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

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Abstract

Titanium dioxide (TiO_2) 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 ($H:TiO_2$). 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 photocalytic 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 $H:TiO_2$ was more than that of TiO_2. Furthermore, energy gap of $H:TiO_2$ thin film was found to be lower than that of TiO_2.

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.TiO_2 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

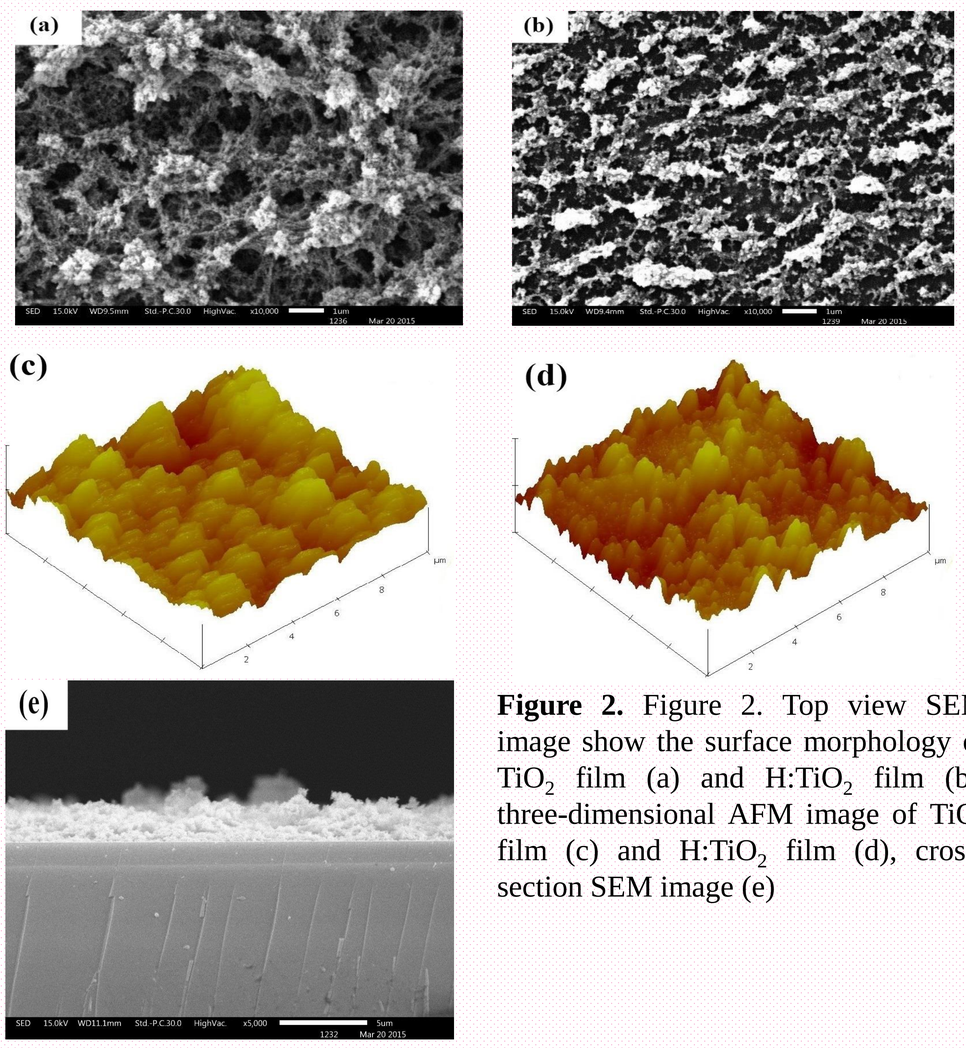

Figure 2. Figure 2. Top view SEM image show the surface morphology of TiO_2 film (a) and $H:TiO_2$ film (b), three-dimensional AFM image of TiO_2 film (c) and $H:TiO_2$ film (d), cross-section SEM image (e)

Table 1. Comparison of root-mean-square roughness, absorption band edge (λ) and the energy gap of TiO_2 and $H:TiO_2$ thin films

Sample	Roughness, nm	Absorption Band Edge (λ), nm	Energy Gap (Eg), eV
TiO_2	185	370	3.35
$H:TiO_2$	176	416	2.98

