Synthesis and Characterization of SnO_2 Nano Photocatalyst with High Visible Light Activity

S.Haya[a],*, O. Brahmia[b], O. Halimi [a], M. Sebais[a], B. Boudine[a]

Abstract—SnO_2 nanoparticles were successfully synthesized using a sol-gel method deposited on a glass substrate, and then annealed in air at 500°C for 2hour .the prepared SnO_2 nanoparticles were characterized using XRD diffraction, UV-visible, Raman spectra, and scanning electron microscopy (SEM). The board XRD peak confirms the formation of nanocrystalline SnO_2 having a tetragonal crystal structure.SEM indicates the formation of the SnO_2nanostructure with the tetragonal shape. The photocatalytic activity of prepared SnO_2 was studied by observing the degradation of methylene blue under UV and solar irradiation. The photocatalytic activity of SnO_2 thin films is higher under sunlight than UV irradiation. This study shows that the thin films prepared have a tendency towards application in environmental remediation.

Keywords—SnO_2 nanoparticles, sol-gel, method, methylene blue, UV irradiation, Solar irradiation

I. INTRODUCTION

TO develop nano photocatalysts with high efficiency with a low energy cost ,to remove a wide range of organic pollutants, is one of the most important subjects in pollution control. All attention researchers now were focused on the fabrication of the nano photocatalysts such as TiO_2,In_2O_3,ZnO and SnO_2 with a good Photocatalytic performance and environmentally friendly.The tin oxide (SnO_2) with wide band gap (3.5 eV) at bulk state [1], tetragonal rutile structure [2] and excellent optical transparency, make it very attractive material for many kinds of applications photo -catalysis [3], gas sensors[4],solar cells. Using UV photocatalysis for the treatment of organic compounds seems costly and can be hazardous, solar photocatalysis could be preferable Sunlight is an abundantly available natural source of energy that can be exploited for irradiation of nano photocatalysis in the photodegradation of pollutants particularly in Algeria which receives a huge amount of solar energy during the whole of the year, so the use of solar photocatalysis is great important. In this study, the SnO_2 thin films synthesized by sol-method were used as nano photocatalysis to eliminate the degradation of methylene blue (MB) textile dye that contaminates the surface using photocatalysis under UV and solar light (SL), and compared the efficiency of UV and Solar photocatalysis regarding MB degradation.

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II. EXPERIMENTAL

A. Preparation of SnO2 thin films

SnO_2 thin films were deposited on microscope slide glass substrate by sol-gel method using a dip-coating technique. To obtain 0.5 M of the undoped SnO_2 solution 25mmol of the precursor tin (II) chloride dihydrate ($SnCl_2$, $2H_2O$, Merck) was first dissolved in 50 mL of absolute ethanol (C_2H_5OH, Merck). After stirring and heating at 70°C for 2 h, a clear and homogeneous solution was obtained. The deposited films were dried at 200°C for 15min and finally annealed at 500°C for 2 hours. The procedures from coating to drying were repeated ten times.

B. Photocatalysis procedure

Photocatalytic activities of the SnO_2 thin films were assessed by photocatalytic degradation of Methylene Blue (MB) dye (Aldrich) under UV light source (VL-215. LC, 15 W, the maximum emission is at 365 nm). The thin films were placed in a beaker containing 20 mL of 5 mg/L of MB aqueous solution. After several irradiation times, a 3 mL of the solution was withdrawn and the MB concentration was determined by UV-1800 SHIMADZU Spectrophotometer. The wavelength used to follow the photodegradation was 654 nm (MB maximum absorption wavelength). Photocatalytic degradation was calculated based on equation (1) [6].

$$\%\ \text{Degradation efficiency} = \left[\frac{C_0 - C_t}{C_0}\right] \times 100 \quad (1)$$

Where, C_0 is the initial concentration, and C_t the concentration at t time.

III. RESULTS AND DISCUSSION

A. Structural analysis

The structural properties of the thin films were investigated by XRD in the 2θ range of 20°-70°. From Figure 1, it appears that the films have a polycrystalline structure. All diffraction peaks correspond respectively to the planes (110), (101), (200)

and (211) of the rutile tetragonal structure of the tin oxide SnO_2 according to the (JCPDS Data Card no 41-1445).

