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Synthesis, characterizations, photocatalytic and sensing studies of ZnO nanocapsules

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ABSTRACT

ZnO nanocapsules have been synthesized hydrothermally. The structural and morophological properties were investigated using X-ray powder diffraction (XRD), field emission scanning electron microscopy (FESEM), FTIR, Raman, EDS and UV–vis absorption spectroscopy. For the first time chemical sensing properties of the synthesized ZnO nanocapsules have been investigated by *I–V* technique, where chloroform is used as a target compound. The chloroform sensors show good sensitivity (0.478 $\mu A\,cm^{-2}\,mM^{-1}$), lower detection limit (6.67 μM), and large linear dynamic range (LDR, 12.0 μM–12.0 mM) with good linearity (*R*, 0.8523) in short response time. Additionally, photocatalytic activity of the prepared capsule shaped ZnO photocatalyst was evaluated by the degradation of acridine orange. Prepared ZnO nanocapsules posses high photocatalytic activity when compared with TiO_2-UV100.

1. Introduction

Due to rapid urbanization and industrial development, environmental problem become a serious matter day by day. A large number of organic pollutants introduced into the environment as a result of human activities. The water present on the earth is contaminated through various sources such as industrial effluents, agricultural runoff and chemical spills [1]. These organic pollutants include several non-biodegradable, toxic organic substances like pesticides, herbicides, dyes, chloroform, etc. Of all these organic substances, dyes and chloroform pose a great threat to the environment. To sense and clean up these toxic chemicals from water has been a complex problem. To combat this critical environmental hazard, advanced methods are in demand for the effective treatment of polluted water. Physical methods, such as adsorption [2], biodegradation [3] and chemical techniques like chlorination and ozonation [4] are frequently used. Among these processes, biodegradation has received greatest attention but it is pertinent to mention that dye stuff is highly structured organic compounds and difficult to break down biologically [5–9]. Thus decolourisation of these dye effluents acquired increasing attention.

Photocatalytic process involving semiconductors (TiO_2 and ZnO) under UV light illumination has been shown to be potentially advantageous and useful in the treatment of waste water pollutant [10,11]. The mechanism constituting heterogeneous photocatalytic oxidation processes has been discussed extensively in literature [12,13]. Briefly on absorbing photon having energy greater than its band gap by a semiconductor led to the formation of electron/hole (e^-/h^+) pairs with free electrons produced in the empty conduction band (e_{CB}^-) leaving behind an electron vacancy or “hole” in the valence band (h_{VB}^+). Maintaining charge separation, the electron and hole may migrate to the catalyst surface where they participate in redox reactions with organic substrate. Generation of hydroxyl radical takes place when h^+_{VB} react with surface-bound H_2O or OH^-. Conduction band electron (e_{CB}^-) is picked up by oxygen to generate superoxide radical anion as indicated in the following Eqs. (1)–(3).

$$SC + h\upsilon \rightarrow e_{CB}^- + h_{VB}^+ \quad (1)$$

$$O_2 + e_{CB}^- \rightarrow O_2^{\bullet -} \quad (2)$$

$$H_2O + h_{VB}^+ \rightarrow OH^\bullet + H^+ \quad (3)$$

It has been suggested that the hydroxyl radicals ($OH^\bullet$) and superoxide radical anions ($O_2^{\bullet -}$) are the main oxidizing species in the photocatalytic oxidation processes.

It is well known that TiO_2 is universally accepted as the most active photo catalyst for the degradation of wide range of organic

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