Photoelectrochemical properties of various α-Fe$_2$O$_3$ thin film nanostructures synthesized using solution methods for efficient solar water splitting

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Hydrogen is of great interest as a clean and storable energy. The greatest advantage of hydrogen is that we can get it easily from water. Solar water splitting is one of the most effective ways to generate hydrogen due to renewable and sustainable production method. The most widely used photocatalyst was TiO$_2$, but its narrow absorption wavelength range limits achieving the maximum conversion efficiency. The alternate catalyst which can replace TiO$_2$ in solar water splitting has to satisfy several requirements. The requirements are the proper band gap energy which can cover the water dissociation energy, widening visible light absorption, suitable band positions to generating oxidation and reduction reaction of water and enough electron and hole mobility to reach to reaction sites [1].

α-Fe$_2$O$_3$ is one of the noticed photocatalysts which can improve the weakness of TiO$_2$. The band gap energy of α-Fe$_2$O$_3$ is 2.1 eV, which can absorb the wider range of visible light than TiO$_2$. It satisfies almost requirements to alternate TiO$_2$ except the hole mobility [2]. The hole diffusion length of Fe$_2$O$_3$ is 2–4nm, 1/20 of TiO$_2$ [3]. Diffusion length is proportional to mobility and lifetime of carrier. So improving the mobility can increase diffusion length. One of the ways to increase the diffusion length is fabricating one-dimensional (1-D) nanostructures like nanowires, nanorods, nanoribbons, and nanotubes. Also, nanostructuring increases the reaction sites by enhancing the porosity of thin film.

There are many ways to synthesis the α-Fe$_2$O$_3$ nanostructures. For example, electron-beam evaporation, anodization, chemical vapor deposition, and solution methods are known ways. Among them, solution methods can be the most promising route due to its cost effectiveness and facile process.

In this study, we report the photoelectrochemical properties of various α-Fe$_2$O$_3$ thin film nanostructures hydrothermally synthesized on fluorine-doped-tin oxide (FTO) coated glass. We could tune the nanostructures by altering precursors, temperatures, and concentrations. The typical representative structure is planar nanorods, vertical nanorods, spherical particles, and urchin-like structures [Figure 1]. As a result, we found that photocurrent depends on the nanostructure of α-Fe$_2$O$_3$ thin film. We could confirm our argument by measuring the IPCE and photocurrent as the nanostructure changed. Our results show that the absorption of visible light is dramatically varied by changing nanostructures and the electron transport in the thin films strongly depends on the local nanostructures. Based on our results, we will suggest that which nanostructure shows the best photoconversion efficiency. Finally, we believe that hydrothermal method is one of the most effective and trendy methods owing to its high accessibility and wide applications.

Figure 1. SEM images of α-Fe$_2$O$_3$ on FTO glass: (a) planar nanorods, (b) vertical nanorods, (c) spherical particles, and (d) urchin-like structures

References