Research Article

Silicon Nanowires with MoS_x and Pt as Electrocatalysts for Hydrogen Evolution Reaction

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A convenient method was used for synthesizing Pt-nanoparticle/ MoS_x /silicon nanowires nanocomposites. Obtained Pt- MoS_x /silicon nanowires electrocatalysts were characterized by transmission electron microscopy (TEM). The hydrogen evolution reaction efficiency of the Pt- MoS_x /silicon nanowire nanocomposite catalysts was assessed by examining polarization and electrolysis measurements under solar light irradiations. The electrochemical characterizations demonstrate that Pt- MoS_x /silicon nanowire electrodes exhibited an excellent catalytic activity for hydrogen evolution reaction in an acidic electrolyte. The hydrogen production capability of Pt- MoS_x /silicon nanowires is also comparable to MoS_x /silicon nanowires and Pt/silicon nanowires. Electrochemical impedance spectroscopy experiments suggest that the enhanced performance of Pt- MoS_x /silicon nanowires can be attributed to the fast electron transfer between Pt- MoS_x /silicon nanowire electrodes and electrolyte interfaces.

1. Introduction

In recent years, renewable energy sources have attracted great scientific interest because of the depletion of the world's fossil-fuel reserves and growing environmental pollution. Hydrogen, a clean and practically unlimited power supply, is abundant and renewable clean chemical fuel that can replace fossil fuels in the future. Currently, one effective way to prepare hydrogen is by splitting water. Electrochemical water splitting needs high-performance electrocatalysts for the hydrogen evolution reaction (HER) to afford a high current at low overpotential [1]. As is well known, Pt or Pt-based materials have been regarded as the most efficient catalysts [2, 3]. However, such catalysts are too expensive to be widely used. This limitation has motivated great research effort to minimize the use of precious Pt to obtain the same high active HER catalysts [4, 5]. An efficient strategy loads Pt on carbon materials such as graphene [6]. Support materials play an important role in the performance of catalytic activity.

Molybdenum disulfide (MoS_2) with a characteristic layered structure is shown to have attractive activities in solid lubricants [7], lithium battery cathodes [8], and catalysis [9].

Recently, some reports have demonstrated that MoS_x could be a good alternative cocatalyst for hydrogen production reaction [10, 11]. Chang et al. [12] synthesized MoS_x on the 3D Ni foam deposited with graphene layers which exhibited superior electrocatalytic activity in the hydrogen evolution reaction. The hydrogen evolution rate reaches $302 \text{ mL g}^{-1} \text{ cm}^{-2} \text{ h}^{-1}$ ($13.47 \text{ mmol g}^{-1} \text{ cm}^{-2} \text{ h}^{-1}$) at an overpotential of $V = 0.2 \text{ V}$. Recently, Ge et al. [13] synthesized the layered MoS_x cocatalysts on the surface of $\text{g-C}_3\text{N}_4$ and the MoS_2 - $\text{g-C}_3\text{N}_4$ composite samples exhibited stronger absorption in the visible light region. The 0.5 wt% MoS_2 - $\text{g-C}_3\text{N}_4$ exhibits the highest H_2 evolution rate of $23.10 \mu\text{mol h}^{-1}$, which is about 11.3 times higher than pure $\text{g-C}_3\text{N}_4$. Shen et al. [14] reported the MoS_2 deposited on UiO-66 modified CdS, and the photocatalytic activity of H_2 evolution is increased by up to 60 times than pure CdS.