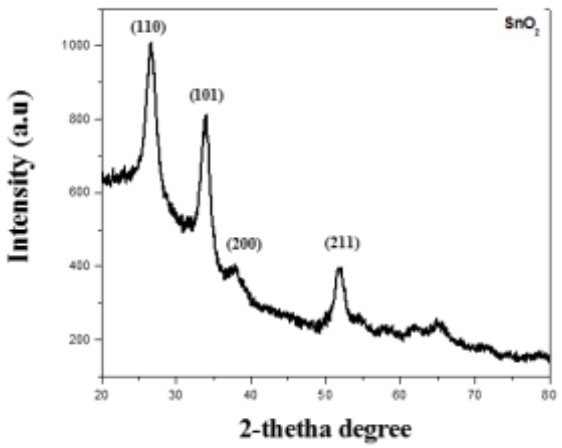

Fig..1 XRD partner of SnO_2 thin films annealing 500°C for 2hour

The properties of SnO_2 thin films was studied by analysing the crystallite sizes and lattice parameters (a, c) using this formula(1),(2)

$$D = \frac{0.9\lambda}{\beta_{hkl}\cos\theta} \quad Eq.(2)$$

$$\frac{1}{d^2} = \frac{h^2 + k^2}{a^2} + \frac{l^2}{c^2} \; Eq.(3)$$

Where D is the average crystallite size, K is the dimensionless shape, λ is the wavelength of X-ray radiation, θ is the diffraction angle and β_{hkl} is the broadening of the diffraction peak calculated at full-width at half maximum(FWHM).The founding values were estimated using the interplanar distance between the (110) planes.The results demonstrated that the lattice parameters calculated for the thin films are in good agreement with the standard values of the SnO_2 tetragonal structure; a=b= 4.738 Å and c= 3.187 Å (JCPDS Data Card no 41-1445).the crystallite size of the sample is 7.61nm prove thin films synthesized are in nanoscale .

B. Optical properties study

The UV-vis absorption spectra of the SnO_2 thin films are shown in Fig.3.The average optical transmittance value of the thin films is higher (90%) in the visible region. To calculate the direct band gap we used the Tauc relation:

$$\alpha h\upsilon = A\left(h\upsilon - E_g\right)^n \quad Eq.(4)$$

Where α is the absorption coefficient, A is a constant, n = 1/2 for direct band gap semiconductor. An extrapolation of the linear region of the plot $(\alpha h\upsilon)^2$ versus hυ gives the value of the optical band gap Eg shown in the insert of Fig. 3. The estimated band gap was found to be 3.86 eV for the SnO_2 sample which is higher than the reported value in the case of the bulk SnO2 (3.5 eV)REF. This can be attributed to the well-known quantum confinement phenomenon associated with the nanosized crystallites that form the synthesized samples [7].

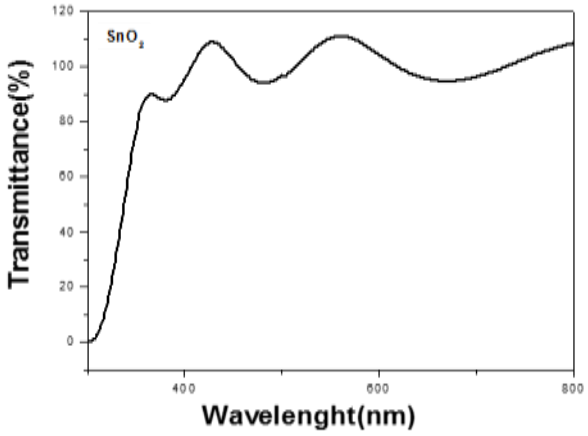

Fig. 3. Transmittance spectra of SnO_2 thin films

C. surface morphology

The SEM images of the surface morphology of SnO_2 thin film Figure 4show the formation of SnO_2 tetragonal which are separated by micro-cracks

