

# Enhancement of visible light photocatalytic activity of MoO<sub>3</sub> with V<sub>2</sub>O<sub>5</sub> additive

T. Narasimha Murthy, P. Suresh and A.V. Prasada Rao

**Abstract**— Both MoO<sub>3</sub> and V<sub>2</sub>O<sub>5</sub> exhibit considerable absorption in the visible region as seen from their UV-visible diffuse reflectance spectra. In view of higher absorption of V<sub>2</sub>O<sub>5</sub> compared to MoO<sub>3</sub>, the present study is taken up to see whether addition of V<sub>2</sub>O<sub>5</sub> will improve the visible light photocatalytic activity of MoO<sub>3</sub>. 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub> showed the highest efficiency and degraded Methyl orange, Rhodamine-B and Eosin Y completely in 30, 160 and 40 mins respectively, while Methylene blue is only partially degraded..

**Index Terms**— MoO<sub>3</sub>, V<sub>2</sub>O<sub>5</sub>, Rhodamine-B, Methylene blue, Methyl orange, Eosin-Y, Photocatalysis

## I. INTRODUCTION

Semiconductor mediated photocatalytic oxidation of organic pollutants has attracted worldwide scientific research because of the ease of performance of reaction at ambient conditions exploiting the inexhaustible solar radiation that provides a cost effective clean technology. Among the binary metal oxide semiconductors, TiO<sub>2</sub> is proved to be the most suitable photocatalyst for non-selective mineralization of several mutagenic/carcinogenic hazardous organic pollutants present in industrial waste water effluents. TiO<sub>2</sub> is useful because it is inexpensive, photo stable, non-toxic, chemically inert and easy to synthesize.

However, major drawback of TiO<sub>2</sub> is its relatively small absorption in the visible region due to its wide band gap of 3.2eV requiring U.V radiation of < 380nm for excitation. Since U.V. radiation is < 5% of solar radiation, intensive research efforts were focused to render TiO<sub>2</sub> into a visible light active photocatalyst either through suitable doping, or addition of a sensitizer or by forming a nano/meso composite [1]. Alternately, photocatalysts from other binary metal oxides ZrO<sub>2</sub> [2], MnO<sub>2</sub> [3], NiO [4], Fe<sub>2</sub>O<sub>3</sub> [5], ZnO [6], CO<sub>3</sub>O<sub>4</sub> [7], WO<sub>3</sub> [8], SnO<sub>2</sub> [9], CdO [10], Bi<sub>2</sub>O<sub>3</sub> [11], CeO<sub>2</sub> [12], La<sub>2</sub>O<sub>3</sub> [13] as well as mixed metal ternary oxides such as ZnWO<sub>4</sub> [14], BiVO<sub>4</sub> [15], Bi<sub>2</sub>MoO<sub>6</sub> [16], Bi<sub>2</sub>WO<sub>6</sub> [17], Bi<sub>2</sub>Mo<sub>3</sub>O<sub>12</sub> [18], Fe<sub>2</sub>Mo<sub>3</sub>O<sub>12</sub> [19] etc with band gap suitable for absorption in the visible region of solar radiation are also being explored. Recently, the authors reported a comparative study of visible light photocatalytic activities of MoO<sub>3</sub>, Cu<sub>2</sub>O and V<sub>2</sub>O<sub>5</sub> against Degusa P25 [20]. The study revealed that photocatalytic activities of the above catalysts varied in the order TiO<sub>2</sub><MoO<sub>3</sub><Cu<sub>2</sub>O<V<sub>2</sub>O<sub>5</sub> for the degradation of

Rhodamine-B, Methylene blue, Methyl orange and Eosin Y. The present study is taken up to explore whether addition of V<sub>2</sub>O<sub>5</sub> because of its lesser band gap compared to MoO<sub>3</sub> will enhance the efficiency of MoO<sub>3</sub> towards photocatalytic degradation of Rhodamine-B (Rh-B), Methylene blue (MB), Methyl orange (MO) and Eosin-Y (EY).

