**Photoelectrochemical study of lanthanum titanate for the hydrogen production from water splitting**

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**Abstract**

In this work, photoelectrochemical (PEC) water splitting has been proposed for the hydrogen production as a green energy carrier using sunlight irradiation. So, lanthanum titanate (La2Ti2O7) was used as an appropriate n-type photoactive semiconductor for the hydrogen production from water. All the experimental conditions were optimized for the fabrication of La2Ti2O7-based photoanode. Sol-gel method was used for the deposition and growth of photoactive on indium tin oxide (ITO) substrate with various La and Ti ratios. Linear sweep voltammetry (LSV) and chronoamperometry techniques were used to study the photoactivity and the performance of the fabricated photoanodes. The results showed that the sample with the molar ratio of La:Ti equal to 1:1 shows higher photocurrent density of about 0.35 mA cm-2 at the applied potential of 0.5 V vs. Ag/AgCl reference electrode.

**Keywords:** Photoelectrochemical water splitting, lanthanum titanate, La2Ti2O7

**مطالعه فوتوالکتروشیمیایی لانتانیوم تیتانات برای تولید هیدروژن از شکافت آب**

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# چكيده

در این پژوهش، شکافت فوتوالکتروشیمیایی آب برای تولید هیدروژن به عنوان حامل انرژی پاک پیشنهاد شده­است. لذا، لانتانیوم تیتانات (La2Ti2O7) به عنوان نیم­رسانای نوع n مناسب جهت تولید هیدروژن از آب به کار رفت. تمام شرایط آزمایشگاهی برای ساخت فوتوآند مناسب مبتنی بر La2Ti2O7 بهینه شدند. روش پیشنهادی برای لایه نشانی ماده فعال نوری روش سل-ژل می باشد و با استفاده از این روش، ترکیب La2Ti2O7 بر روی بستر ایندیوم قطع اکسید (ITO) لایه نشانی شد. تکنیک های ولتامتری روبش خطی (LSV) و کرونوآمپرومتری برای بررسی رفتار نوری و عملکرد فوتوالکتروشیمیایی فوتوآندهای ساخته شده به کار رفت. نتایج نشان داد که فوتوآند ساخته شده با نسبت 1:1 از La:Ti بهترین عملکرد نوری با چگالی جریان نوری برابر با mA cm-2 35/0 در پتانسیل اعمالی V 5/0 در مقابل الکترود رفرنس Ag/AgCl را از خود نشان می­دهد.

**کليدواژه­ها:** شکافت فوتوالکتروشیمیایی آب، لانتانیوم تیتانات، La2Ti2O7

**Introduction**

n-Type semiconductors play a very noteworthy role in alleviating global energy demand and promoting environment remediation [1,2]. La2Ti2O7 as an n-type semiconductor has been used for the hydrogen production from water splitting. The energy band gap (Eg) of this photoactive semiconductor has been reported to be 3.8 eV. In this study, La2Ti2O7 was deposited on indium tin oxide (ITO) by using sol-gel method. All the experimental conditions including the molar ratio of Ti:La and the deposition conditions were optimized to obtain higher photoactivity of La2Ti2O7-based photoanode. The electrochemical techniques including linear sweep voltammetry and chronoamperometry were used to study the photoactivity of the fabricated La2Ti2O7-based photoanodes. The results showed that the photoanode which was fabricated with the La:Ti molar ratio of 1:1 is the best photoanode with higher photocurrent density of 0.35 mA cm-2 at 0.5 V.

**Experimental**

The sol-gel solution was prepared by the dissolution of n-butyl titanate and lanthanum nitrate in absolute ethanol with various molar ratios of La:Ti in the range of 1:1 to 1:10. A light source and an electrochemical analyzer are two key components to assess the photoactivity of the fabricated photoelectrodes. The electrochemical measurements of the samples were carried out using a Galvanostat/Potentiostat Autolab PGSTAT302N instrument. The fabricated photoanodes, Ag/AgCl electrode (3.0 M KCl), and Pt plate were employed as working, reference, and counter electrodes, respectively. A 300-W Xenon lamp with an intensity adjusted to 100 mWcm-2 (AM1.5G) was utilized as the light source of the experiments. The electrolyte of PEC processes was KOH (0.5 M).

**Results and Discussion**

The surface morphology of the samples which were fabricated by sol-gel method was investigated by scanning electron microscopy (SEM). Under the optimized experimental conditions, there was not observed any crack at the surface of the samples. Fig. 1 shows the SEM image of the photoanode fabricated with La2Ti2O7, in which the molar ratio of La:Ti was 1:1.

A picture containing graphical user interface

Description automatically generated

**Fig 1**. SEM image of the La2Ti2O7 -based photoanode with the molar ratio of La:Ti equal to 1:1.

Linear sweep voltammetry of the photoanode La2Ti2O7 -based photoanode in dark and under the AM1.5G illumination was shown in Fig. 2. As it is clear, under the illumination of the surface of photoanode, the current densities are higher t the applied potential range from -0.3 V to 2.0 V, indicating the photoactivity of the sample. Chronoamperometry of the photoanode samples with various La:Ti ratios has been depicted in Fig. 3. As the results show, the sample with the molar ratio of La:Ti equal to 1:1 shows higher photocurrent density of 0.35 mA cm-2 at the applied potential of 0.5 V vs. Ag/AgCl reference electrode.

**Fig 2**. LSV of La2Ti2O7-based photoanode fabricated with the La:Ti molar ratio of 1:1 at dark and under the 100 mWcm-2 (AM1.5G) illumination .

**Fig 3**. Chronoamperometry of La2Ti2O7 photoanode with various La:Ti molar ratios of 1:1, 1:2, 1:4, 1:6,1:8 and 1:10 at 0.5 V (vs. Ag/AgCl) under the standard AM1.5G solar light illumination.

**Conclusions**

In this study, La2Ti2O7 was proposed as an appropriate photoactive material for the fabrication of photoanode. La2Ti2O7-based photoanode was fabricated by the use of sol-gel approach on the ITO. The results showed that the sample with the molar ratio of La:Ti equal to 1:1 shows higher photocurrent density of 0.35 mA cm-2 at Eappl of 0.5 V.

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