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Communication

Room-temperature sputtered electrocatalyst WSe_2 nanomaterials for hydrogen evolution reaction

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A B S T R A C T

The low-temperature physical vapor deposition process of atomically thin two-dimensional transition metal dichalcogenide (2D TMD) has been gaining attention owing to the cost-effective production of diverse electrochemical catalysts for hydrogen evolution reaction (HER) applications. We, herein, propose a simple route toward the cost-effective physical vapor deposition process of 2D WSe_2 layered nanofilms as HER electrochemical catalysts using RF magnetron sputtering at room temperature (<27 °C). By controlling the variable sputtering parameters, such as RF power and deposition time, the loading amount and electrochemical surface area (ECSA) of WSe_2 films deposited on carbon paper can be carefully determined. The surface of the sputtered WSe_2 films are partially oxidized, which may cause spherical-shaped particles. Regardless of the loading amount of WSe_2, Tafel slopes of WSe_2 electrodes in the HER test are narrowly distributed to be ~120–138 mV dec^{-1}, which indicates the excellent reproducibility of intrinsic catalytic activity. By considering the trade-off between the loading amount and ECSA, the best HER performance is clearly observed in the 200W-15min sample with an overpotential of 220 mV at a current density of 10 mA cm^{-2}. Such a simple sputtering method at low temperature can be easily expanded to other 2D TMD electrochemical catalysts, promising potentially practical electrocatalysts.

As energy consumption has exponentially increased, fossil fuels, one of the main energy sources over the last century, have been regarded as a serious issue because they are not only limited in resources but also cause serious environmental pollution owing to the emission of carbon dioxide. Sustainable and environmentally friendly energy sources have been investigated. Particularly, hydrogen is one of the most ideal energy sources to replace fossil fuels because it possesses the highest energy density per weight as well as serves as infinite and environmentally friendly energy that does not emit CO_2 [1–3]. However, the sustainable and large-capacity production of hydrogen is essential. Water electrolysis can be adopted as a promising approach to generate hydrogen [4]. The hydrogen evolution reaction (HER) requires a high-efficiency catalyst to reduce the overpotential [5–10]. In this regard, platinum group metals exhibit excellent intrinsic catalytic activity for electrocatalysts [11–13]. However, these noble metal catalysts are expensive; thus, many non-noble metal materials have been developed as HER electrocatalysts [14–18].

Meanwhile, two-dimensional transition-metal dichalcogenides (TMDs) have attracted a tremendous amount of attention because of their superior electrochemical reactivity, low cost, and abundant components [19–23]. The HER catalytic activity of MoS_2 and WSe_2, the most well-known 2D semiconductors, was previously reported [24–28]. Several approaches have been proposed to demonstrate the WSe_2 catalyst for HER. First, wet-processing-based WSe_2 flakes were exfoliated from bulk WSe_2 using aromatic intercalation [29], partly limiting its high yield and uniform large area deposition. Even if different solution-based synthesis methods [30,31] and chemical vapor depositions [32–34] could enable the large-area synthesis of WSe_2, such methods require high temperature and relatively complicated processing sequences. Furthermore, the precise and delicate control of the loading amount for determining the performance optimization of the electrode catalyst is highly essential, which can be achieved by the process development

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