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Loading cobalt phosphate on TaON surface as efficient noble-metal-free co-catalyst for enhanced photocatalytic water oxidation performance

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ABSTRACT

Cobalt phosphate (CoPi) was loaded on the surface of TaON by a photochemical deposition method as an efficient oxygen evolution co-catalyst for the first time. Loading of CoPi showed little effect on the crystal structure and optical properties of TaON. While, the photogenerated charge carriers were efficiently separated in TaON after CoPi loading. Sample of CoPi/TaON (1 wt%) showed enhanced photocatalytic oxygen evolution performance of 1.75 mmol h^{-1} g^{-1} from water-splitting under visible light irradiation, which is about two times of that for pristine TaON.

1. Introduction

The development of efficient semiconductor photocatalysts for direct conversion of solar energy to chemical energy is one of the most potential approaches to solve the environmental and energy issues nowadays [1]. During the past decades, oxides such as La-doped $NaTaO_3$ have been demonstrated as highly efficient photocatalysts [2]. However, most of these oxides only absorb ultraviolet (UV) light which is less than 5 percent of the sunlight. Therefore, a great amount of photocatalysts with visible light response capability have been developed. Domen and coworkers demonstrated that (oxy)nitrides containing Ti^{4+}, Nb^{5+} and Ta^{5+} have reasonable absorption in visible light region [3]. Among (oxy)nitride photocatalysts, TaON has been intensively investigated as a promising photocatalyst and photoelectric catalyst due to its relatively high catalytic performance and narrow bandgap [4]. Unfortunately, TaON shows low catalytic performance without any surface modification. Co-catalyst loading is one of the most common and effective methods to improve the performance of photocatalysts. [5] However, most of the effective co-catalysts contain noble metal which is expensive for the further practical application. Therefore, the development of efficient noble-metal-free co-catalysts has always been of great significance in this research area.

Cobalt phosphate (CoPi) – an efficient earth-abundant oxygen evolution catalyst – has been applied as oxygen evolution co-catalyst in electrocatalytic water oxidation. [6–8] Furthermore, according to recent research, CoPi could also be taken as co-catalyst for various kinds of photocatalysts for photocatalytic oxygen evolution from water splitting [9–11]. It was commonly suggested that photogenerated holes can be easily trapped by CoPi catalyst loaded on the photocatalyst surface where water oxidation occurs, leading to the efficient charge separation and enhanced activities. However, to the best of our knowledge, there is no report about taking CoPi as co-catalyst for TaON photocatalyst.

In this work, CoPi was loaded on the surface of TaON through the photochemical deposition method for the first time to enhance its photocatalytic performance. The effects of CoPi loading on the crystal structure, morphology, optical properties and photocatalytic water oxidation performance were investigated.

2. Experimental

Preparation of TaON photocatalyst: Typically, 1.0 g Ta_2O_5 powder was heated at 850 °C for 15 h under a NH_3 flow (100 mL min^{-1}) in a tube furnace. After nitridation, the powder was cooled to room temperature under NH_3 flow and then washed with deionized water and absolute ethanol three times and finally dried at 60 °C for 2 h.

Preparation of CoPi loaded TaON photocatalysts: In this work, CoPi was loaded on the surface of TaON through the photochemical deposition method [12]. In a typical synthesis, 0.2 g of the as-prepared TaON powder was dispersed ultrasonically for 10 min in

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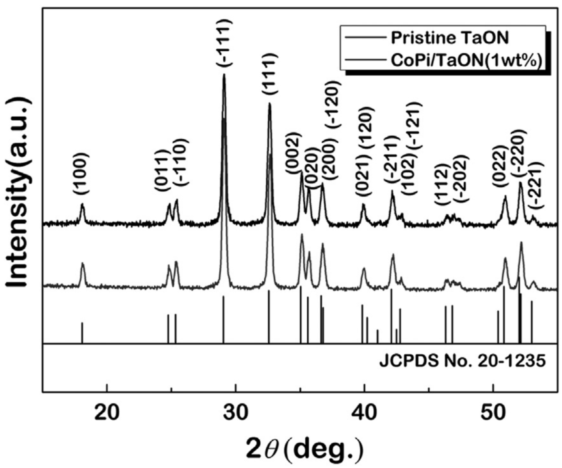

Fig. 1. XRD patterns of TaON and CoPi/TaON (1 wt%).

50 mL of sodium phosphate buffer solution (0.01 mol L^{-1}, pH = 7.0) prepared from NaH_2PO_4 and Na_2HPO_4. Then a certain volume of $Co(NO_3)_2 \cdot 6H_2O$ (0.02 mol L^{-1}) aqueous solution was added into the TaON suspension under stirring drop by drop. The loading amount was adjusted by adjusting the different mass ratios of TaON:Co. Then the mixture was illuminated using with a Xe lamp (Trusttech PLS-SXE 300, Beijing) for 30 min under constantly stirring. The final precipitate was collected by centrifugation and washed with deionized water and absolute ethanol thoroughly and finally dried at 60 °C for 12 h.