## II. MATERIALS AND METHODS

Samples of A.R grade MoO<sub>3</sub>, V<sub>2</sub>O<sub>5</sub>, Cu<sub>2</sub>O and TiO<sub>2</sub> (Degusa P-25) as purchased are used in the photocatalytic studies.

### A. Characterisation Techniques

Phase purity of MoO<sub>3</sub> was investigated with X-ray diffractometer (PANalytical- X' Pert PRO, Japan) at room temperature, using Nickel filtered Cu-K<sub>α</sub> radiation ( $\lambda=1.54059 \text{ \AA}$ ), with a scan rate of 2° min<sup>-1</sup>. UV-visible diffuse reflectance spectrum (UVDRS) of the sample was obtained with dry pressed disk samples using Shimadzu UV-visible spectrophotometer (UV-3600) between 200 to 800 nm range. Spectral grade BaSO<sub>4</sub> was taken as reference in the UV-DRS.

### B. Photocatalytic Studies

100 mg of catalyst powder was added into 100 ml Rh-B aqueous solution (5 mg/L). The suspension was magnetically stirred for 30 minutes in dark. The suspension was then exposed to 400 watts metal halide lamp; 5ml aliquots were pipetted at periodic time intervals and filtered through 0.45 micron Millipore filters to remove the suspended powder. Progress of decoloration was followed by recording the corresponding absorption spectra. The same procedure has been adopted for (10mg/L) MB, MO, Rh-B and EY dyes. All the experiments were conducted under ambient conditions. Extent of degradation of dye is calculated by using the expression.

$$\% \text{ degradation} = (A_0 - A_t) / A_0 \times 100$$

where A<sub>0</sub> and A<sub>t</sub> are respectively initial absorbance and absorbance at time 't'

## III. RESULTS AND DISCUSSION

MoO<sub>3</sub> is known to exist in three polymorphic forms-namely  $\alpha$  (orthorhombic),  $\beta$  (monoclinic) and h (hexagonal). The sample used in the present study is orthorhombic as identified from its XRD pattern shown in Fig. 1.

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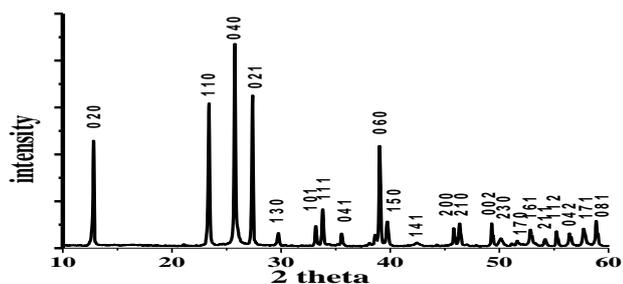


Fig 1. XRD pattern of MoO<sub>3</sub> sample used.

Temporal variations of spectral contours for methyl orange aqueous solution + MoO<sub>3</sub> as a function of irradiation time in presence and in absence of H<sub>2</sub>O<sub>2</sub> are depicted in Fig 2.

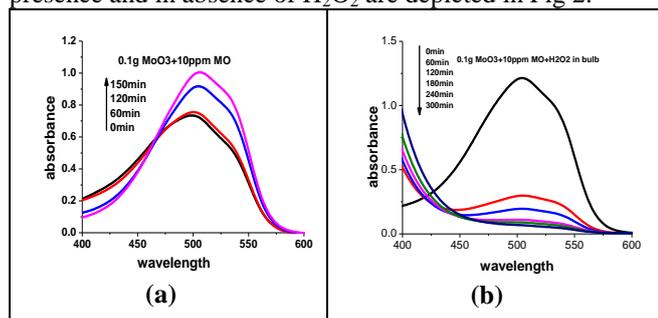


Fig. 2. Temporal variation of spectral contours of aqueous solution of MO+MoO<sub>3</sub> as a function of irradiation time (a) in the absence and (b) in the presence of H<sub>2</sub>O<sub>2</sub>

