Properties of hydrogenated titanium dioxide thin films prepared by sparking method for photocatalytic application

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Abstract
Titanium dioxide (TiO₂) is a widely used photocatalyst in water splitting process for hydrogen production. In this study, hydrogenation of titanium dioxide thin films was investigated in order to examine the photocatalytic properties and to improve the performance for photocatalytic application. Titanium dioxide thin films were prepared by sparking method, then annealed at 500 °C in hydrogen atmosphere for 2 h to get hydrogenated titanium dioxide thin films (H:TiO₂). The result of scanning electron microscopy and atomic force microscopy show that the film was a very high porosity with high specific area for better photocatalytic activity. The structure of films were found to be a mixture of anatase and rutile phase. UV-Vis-NIR spectrometer measurement indicated that the absorbance from 300 to 700 nm of H:TiO₂ was more than that of TiO₂. Furthermore, energy gap of H:TiO₂ thin film was found to be lower than that of TiO₂.

Materials and Methods
The sparking apparatus equipped with 9 pairs of titanium tips were sparked in air at room temperature. The tips were placed horizontally at 1 mm spacing at 1 mm above the surface of quartz substrate. The power supply for a sparking voltage of 3 kV with limited current of 3 mA was connected to apparatus. TiO₂ thin film was prepared by sparking NPs of Ti on quartz substrate for 100 times with a substrate speed of 1.5 cm/min and then annealed in air at 500 °C. For hydrogenated titanium dioxide thin film, the hydrogen gas was generated by water electrolysis process (1 M KOH solution, voltage of 15 volt, stainless steel electrodes) and flowed into the quartz tube (diameter 3.81 cm, the length of 100 cm) which the sample (sparked 100 times ) was placed inside for 40 minutes after that heat to 500 °C for 2 h.

Results and Discussion

From the figure 2(a) found that the phase structure of TiO₂ and H:TiO₂ at 500 °C are anatase-rutile mixture phase. The result from figure 2(b) show that TiO₂ and H:TiO₂ are strong absorption in UV region and weak absorption in visible region. When compare between TiO₂ and H:TiO₂, found that H: TiO₂ exhibit stronger absorbance than TiO₂. The result confirm that hydrogenation on TiO₂ can enhance solar absorption. The direct energy gap were estimated to be 3.35 eV for the TiO₂ film and 2.98 eV for H: TiO₂ film. The energy gap of films was demonstrated that it can be reduced by hydrogenation as show in figure 2(c).

Conclusion
Titanium dioxide (TiO₂) and hydrogenated titanium dioxide (H:TiO₂) mixture anatase-rutile phase thin films were successfully prepared by sparking method and annealed at 500 °C for 2 h in air and in H₂ atmosphere, respectively. The surface morphology of films have more porous and high roughness, as well as high specific area for photocatalytic activity. H:TiO₂ increase UV-Vis-NIR absorption for 20.7%. Direct energy gap of TiO₂ and H:TiO₂ were determined to be 3.35 eV and 2.98 eV, respectively.

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