Au/ZnO nanocomposites obtained at different Au precursor concentration for highly efficient photo-degradation of methylene blue under UV light

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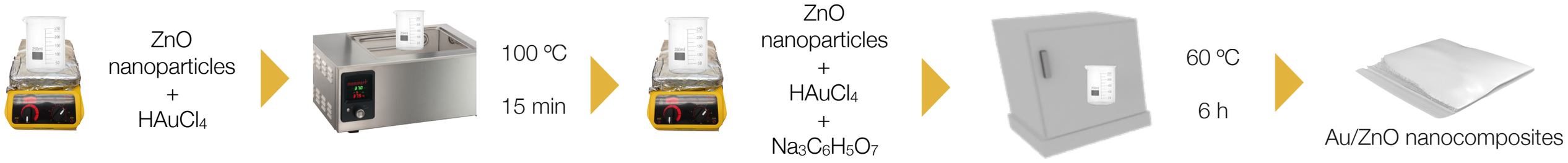
Abstract

Au/ZnO nanocomposites were successfully synthesized by a facile and low cost methods. ZnO nanoparticles and Au/ZnO samples growth at different Au precursor ($HAuCl_4$) concentrations were obtained by hydrothermal synthesis and chemical reduction method, respectively. The influence of Au content in morphological and optical properties were analyzed by scanning electron microscopy (SEM) with energy dispersive X-ray (EDS) spectrometer, Raman and UV-Vis spectroscopy. Photocatalytic activity of ZnO nanoparticles and Au/ZnO nanocomposites were evaluated in the photo-degradation of methylene blue (MB) solution under UV irradiation. Compared with ZnO nanoparticles, Au/ZnO nanocomposites showed enhanced photocatalytic activity for degradation of MB under UV light irradiation, due to the charge transfer that occurs between ZnO and Au interface. The Au/ZnO sample with lowest $HAuCl_4$ concentration (0.5 mM) showed the best photocatalytic performance, reaching a MB degradation rate of 99.99 % within 60 min, which exhibits an enhancement of 60 % compared with ZnO nanoparticles.

Method



Results

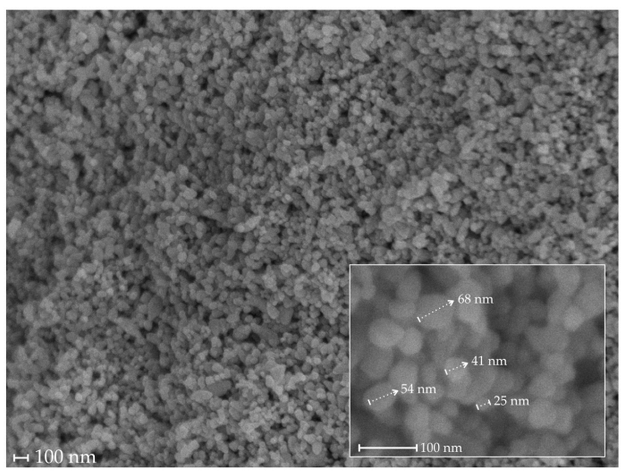


Fig 1. SEM image of ZnO nanoparticles. The inset image shows a high magnification

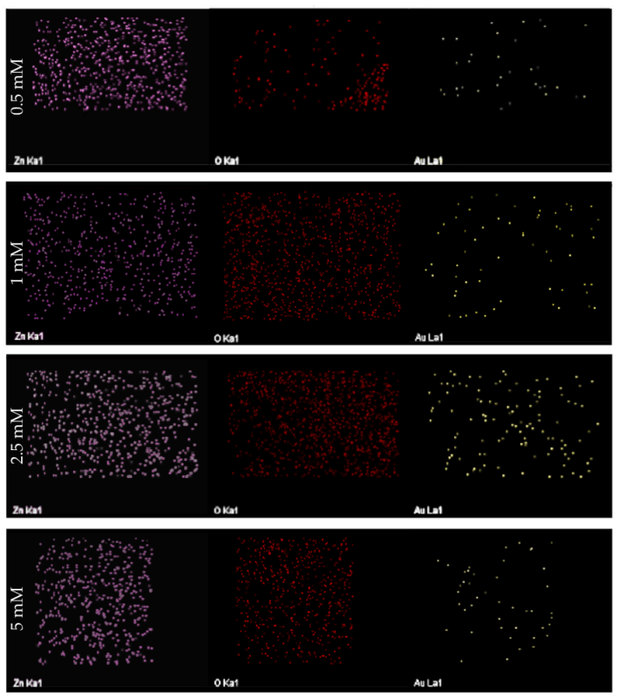


Fig 2. EDS elemental mapping images of Au/ZnO nanocomposites obtained at 0.5, 1, 2.5 and 5 mM of $HAuCl_4$.

