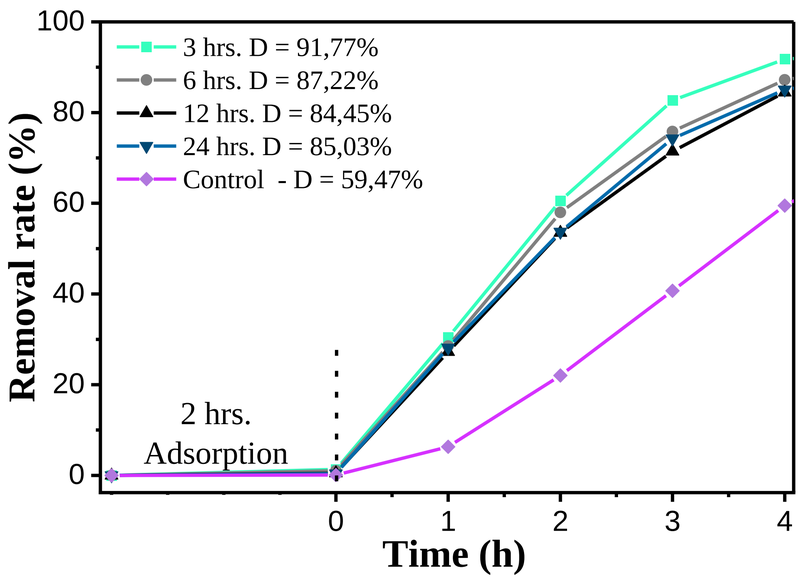
Band Gap Calculations



The emission spectra are dominated by Cu plasmonic nanoparticles. However, emission peaks of Cu_2O at 750 nm are visible. Cu_3N emission is in the infrared and therefore not visible in Room Temperature PL spectra.

Band gaps were calculated from UV-Vis spectra using the Tauc plots. For the mixed phase samples 2 band gaps were obtained. The narrow band gaps correspond to the metallic nature of Cu_3N due to the presence of Cu.

Photocatalysis Experiments



Photocatalytic experiments were performed to degrade 50 ml containing 5 ppm of methylene blue using 5 mg of the synthesized nanoparticles. The study shows that all the nanoparticles have photocatalytic properties. However, the sample synthesized in 3h containing 18% Cu_3N showed the best performance.

Acknowledgments

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