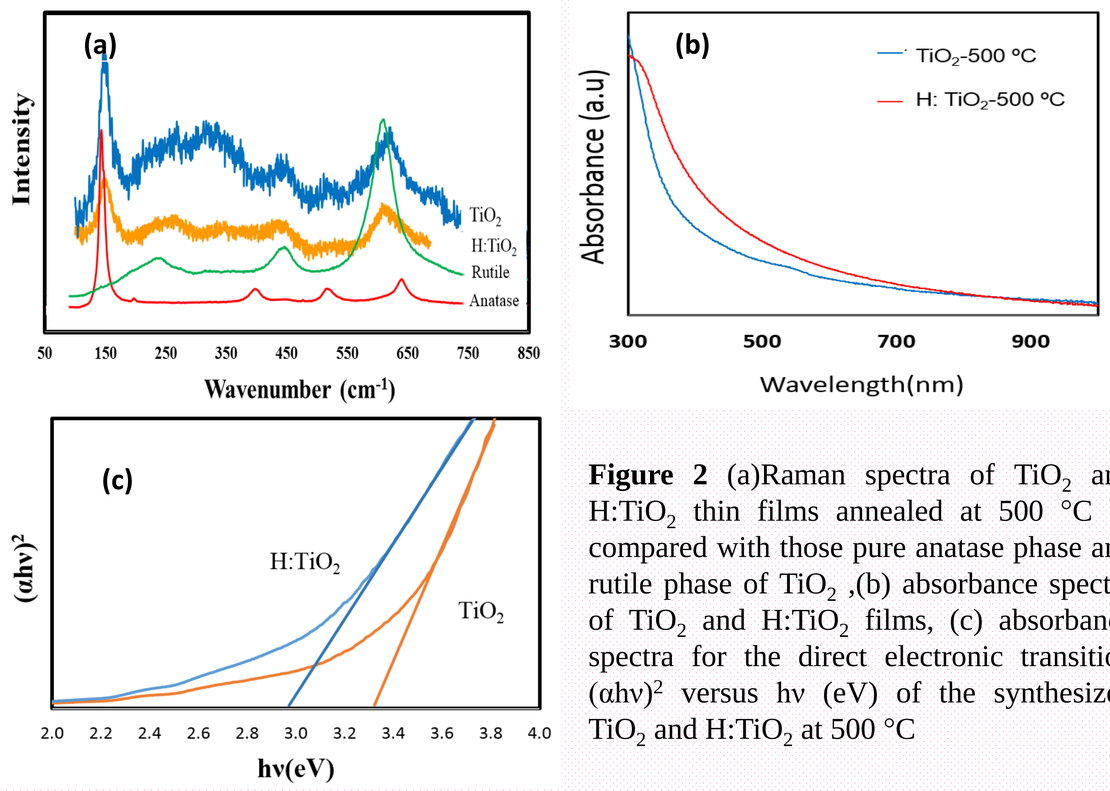

Figure 2 (a)Raman spectra of TiO_2 and $H:TiO_2$ thin films annealed at 500 °C as compared with those pure anatase phase and rutile phase of TiO_2 ,(b) absorbance spectra of TiO_2 and $H:TiO_2$ films, (c) absorbance spectra for the direct electronic transition $(\alpha h\nu)^2$ versus hν (eV) of the synthesized TiO_2 and $H:TiO_2$ at 500 °C

From the figure 2(a) found that the phase structure of TiO_2 and $H:TiO_2$ at 500 °C are anatase-rutile mixture phase. The result from figure 2(b) show that TiO_2 and H: TiO_2 are strong absorption in UV region and weak absorption in visible region. When compare between TiO_2 and H: TiO_2 found that H: TiO_2 exhibit stronger absorbance than TiO_2. The result confirm that hydrogenation on TiO_2 can enhance solar absorption. The direct energy gap were estimated to be 3.35 eV for the TiO_2 film and 2.98 eV for H: TiO_2 film. The energy gap of films was demonstrated that it can be reduced by hydrogenation as show in figure 2(c).

Conclusion

Titanium dioxide (TiO_2) and hydrogenated titanium dioxide ($H:TiO_2$) mixture anatase-rutile phase thin films were successfully prepared by sparking method and annealed at 500 °C for 2 h in air and in H_2 atmosphere, respectively. The surface morphology of films have more porous and high roughness, as well as high specific area for photocatalytic activity. $H:TiO_2$ increase UV-Vis-NIR absorption for 20.7%. Direct energy gap of TiO_2 and $H:TiO_2$ were determined to be 3.35 eV and 2.98 eV, respectively.

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