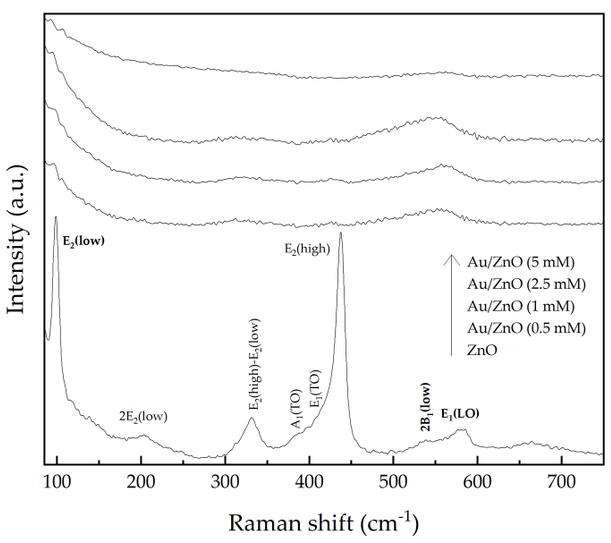


Fig 3. Raman spectra of ZnO nanoparticles and Au/ZnO nanocomposites.

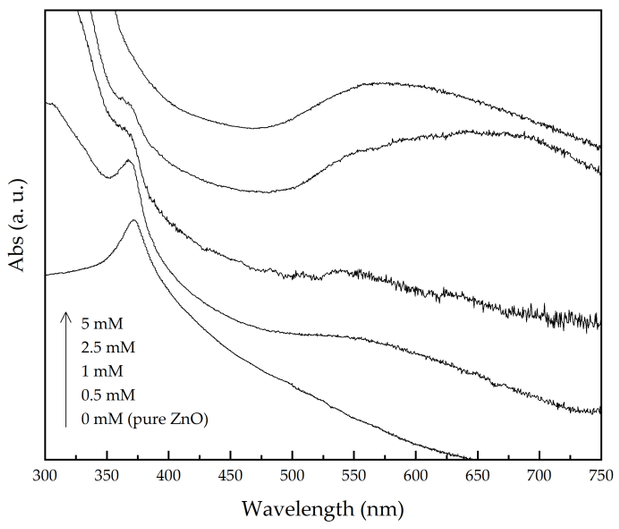


Fig 4. UV-Vis spectra of ZnO and Au/ZnO nanocomposites at different Au precursor concentration.

