# Photocatalytic degradation of methyl orange using commercial $TiO_2$ photocatalyst-loaded alginate capsules under ultraviolet light irradiation

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**Abstract:** Encapsulating commercial $TiO_2$ photocatalyst (P25) powder in an alginate shell was conducted, and the prepared capsules were used for the photocatalytic degradation of methyl orange under ultraviolet light irradiation. It was confirmed from the microscopic images of the capsules that P25 powder was encapsulated. The photocatalytic activity of P25-loaded capsules was affected by the P25 loading amount and the number of capsules charged in methyl orange solution. In the present study, the optimum loading amount and number of capsules were found to be 3.89 wt.% and 100 capsules, respectively.

**Keywords:** Photocatalyst-loaded capsule, Methyl orange, Photocatalytic degradation

## 1. Introduction

Photocatalysis is environmental friendly degradation method for organic pollutants since it does not generate any harmful substances during the photocatalytic degradation[1]. A typical photocatalyst is titanium dioxide ($TiO_2$), which exhibits a high activity in the photocatalytic degradation of organic substances under ultraviolet light irradiation[2]. However, a difficulty for the recovery of the photocatalyst powder suspended in the polluted water hinders the practical application of the photocatalytic degradation process[3].

To solve this problem, three methods have been proposed to facilitate recovery of the photocatalyst. First one is to prepare magnetic separable $TiO_2/SiO_2/Fe_3O_4$ (TSF) photocatalyst composite[4]. Although our research group prepared TSF composite material and applied it for the photocatalytic degradation of methyl orange, it was found that the photocatalytic activity is not comparable to commercial $TiO_2$ catalyst under any reaction condition. Second one is to coat the photocatalyst on a propeller or a stirrer; however, sufficient activity could not be obtained because the surface area of the photocatalyst was lost. Third one is to prepare an alginate capsule loaded with photocatalyst powders. The powder could not transfer out of the capsule, while water and organic substance could pass through the capsule shell when the photocatalyst powder was encapsulated. Therefore, this capsule system makes the recovery of photocatalyst powder easily, and could establish a novel photocatalytic microreactor if it showed sufficient photocatalytic activity.

In the present study, P25 powder was selected as a photocatalyst, P25-loaded alginate capsules were prepared, and the prepared capsules were used for the photocatalytic degradation of methyl orange which is a typical azo dye in polluted water.

## 2. Experimental

First, 15 wt.% polyvinylpyrrolidone (M.W.=55k) was dissolved in 0.1 M $CaCl_2$ aqueous solution, and the certain amount of P25 powder was suspended in this aqueous solution. This suspension was used as a core material. Encapsulation of P25 powder in alginate shell was conducted by dropping a core material into a sodium alginate aqueous solution using a syringe, and then stirred for 10 min. The capsules were collected and washed with distilled water several times. After washing, the capsules were added to 0.1 M $CaCl_2$ aqueous solution and stirred for 1 h to form thin capsule shell[5]. The capsules were again collected, washed

with distilled water several times, and dried at 303 K for 1 h. A digital camera connected to a microscope was used to obtain the microscopic images of the prepared capsules.

The photocatalytic degradation activity test of methyl orange (MO) was carried out in a dark room equipped with black light. 10 ppm MO aqueous solution was placed in a beaker and P25-loaded alginate capsule was added. The reaction solution was irradiated by ultraviolet light under stirring at 300 rpm in a dark room. During the degradation process, water jacket was used to prevent an increase of the reaction mixture temperature. Samples were taken out over time, and the absorbance of MO at 464 nm was measured by UV-vis spectrometer. The concentration of MO was calculated from the obtained absorbance and the photocatalytic activity was evaluated.

## 3. Results and discussion

Figure 1 shows the microscopic images of a P25-loaded alginate capsule. The capsule was white, which suggested that P25 powder was encapsulated. The outer diameter of the prepared capsules was estimated to be around 5 mm (Fig. 1(a)), and the alginate shell thickness was estimated as 100 μm (Fig. 1(b)). Furthermore, the permeation test results indicated that MO could pass through the alginate shell.

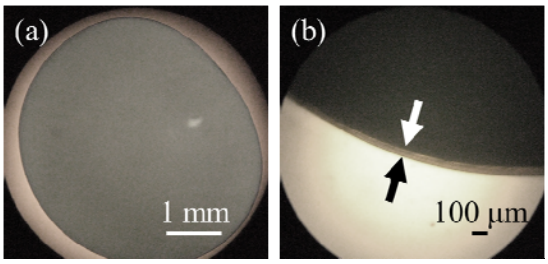


**Figure 1** Microscopic images of (a) the entire capsule and (b) the capsule shell.

Figure 2 shows the photocatalytic activity of P25-loaded alginate capsules for the degradation of methyl orange. The results indicated that the photocatalytic activity was increased from 2.63 wt.% to 3.89 wt.% of photocatalyst loading amount, and then declined with further increase in loading amount. This is because too much loading prevented the penetration of light inside the capsules and it was quite difficult to disperse powder inside the capsule. In contrast, when the number of capsules loaded with P25 powder of which concentration is 3.89 wt.% was increased from 50 to 100, the degradation rate was greatly increased. This is probably because of an increase in the reaction field for the photocatalytic degradation of methyl orange.

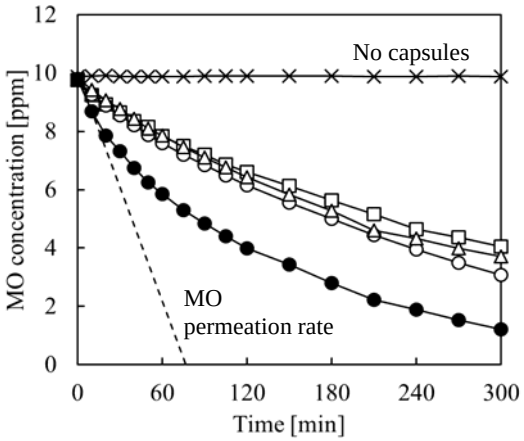


**Figure 2** Concentration profiles of MO during the photocatalytic degradation using P25-loaded alginate capsules: □ 2.63 wt.%, ○ 3.89 wt.%, △ 7.5 wt.%, ● double number of 3.89 wt.% loaded capsules.

## 4. Conclusion

P25 photocatalyst powder was successfully encapsulated in the alginate capsule. It was confirmed that the photocatalytic degradation of methyl orange using P25-loaded alginate capsules was possible. It was concluded from the obtained results that this novel capsule system could be used for the photocatalytic degradation of methyl orange under ultraviolet light irradiation.

## References

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