Synthesis of Pt-graphene/TiO_2 nanocomposite with enhanced photocatalytic hydrogen production efficiency via water splitting

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Energy depletion and environmental pollution are now among the top concerns in every region of the world. Hydrogen has gradually become a research hotspot due to its several advantages, including high renewability, high energy conversion and high energy yield (122 kJ g^{-1}) without creating environmental pollution (Su et al., 2015).

Various semiconductor materials have been developed as photocatalysts for water splitting to generate hydrogen since the first report of water splitting system based on TiO_2 and Pt semiconductor electrodes under light irradiation in 1972 by Fujishima and Honda (1972). Among the variety of semiconductor materials, TiO_2 has been the most widely investigated as a photocatalyst for hydrogen production via water splitting because of its outstanding properties, including superior photocatalytic activity, chemical stability, non-toxicity, cost effectiveness, abundant availability and environmental friendliness (Hakamizadeh et al., 2014).

However, there are some factors which affect the efficiency of hydrogen production. One of these factors is the wide band gap of TiO_2 that results in only harvesting UV light which accounts for 4% of the solar spectrum. In addition, the high recombination rate of electron-hole pairs which may also lead to low hydrogen production efficiency (Chowdhury et al., 2015). To improve the activity of TiO_2 as photocatalyst for hydrogen production, considerable efforts have been exerted to develop different methods, such as the deposition of noble metals, doping with non-metallic elements and adding organic matters as sacrificial agents. All these methods can reduce the electron-hole recombination rate which is the immediate cause of low hydrogen production efficiency. The aim of this study is to investigate the activity of different synthesis methods of Pt-graphene/TiO_2 photocatalysts and influence parameters toward hydrogen production when exposed to UV-visible light.

In this study, the Pt-graphene/TiO_2 nanoparticles have been successfully prepared by Hummer's method, hydrothermal method and photodeposition of Pt on TiO_2 surface and characterized using XRD, UV-vis, TEM, FTIR and BET methods. As the results indicated, the TiO_2 nanoparticles (10-20 nm) were dispersed on graphene and Pt nanoparticles are uniformly deposited on the surface of partial TiO_2.

The hydrogen production under UV-visible light irradiation in aqueous solution with adding different alcohols including methanol, ethanol, n-propanol, ethylene glycol, glycerol has been studied. The operational parameters including graphene content, Pt content, catalyst concentration, sacrificial agents initial concentration, solution pH that affect photocatalytic hydrogen production efficiency were also investigated. The rate of hydrogen produced from the various Pt-Graphene/TiO_2 photocatalysts suspended in the 10 vol.% glycerol solution was found to be the highest using the 0.5 wt.% Pt-10 wt.% graphene/TiO_2 photocatalyst, and the average maximum hydrogen production rate was 4.872 mmol h^{-1} g^{-1} with a measured time of 6 h. The reaction rate depends strongly on the initial glycerol concentration in solution. The dependence of the reaction rate on glycerol can be described by saturation-type kinetics according to the Langmuir-Hinselwood model. It leads to the conclusion that glycerol favors a high rate of hydrogen production due to the number of hydroxyl groups (Nomikos et al., 2014).

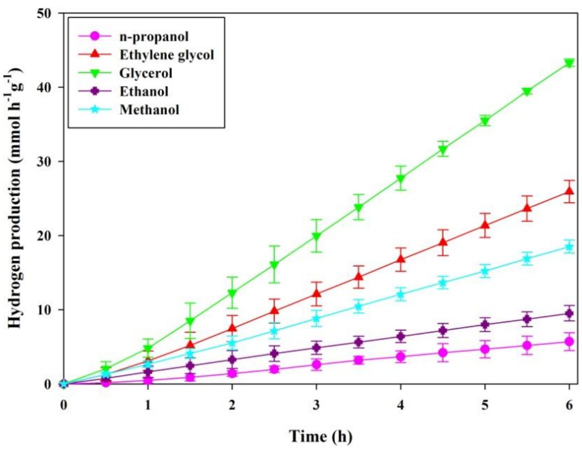

Figure 1. Comparison of the photocatalytic hydrogen production over Pt-GN/TiO_2 for different organic scavengers under UV-visible irradiation. Catalyst: 0.08 g; 10 vol.% aqueous solution (800 mL).

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