Photoanodes of photoelectrochemical (PEC) cells have been extensively investigated [15–18], because Si nanowires (SiNWs) can provide several performance and manufacturing benefits [19]. Many methods have been developed for preparing SiNWs, such as chemical vapor deposition (CVD)

[20], electron beam lithography (EBL) [21], pulsed laser deposition (PLD) [22], molecular beam epitaxy (MBE) [23], and wet chemical etching (WCE) [24]. The improvement of electrocatalytic HER efficiency is crucial to effectively increase the surface area for catalyst loading. Hence, research into three-dimensional (3D) electrode structures is emergent [12]. The SiNWs have a high surface area, which can be used as a support material to host catalysts for increasing the number of reaction sites. The promotion of the performance of hydrogen evolution reactions can be modified by metal nanoparticles, such as SiNWs anodes from modifications by metal nanoparticles such as Pt [25] and Ru [26]. Recently, Huang et al. reported that the photoelectrochemical performance of SiNWs@MoS₃ is comparable to the composite of SiNWs and Pt nanoparticles (SiNWs@PtNPs) [27]. Such findings implicitly indicate a promising potential for SiNWs as support materials in electrocatalysis. In our early study, the promotion of the performance of hydrogen evolution reactions can be modified by metal nanoparticles and MoS_x [28].

In this study, we studied HER activity of Pt-MoS_x catalysts onto SiNWs under visible light irradiation. We used SiNWs as HER electrode materials and Pt-MoS_x composite catalysts were grown on the surface of SiNWs. Using Pt-MoS_x composite catalysts can reduce the loading of Pt and obtain the higher catalytic activity. The Pt-MoS_x/SiNWs nanocomposite catalysts were synthesized by a two-step method. Step one, the MoS_x/SiNWs was synthesized by solution and spin-coating methods. Step two, the Pt nanoparticles were deposited on the surface of MoS_x/SiNWs by a chemical reduction method. The electrocatalytic performance of the electrodes in terms of HER was evaluated using a 0.5 M K₂SO₄ solution (pH = 1) based on their cathodic polarization curves. The results demonstrate that the Pt-MoS_x/silicon nanowire electrodes exhibit an excellent catalytic activity for hydrogen evolution reaction in an acidic electrolyte.

2. Experimental

2.1. The Fabrication of SiNWs. SiNWs were fabricated with the metal-assisted chemical etching method. A p-type Si as the substrate was first pretreated for surface cleaning, which included the following two steps: (1) cleaning in an acetone solution with ultrasonic vibration for 15 min and (2) washing with deionized water, pickling in a solution of H₂SO₄/H₂O₂ (3:1) for 15 min and then washing with deionized water.

The cleaned Si was then treated for the preparation of the Si nanowires. The treating process has three steps as follows: (1) immerse in a solution of 1% HF for 30 sec for removal of the oxide layer; (2) immersion in a solution of 8.5% HF and 25 mM AgNO₃ for preparation of the Si nanowires on the Si substrate; and (3) immersion in a solution of 30% HNO₃ for 15 min for removing the Ag layer from the Si nanowires.

2.2. Preparation of MoS_x/Silicon Nanowire (MoS_x/SiNW) by the Solution Method. A total of 26 grams of (NH₄)₂MoS₄ was dissolved in 10 mL of dimethylformamide (DMF) and stirred for 30 min by ultrasonic. SiNWs substrate was cut into small pieces (1.25 × 1.25 cm²). To grow the MoS_x catalysts on the

SiNWs surfaces, the SiNWs substrate was immersed in an (NH₄)₂MoS₄/DMF solution for 1 min. The SiNWs substrate with (NH₄)₂MoS₄/DMF was then backed on an oven at 100°C for 10 min the MoS_x layer was then formed after subsequent annealing at various temperatures (150, 200, 250, 300, and 350°C) in an Ar environment for 2 h. MoS_x/SiNWs prepared by solution method are denoted by MoS_x/SiNWs(S).