Characterization: The structures of the samples were characterized with a powder X-ray diffractometer (XRD, Rigaku D/max-2000) using Cu-Kα radiation (l = 0.15406 nm, 45 kV, 50 mA) at a scanning rate of 5° min^{-1} in the 2θ range 10–90°. The morphologies of GNZO powder were observed by scanning electron microscopy (SEM) (FEI, Quanta 200F) equipped with an EDS analyzer. TEM and HADDF analyses were carried out on t Tecnai G^2 S-Twin. UV–vis diffuse reflectance spectra were recorded on a spectrophotometer

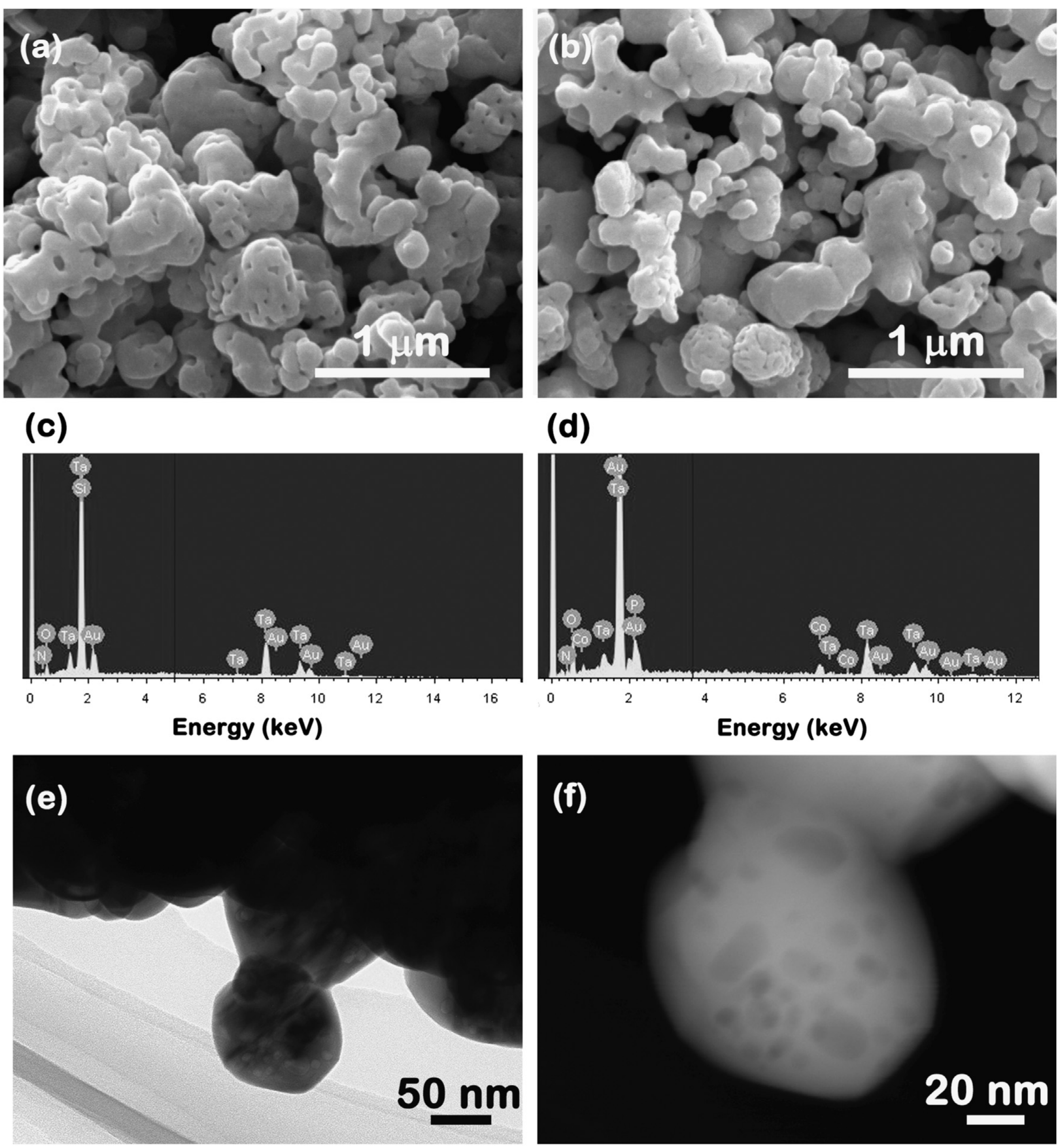

Fig. 2. SEM images of pristine TaON (a) and CoPi/TaON (1 wt%) (b) and their corresponding EDS spectra (c) TaON, (d) CoPi/TaON (1 wt%). TEM image (e) and HAADF image (f) of CoPi/TaON (1 wt%).