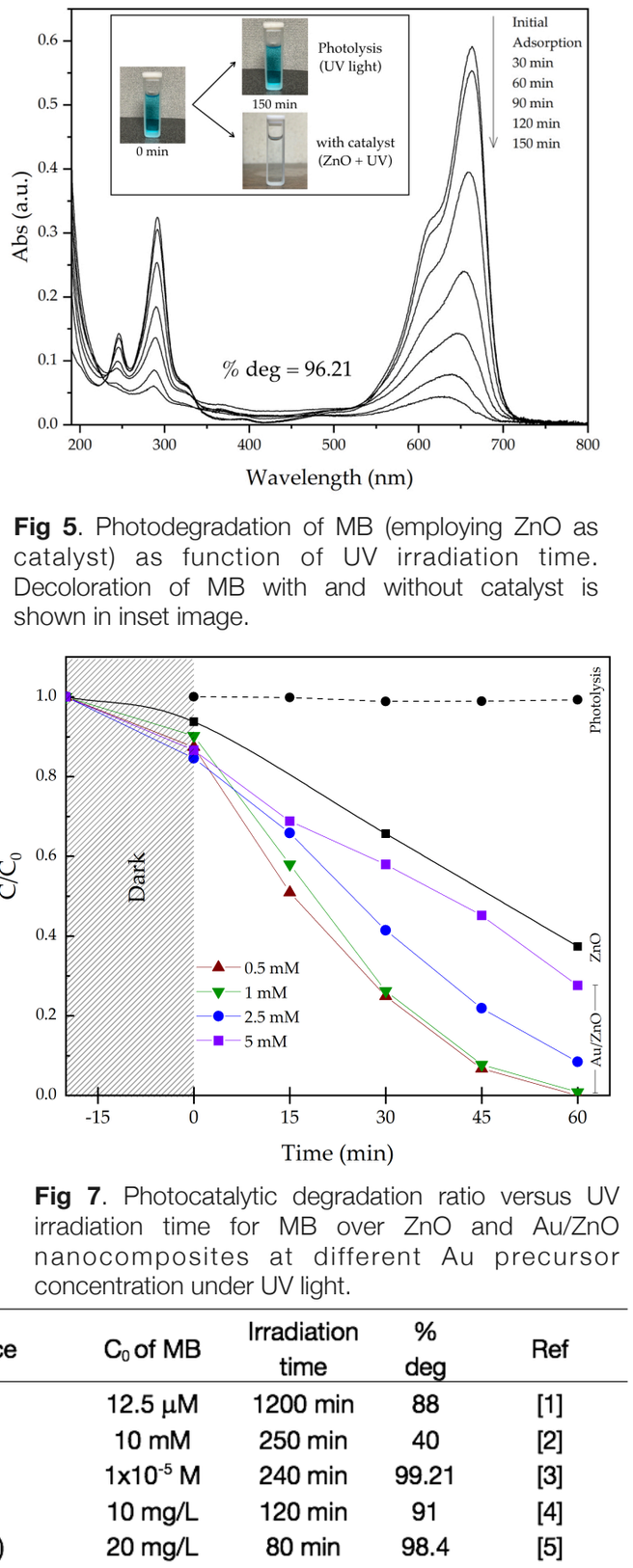


Fig 5. Photodegradation of MB (employing ZnO as catalyst) as function of UV irradiation time. Decoloration of MB with and without catalyst is shown in inset image.

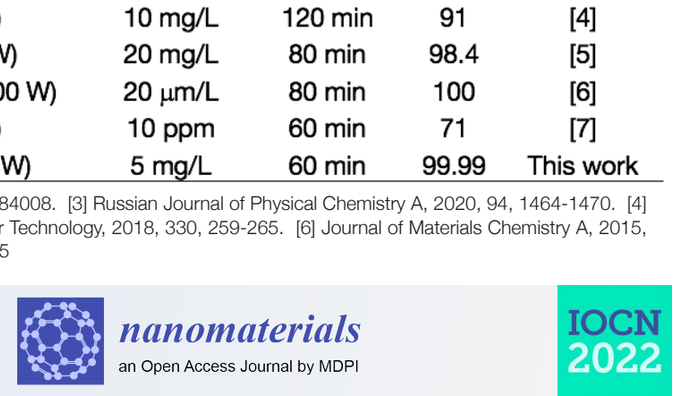


Fig 7. Photocatalytic degradation ratio versus UV irradiation time for MB over ZnO and Au/ZnO nanocomposites at different Au precursor concentration under UV light.