2.3. Preparation of MoS_x/Silicon Nanowire (MoS_x/SiNW) by Spin-Coating. A total of 26 grams of (NH₄)₂MoS₄ was dissolved in 10 mL of dimethylformamide (DMF) and stirred for 30 min by ultrasonic. SiNWs substrate was cut into small pieces (1.25 × 1.25 cm²). In a typical experiment, 25 μL of (NH₄)₂MoS₄/DMF solution was dropped onto SiNWs sample and spun at a speed of 600 rpm until DMF was totally evaporated. The MoS_x layer was then formed after subsequent annealing at various temperatures (150, 200, 250, and 300°C) in an Ar environment for 2 h. MoS_x/SiNWs prepared by spin-coating method are denoted by MoS_x/SiNWs(C).

2.4. Preparation of Pt/Silicon Nanowire (Pt/SiNWs) and Pt/MoS_x/Silicon Nanowire (Pt-MoS_x/SiNWs). We followed the process below to obtain the Pt deposited on the surface of MoS_x/SiNWs and SiNWs. Firstly, H₂PtCl₆·6H₂O (50 mg) were dissolved in 40 mL of ethylene glycol by ultrasonic treatment 1 h. Then MoS_x/SiNWs or SiNWs were added to the above solution. Additionally, the pH value of this mixture was adjusted to 2 using HCl. Finally, the solution reflux at 120°C and 150°C for 3 and 6 h, respectively. Pt-MoS_x/SiNWs prepared from MoS_x/SiNWs made by solution and spin-coating method are denoted by Pt-MoS_x/SiNWs(S) and Pt-MoS_x/SiNWs(C), respectively.

2.5. Characterization Methods. A 200 kV transmission electron microscope (TEM, JEOL JEM-2010, and JEM 3010) and scanning electron microscope (JEOL, JSM-6510LV) were used for the observation of microstructure and analysis of crystal structure of the SiNWs, Pt/SiNWs, MoS_x/SiNWs, and Pt-MoS_x/SiNWs. TEM samples were prepared by depositing a drop of sample dispersion onto the Cu grids coated with a carbon layer.

2.6. Photoelectrochemical Measurements. Electrochemical measurements were performed at a standard three-electrode electrochemical cell with a Jiehan (made in Taiwan) electrochemical workstation. The Jiehan electrochemical workstation is a single compact unit that consists of hardware that is capable of ±10 V scan ranges and 1000 mA current capability. The workstation has measurement resolution and accuracy down to 50 μV for the reference electrode and 500 pA for the working electrode with 0.1% of reading accuracy. SiNWs, MoS_x/SiNWs, Pt/SiNWs, and Pt-MoS_x/SiNWs were working as electrodes. A saturated calomel electrode (SCE, Hg/Hg₂Cl₂ (sat. KCl)) was used as the reference and a platinum plate was used as the counter electrode. The visible light irradiation proceeded by a solar simulator under the one-sun global solar spectrum of air mass (AM) 1.5 (under 100 mWcm⁻²). H₂SO₄ solution containing 0.5 M K₂SO₄ (pH = 1) aqueous solution was used as the electrolyte. The working electrodes

FIGURE 1: (a) Surface morphology and (b) cross-sectional scanning electron microscope images of the SiNWs array.

were assembled into a homemade electrochemical cell, with only a defined area (1 cm^2) of the front surface of sample exposing to solution during measurements. Silver paste was applied to the backside of SiNWs samples enabling Ohmic contact. Photocurrent density-potential (J - E) relations were measured at scan rate of 50 mV/s . The electrochemical impedance spectroscopy measurements were performed at 50 mV versus SCE in the frequency range of $1\text{--}10^5\text{ Hz}$.

3. Result and Discussion

3.1. Characterization of SiNWs, $\text{MoS}_x/\text{SiNWs}$, Pt/SiNWs , and $\text{Pt-MoS}_x/\text{SiNWs}$. The surface morphology of Si nanowires is prepared in a solution of 8.5% HF + 25 mM AgNO_3 for 30 minutes as Figure 1(a) shows. The Si nanowires are bundled up into clusters, which occurs naturally for high aspect ratio vertical nanowires due to surface tension [29]. Figure 1(b) shows the cross-sectional scanning electron microscope image of the SiNWs array, showing large-area aligned SiNWs perpendicular to the Si surface. The length of Si nanowires is about $9\text{ }\mu\text{m}$ and they are relatively uniform in length. The diameter distribution of the nanowires is in the range of $80\text{--}250\text{ nm}$.

