Hydrogen is a clean-burning fuel, but using it as an environmentally friendly energy source requires finding clean ways to produce it. A good attempt is solar water splitting achieved by illuminating semiconductor to drive the chemical separation of hydrogen and oxygen from water. TiO$_2$ has been considered to be one of the most promising semiconductors for photocatalytic hydrogen evolution owing to its good stability, nontoxicity, low cost and broad functionality. Up to now, the applications of TiO$_2$ suffers from more or less drawbacks such as the wide band gap and low quantum yield [11]. Thus, to increase the quantum yield and extend the light absorption are the key factors for improving the photocatalytic activity of TiO$_2$.

As we all know, the approaches to enhance photocatalytic properties of TiO$_2$ include doping with metal elements, non-metal elements and combining with other materials such as CQDs, graphene sheets (GSs) [2], graphene oxide (GO) [3] and carbon nanotubes. It is worth mentioning that combining TiO$_2$ with carbonaceous nanomaterials has been studied extensively for improving the photocatalytic water splitting activity of TiO$_2$ [3].

Nanostructured carbon represents the most promising and challenging materials for the decade. In recent years, we have been worked on the composite of nanostructured carbon modified TiO$_2$ composite for efficient solar water splitting [3, 2, 5 – 11]. A sol–gel method was developed to synthesize a series of TiO$_2$/GSs composites with different GSs content [3]. Higher photocatalytic activity than that of P25 for H$_2$ evolution from water splitting was illustrated for the obtained TiO$_2$/GSs composites and the highest photocatalytic activity was observed for the sample with 5% GSs. We also synthesized TiO$_2$/GSs composites from TiCl$_4$ and GO aqueous solution by a one-step hydrothermal method to confirm the role of GS [3]. When the GS content increases from 5.0 to 10.0 wt%, the highest hydrogen evolution rate of 5.4 mmol·h$^{-1}$ is observed for sample TiO$_2$/2.0wt% GS, which is about 1.6 times higher than that of P25.

Graphene oxide is the precursor of graphene sheet, we studied its photoelectrochemical properties and photoinduced superhydrophilicity [6, 12]. Furthermore, we assembled GO onto TiO$_2$ nanotube arrays through a simple impregnation method [12]. And we found that the maximum photoconversion efficiency of the composite electrode in the presence of visible light was 0.0487%, while it is only 0.0033% for the pristine TiO$_2$ nanotube electrode.

Recently, carbon quantum dots (CQDs) have triggered great interest due to the properties of facile synthesis and stable photoluminescence. We synthesized nanocomposite of CQDs and TiO$_2$ nanotube arrays by immersing TiO$_2$ nanotubes in CQDs solution to get a composite [7]. Particularly, the degradation efficiency of TiO$_2$ nanotubes towards methylene blue aqueous solution was enhanced by about 14% with the presence of CQDs. And the photocurrent density of CQDs/TiO$_2$ nanocomposite electrode was 2.7 times larger than that of pristine TiO$_2$ under visible light illumination, which was advantageous for solar water splitting [7]. In summary, the results may help the application of CQDs and further work is underway to enhance the photocatalytic water splitting efficiency through combining TiO$_2$ with carbonaceous nanomaterials.

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References