From the figure it can be seen that in the absence of H<sub>2</sub>O<sub>2</sub>, the decrease in absorption intensity is very less indicating no significant dye degradation for exposure up to 150 minutes. However, in presence of H<sub>2</sub>O<sub>2</sub>, there is 98 % decrease in intensity for 180 min of exposure. In photocatalytic process, presence of external oxidant H<sub>2</sub>O<sub>2</sub> has been found to be beneficial in several photocatalytic studies over TiO<sub>2</sub> [21], Bi<sub>2</sub>Mo<sub>3</sub>O<sub>12</sub> [22] and Fe<sub>2</sub>Mo<sub>3</sub>O<sub>12</sub> [19]. H<sub>2</sub>O<sub>2</sub> increases the electron-hole recombination time by accepting the conduction band electrons in the catalyst to form ·OH radicals which act as powerful oxidants and attack dye molecular frame work and disintegrate it. This provides an additional way for degradation process besides the dye degradation due to e<sup>-</sup> directly. The enhanced activity due to H<sub>2</sub>O<sub>2</sub> is attributed to the following reactions.

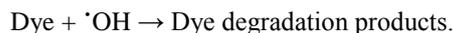
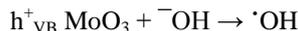


Fig. 3 shows temporal variation of spectral contours for MO aqueous solution with 5, 10, 20 and 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub>. From the figure, it can be seen that complete decoloration in these cases occurred for 180, 100, 90 and 30 min respectively.

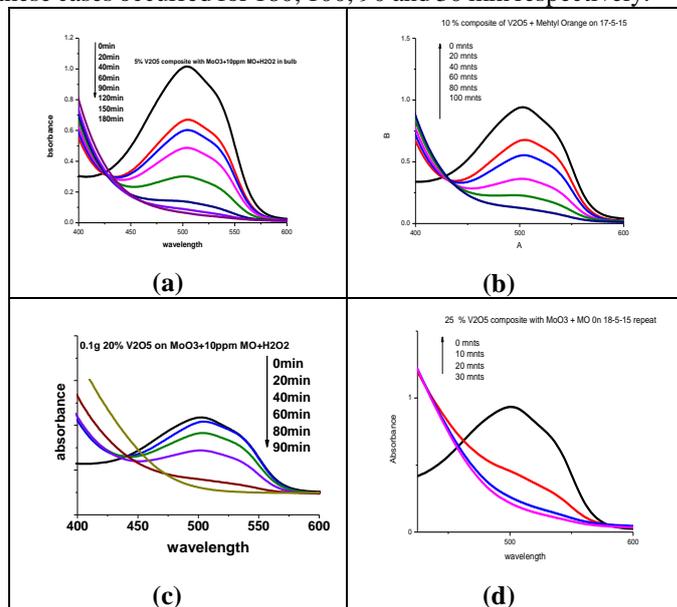


Fig. 3. Temporal variation of spectral contours for MO aqueous solution with (a) 5wt% (b) 10wt% (c) 20wt% and (d) 25wt% V<sub>2</sub>O<sub>5</sub> as a function of irradiation time

The observed decrease in lowering of degradation time could be understood in terms of the UV-visible diffuse reflectance spectra of V<sub>2</sub>O<sub>5</sub>, MoO<sub>3</sub> and 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub> shown in Fig. 4. Since V<sub>2</sub>O<sub>5</sub> shows higher absorption compared to MoO<sub>3</sub> in the visible region up to ~550 nm, the observed increase in catalytic efficiency for 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub> is attributed to the additive.