To find the optimum reducing time for obtaining catalyst Pt particles with a smaller size and a better distribution on SiNWs, reduction reactions of $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$ in ethylene glycol were carried out at 120 and 150°C for 3 and 6 h, in which the weight of $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$ is $50\text{ mg}/100\text{ mL}$ (0.5 g/L). A typical cross-sectional SEM image of the Pt/SiNWs using chemical reduction at 120°C for 3 h is shown as in Figure 2(a). Figures 2(b)–2(e) show cross-section SEM images (lower part) of catalyst Pt particles reduced on silicon nanowires at 120 and 150°C for 3 and 6 h, respectively. These images show that catalyst Pt particles have sizes of about 20 nm , which is nearly independent for the temperature and time of reflux.

Figure 3(a) shows TEM image of SiNWs subjected to MoS_x prepared by spin-coating deposition. The thin MoS_x layer is uniformly coated on the SiNWs. Figure 3(b) shows a HRTEM image of MoS_x layer on the sidewall of a SiNWs. The lattice fringes with a spacing of 0.318 nm were clearly visible in SiNWs, which was in good agreement with the spacing of (111) planes of Si. In contrast to SiNWs, well-defined lattice

fringe is absent in the MoS_x layer, indicating that MoS_x is amorphous. The thickness of MoS_x layer is about 4.4 nm .

The Pt- $\text{MoS}_x/\text{SiNWs}$ was also characterized by TEM, and the images of Pt- $\text{MoS}_x/\text{SiNWs}$ samples are prepared by solution method annealing at 250 and 300°C for 2 h as Figure 4 shows. The illustration shows the selected area electron diffraction pattern. It can be seen that the Pt particles in Figures 4(a) and 4(b) do not uniform distribute on the surface of $\text{MoS}_x/\text{SiNWs}$. Figures 4(c) and 4(d) show high-resolution TEM images of Pt particles and MoS_x layer on the surface of SiNWs. The lattice fringes with a spacing of 0.196 nm were clearly visible in Pt particles, which was in good agreement with the spacing of (200) planes of Pt (Figure 4(c)). The particle size of Pt is about $4\text{--}8\text{ nm}$. Additionally, (111) lattice fringe is also present in the SiNWs, and the amorphous MoS_x layer lies on the sidewall of SiNWs. Figure 5 shows the images of Pt- $\text{MoS}_x/\text{SiNWs}$ samples prepared by the spin-coating method annealing at 250°C for 2 h. Figure 5(a) shows the low-magnification TEM image of Pt-nanoparticle- (NP-) decorated $\text{MoS}_x/\text{SiNWs}$, revealing that the congregate Pt nanoparticles are also randomly located at the silicon nanowire surface. The diameter of Pt nanoparticles is typically $6\text{--}10\text{ nm}$, and amorphous MoS_x layer also lies on the sidewall of SiNW, as in Figure 5(b).

3.2. Electrocatalytic Properties of SiNWs, $\text{MoS}_x/\text{SiNWs}$, Pt/SiNWs , and $\text{Pt-MoS}_x/\text{SiNWs}$. Figure 6 shows the typical photocurrent density (J) versus potential (E) curves for photoelectrochemical measurements made with the naked p-SiNWs array electrode and the naked planar p-Si photocathode in a stirred solution containing 0.5 M K_2SO_4 and H_2SO_4 ($\text{pH } 1$). A three-electrode configuration is used with a SiNWs and planar Si photocathode, a Pt counter electrode, and a standard calomel reference electrode (SCE). The SiNWs and planar Si photocathode were irradiated with a solar simulator at a constant light intensity of $100\text{ mW}/\text{cm}^2$. Dashed line curve represents naked n-SiNWs electrode and solid line the naked planar n-Si electrode. The naked planar Si exhibited a very small photocurrent density because without an electrocatalysts present on the Si surface, electron transfer from the Si surface to H^+ was very slow. In contrast, the SiNWs photocathode generated a higher photocurrent. The