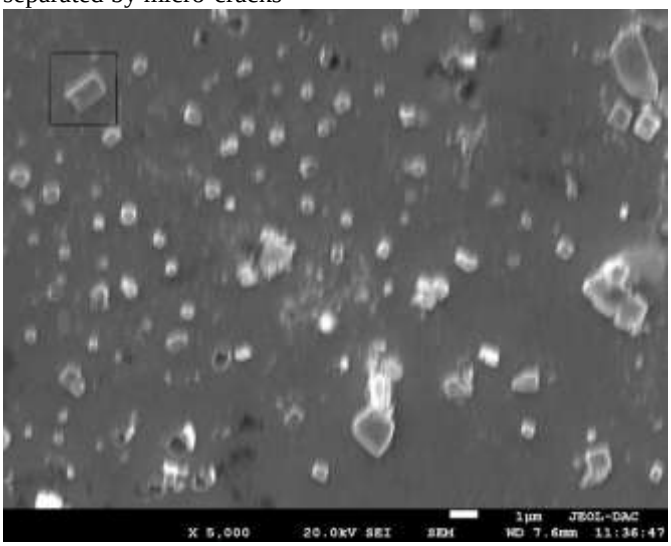

Fig. 4 SEM of SnO_2 thin films

D.MB Photocatalytic Degradation by SnO_2/UV and SnO_2/SL

As shown in figure5, the evolution of the concentration ratio C/C_0 of MB dye in the presence of SnO_2 thin films, where C_0 is the initial concentration and C the concentration at t time, versus irradiation time under UV and the Solar light was investigated. It clearly appears that MB disappearance was much faster under Solar light than UV light. Thus, the process SnO_2 / SL was highly effective than SnO_2/UV regarding MB degradation. It is also to note that MB total oxidation requires more time compared to nanoparticle powders. Efforts should be done to enhance its photocatalytic activity.

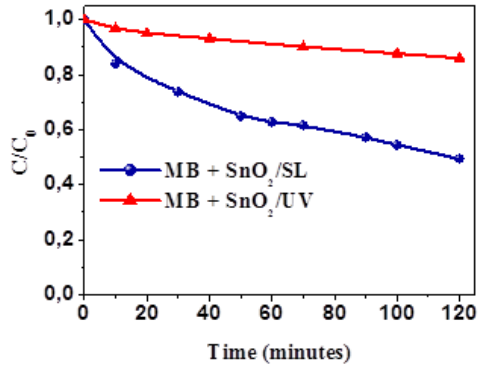

Fig. 5 Kinetics of MB (5 mg/L) photocatalytic degradation using SnO_2 thin films under UV and Solar light irradiation.

The calculated degradation efficiencies after 20 minutes and 120 minutes for both processes (Figure6) clearly indicated the efficiency of the solar photocatalysis.

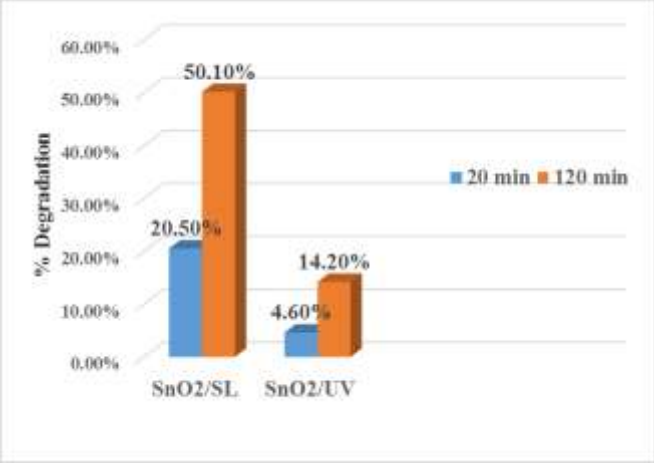

Fig. 6 Comparison between the two processes after 20 and 120 minutes of irradiation time

IV. Conclusion

In summary, the SnO_2 thin filmsnanoparticles can be the attractive candidates for photocatalytic textile wastewaters treatment Under the solar light.

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