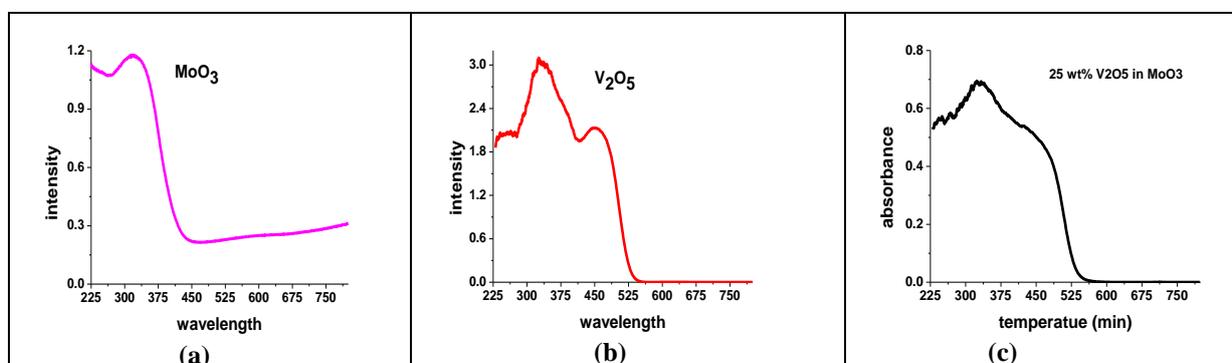


Figure 4. UV-visible diffuse reflectance spectra of (a) MoO<sub>3</sub>, (b) V<sub>2</sub>O<sub>5</sub> and (c) 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub>

Fig 5 shows UV-visible absorption spectra at different times for Rh-B, MB and EY with H<sub>2</sub>O<sub>2</sub> over MoO<sub>3</sub> containing 25wt% V<sub>2</sub>O<sub>5</sub> under progressive irradiation.

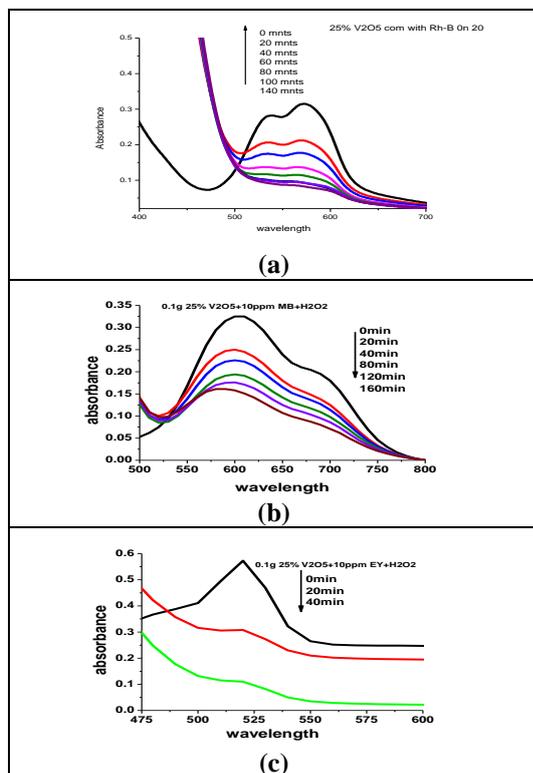


Fig. 5.Variation of spectral intensities as a function of irradiation time for (a) Rh-B, (b) MB and (c) EY.

From the figure it is apparent that 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub> is very effective in decolorizing Rh-B and EY for 140 and 40 min of irradiation while MB is degraded only to an extent of 51.3% for 160 min of irradiation. The obtained experimental data suggests that the photocatalytic efficiency of MoO<sub>3</sub> can be enhanced by mixing of V<sub>2</sub>O<sub>5</sub> to an extent of 25 wt%.

#### IV. CONCLUSIONS

Samples of 5, 10, 20 and 25 wt% of V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub> were evaluated for photocatalytic degradation of Methyl orange in presence of H<sub>2</sub>O<sub>2</sub>. The degradation times for complete decolorisation gradually decreased from 180 to 30min with 5 wt% to 25 wt% respectively. 25 wt% V<sub>2</sub>O<sub>5</sub> in MoO<sub>3</sub> has been successful in effecting ~ 100% photocatalytic degradation of Methyl orange, Rhodamine-B, Eosin-Y and partial degradation in Methylene blue.

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