FIGURE 2: (a) A typical cross-sectional SEM image of the PtNPs/SiNWS using chemical reduction at 120°C for 3 h. The cross-section SEM images (lower part) of catalyst Pt particles reduced on silicon nanowires at (b) 120°C for 3 h, (c) 120°C for 6 h, (d) 150°C for 3 h, and (e) 150°C for 6 h.

FIGURE 3: (a) TEM image of SiNWS subjected to MoS_x prepared by spin-coating deposition. (b) High-resolution TEM image of MoS_x/SiNWS.

FIGURE 4: TEM images of Pt-MoS_x/SiNWs samples prepared by solution method annealing at (a) 250 and (b) 300°C for 2 h. High-resolution TEM images of Pt-MoS_x/SiNWs samples annealing at (c) 250 and (d) 300°C for 2 h.

excellent antireflection ability and higher surface area of SiNWs are responsible for the large increase in photocurrent and high optical absorption owing to multiple scattering of light in the nanowire array [30].

Platinum has been demonstrated as highly efficient electrocatalysts remarkably promoting the photoelectrochemical hydrogen production from SiNWs [25]. In the presence of Pt nanoparticles on the SiNWs surface, H₂ generation from the photoelectrodes was greatly enhanced due to the facile reduction of H⁺ at the Pt electrocatalysts [25]. The effect of reflux temperature and time for Pt decorated on SiNW was investigated. Figure 7 shows the *J-E* measurements for a Pt decorated with SiNW photoelectrode. It is shown that the photocurrent exhibits a maximum for the sample annealed at 120°C for 3 hr and the photocurrent slightly reduces after prolonged Pt deposition time (6 hr). The photocurrent also decreases with the further increase in annealing temperature.

In addition, the onset potential (E_{OS}) is not evidently affected by Pt deposition time and temperature. The highest photoelectrochemical performance of Pt-SiNWs resulted from reflux at 120°C for 3 h. SEM images (Figure 2) show that the size and number density of Pt nanoparticles are almost the same for all conditions (reflux at 120°C for 3 and 6 h and 150°C for 3 and 6 h). The decreased photocurrent may be due to prolonged Pt deposition on SiNWs and would result in the formation of porous silicon layer with large resistance, which reduced the photocurrent [30].

Figures 8(a) and 8(b) show the polarization curves for the MoS_x/SiNWs prepared by solution method and spin-coating, respectively, annealing at different temperatures. It was observed that HER efficiency of the sample annealing at 150°C is slightly higher than for the sample annealing at temperatures in the range of 200–300°C between the applied potential of −0.35 V and −0.9 V (versus SCE). This reveals

FIGURE 5: (a) TEM image and (b) high-resolution TEM image of Pt-MoS_x/SiNWs samples prepared by spin-coating method annealing at 250°C for 2 h.

FIGURE 6: The typical photocurrent density (J) versus potential (E) curves for (a) the naked p-SiNWs array electrode and (b) the naked planar p-Si photocathode.

FIGURE 7: The J - E measurements for a Pt decorated with SiNWs photoelectrode.

that the photoelectrochemical performance of MoS_x/SiNWs is not affected by annealing temperature below 300°C.