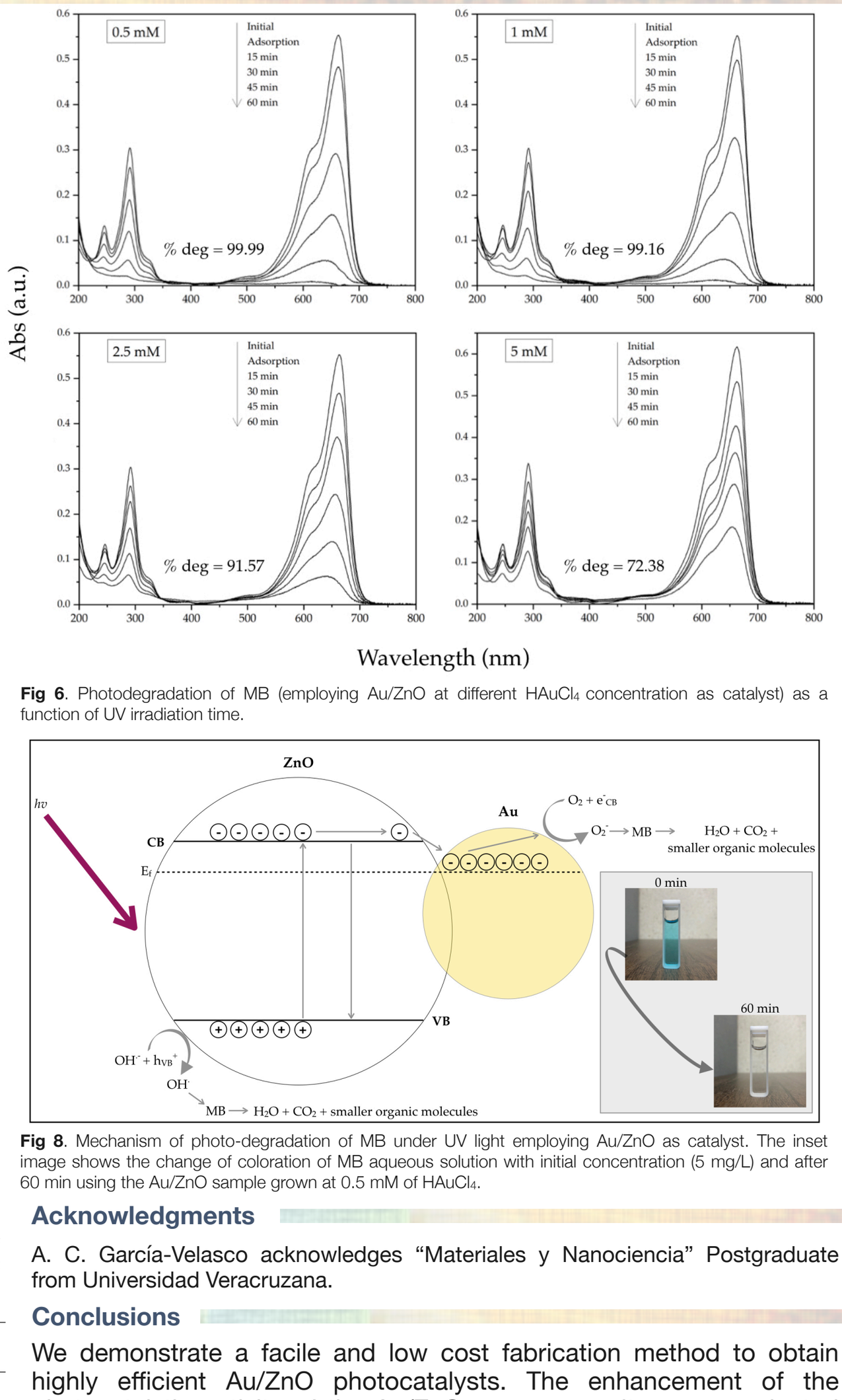


Fig 6. Photodegradation of MB (employing Au/ZnO at different $HAuCl_4$ concentration as catalyst) as a function of UV irradiation time.

Fig 8. Mechanism of photo-degradation of MB under UV light employing Au/ZnO as catalyst. The inset image shows the change of coloration of MB aqueous solution with initial concentration (5 mg/L) and after 60 min using the Au/ZnO sample grown at 0.5 mM of $HAuCl_4$.

Catalyst	Excitation source	C_0 of MB	Irradiation time	% deg	Ref
Au/ZnO nanostructures	UV (365 nm)	12.5 µM	1200 min	88	[1]
Au NPs/ZnO nanorods	UV (40 W)	10 mM	250 min	40	[2]
Au/ZnO nanocomposite	UV	1x10^{-5} M	240 min	99.21	[3]
Au/ZnO nanorods	UV (256 nm)	10 mg/L	120 min	91	[4]
Au NPs/ZnO microstructures	UV-Vis (125 W)	20 mg/L	80 min	98.4	[5]
Au-ZnO nanopyramids	UV (>295 nm, 300 W)	20 µm/L	80 min	100	[6]
Au-ZnO nanocomposites	UV (365 nm)	10 ppm	60 min	71	[7]
Au/ZnO nanocomposites	UV (254 nm, 8 W)	5 mg/L	60 min	99.99	This work

[1] Water, 2019, 11, 1787. [2] Materials Research Express, 2019, 6, 084008. [3] Russian Journal of Physical Chemistry A, 2020, 94, 1464-1470. [4] Chemistry - A European Journal, 2016, 22, 14950-14961. [5] Powder Technology, 2018, 330, 259-265. [6] Journal of Materials Chemistry A, 2015, 3, 15141-15147. [7] Catalysis Communications, 2009, 10, 1380-1385

Acknowledgments

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Conclusions

We demonstrate a facile and low cost fabrication method to obtain highly efficient Au/ZnO photocatalysts. The enhancement of the photocatalytic activity of the Au/ZnO nanocomposites was evaluated by modification of Au content onto ZnO surface through different $HAuCl_4$ molar concentrations (from 0.5 to 5 mM) employed in our methodology. Optical properties were clearly modified after Au deposition, obtaining enhanced light absorption at different wavelengths in the visible region and inhibit the UV absorption with increasing of Au precursor concentration. The MB reaches a degradation rate of 62.62 and from 72.38 to 99.99 % for 60 min under UV light employing ZnO nanoparticles and Au/ZnO nanocomposites, respectively, confirming that the sample with the lowest Au content onto ZnO possesses the best photocatalytic performance.

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