Figure 9 shows the polarization curves for the Pt-MoS_x/SiNWs prepared by solution method at different annealing temperatures for 2 h. The performance of Pt-MoS_x/SiNWs is influenced by the annealing temperature. When the annealing temperature increases from 150°C to 300°C, the photoelectrochemical performance of Pt-MoS_x/SiNWs increases with increasing temperature; the current density of Pt-MoS_x/SiNWs increased from ca. 5 mA/cm² to 18 mA/cm², which was the optimum HER efficiency obtained by solution method. When the annealing

temperature increases from 300°C to 350°C, the photoelectrochemical performance of Pt-MoS_x/SiNWs decreased with increasing temperature; the current density of Pt-MoS_x/SiNWs decreased to 16 mA/cm². Chang et al. report that the MoS_x/graphene is grown on Ni foams [12]. The MoS_x materials are grown by the thermolysis of ammonium thiomolybdates at different temperatures (100, 120, 170, 200, 250, and 300°C) in a CVD chamber. They observed that the HER efficiency exhibits a maxima at $T = 120^\circ\text{C}$ and it decreases with the further increase in annealing temperature. This also evidences that the structure MoS_x prepared at 300°C is close to MoS₂ and the structure of the MoS_x

FIGURE 8: The polarization curves for the $\text{MoS}_x/\text{SiNWs}$ prepared by (a) solution method and (b) spin-coating.

FIGURE 9: The polarization curves for the $\text{Pt-MoS}_x/\text{SiNWs}$ prepared by solution method at different annealing temperatures for 2 h.

FIGURE 10: The J - E measurements for planar Si, SiNWs, $\text{MoS}_2/\text{SiNWs(S)}$, $\text{MoS}_2/\text{SiNWs(C)}$, Pt/SiNWs, Pt- $\text{MoS}_2/\text{SiNWs(S)}$, and Pt- $\text{MoS}_2/\text{SiNWs(C)}$ electrodes.

obtained at lower temperatures such as 100, 120, and 170°C is stoichiometrically close to Mo_2S_5 . In our samples, the transmission electron microscopy (TEM) analyses reveal that all the MoS_x materials obtained in the temperature range of 150 to 350°C are amorphous. The photoelectrochemical performance of Pt- $\text{MoS}_x/\text{SiNWs}$ decreasing with increasing temperature may attribute to the stoichiometry change of the MoS_x .

Planar Si, SiNWs, $\text{MoS}_x/\text{SiNWs(S)}$, $\text{MoS}_x/\text{SiNWs(C)}$, Pt/SiNWs, Pt- $\text{MoS}_x/\text{SiNWs(S)}$, and Pt- $\text{MoS}_x/\text{SiNWs(C)}$ are used as HER electrodes. The J - E measurements for different electrodes are shown as in Figure 10. As can be seen, the $\text{MoS}_x/\text{SiNWs(C)}$ electrode displays a current density of

13 mA/cm^2 when potential is applied at -0.7 V versus SCE. In comparison, the current density of the Pt/ $\text{MoS}_x/\text{SiNWs(C)}$ sample is 18.5 mA/cm^2 . In addition, the cathodic current density of Pt/ $\text{MoS}_x/\text{SiNWs(S)}$ (15.5 mA/cm^2) at -0.7 V (versus SCE) is also much higher than for $\text{MoS}_x/\text{SiNWs(S)}$ (9 mA/cm^2) and Pt/SiNWs (8.5 mA/cm^2). Therefore, the enhanced HER activity of Pt/ $\text{MoS}_x/\text{SiNWs}$ is due to the synergetic effect between MoS_x layer and Pt nanoparticles. The performance of $\text{MoS}_x/\text{SiNWs(C)}$ is slightly higher than $\text{MoS}_x/\text{SiNWs(S)}$ sample. MoS_x deposited via spin-coating method can slightly enhance photocurrent of SiNWs. The

FIGURE 11: (a) Nyquist plots the electrochemical impedance spectroscopy response of the planar Si, SiNWs, MoS₂/SiNWs(S), MoS₂/SiNWs(C), Pt/SiNWs, Pt-MoS₂/SiNWs(S), and Pt-MoS₂/SiNWs(C). (b) Typical results of fitting model to the experimental results of (a).

enhancement may be attributed to the more uniform MoS_x layer using the spin-coating method.

HER kinetics at the electrode/electrolyte interface was investigated with electrochemical impedance spectroscopy (EIS) techniques. Figure 11 presents the Nyquist plots of the EIS response of the planar Si, SiNWs, MoS_x/SiNWs(S), MoS_x/SiNWs(C), Pt/SiNWs, Pt-MoS_x/SiNWs(S), and Pt-MoS_x/SiNWs(C), where the vertical axis is the real part (Z') and the horizontal axis is the imaginary part (Z'') of the impedance. In order to derive a physical picture of the electrode/electrolyte interface and the processes occurring at electrode surface, experimental EIS data were modeled using Z fit analysis software provided with the impedance system and an electrical equivalent circuit was obtained based on one time constant. The EIS data are fitted to the equivalent circuit shown in the inset of Figure 11(a), where R_s represents the total resistance of the electrolyte solution and the electrode, CPE is the capacitance phase element at electrode/electrolyte interface, and R_{ct} is the charge transfer resistance at electrode/electrolyte interface [27]. The charge transfer resistance R_{ct} is related to the electrocatalysis kinetics and a lower value corresponds to a faster reaction rate [31]. Semicircle of the Pt-MoS_x/SiNWs is smaller than the MoS_x/SiNWs and SiNWs indicating a lower charge transfer resistance in the Pt-MoS_x/SiNWs (Figure 11(b)). The fitted value of R_{ct} is about 218, 258, 379, 423, and 720 Ω for Pt-MoS_x/SiNWs(C), Pt-MoS_x/SiNWs(S), MoS_x/SiNWs(C), MoS_x/SiNWs(S), and SiNWs, respectively. The lower charge transfer resistance is in favor of higher photocurrent production, which is in good agreement with our J - E curves described above. The Pt-MoS_x/SiNWs exhibits enhanced photocurrent in comparison with pristine SiNWs, MoS_x/SiNWs, and Pt/SiNWs. The high

HER activity Pt-MoS_x/SiNWs can be attributed to the synergetic effect between MoS_x nanolayer and Pt nanoparticles play the important role in the enhancement of HER activity, which is confirmed EIS results and other reports [27]. Pt-MoS_x/SiNWs related to current electrocatalysts for hydrogen evolution can utilize less Pt. In addition, the enhanced photoelectrochemical performance of Pt-MoS_x/SiNWs can be attributed to the relatively small charge transfer resistance at Pt-MoS_x/SiNWs/electrolyte interface.

4. Conclusions

In summary, the Pt-MoS_x/SiNWs nanocomposite was fabricated by means of a chemical reduction method on MoS_x/SiNWs. The obtained Pt-MoS_x/SiNWs exhibits enhanced photoelectrochemical performance in comparison with SiNWs, MoS_x/SiNWs, and Pt/SiNWs. When applying potential at -0.7 V versus SCE, the current densities of the Pt/MoS_x/SiNWs(C), Pt/MoS_x/SiNWs(S), MoS_x/SiNWs(C), MoS_x/SiNWs(S), and Pt/SiNWs samples are 18.5 mA/cm², 15.5 mA/cm², 13 mA/cm², 9.0 mA/cm², and 8.5 mA/cm², respectively. In this study, Pt-MoS_x/SiNWs exhibits enhanced photocurrent in comparison with pristine SiNWs, MoS_x/SiNWs and Pt/SiNWs. The high HER activity Pt-MoS_x/SiNWs can be attributed to the synergetic effect between the MoS_x nanolayer and Pt nanoparticles play the important role in the enhancement of HER activity, which is confirmed by EIS results and other reports. Pt-MoS_x/SiNWs related to current electrocatalysts for hydrogen evolution can utilize less Pt. The enhancement of photoelectrochemical performance can be attributed to the fast electron transfer between Pt-MoS_x/silicon nanowires electrode and electrolyte interface.

Competing Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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