Direct Growth of Nickel Phosphoride Nanoneedles on Nickel Foam for Efficient Electrocatalytic Hydrogen Evolution

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Abstract:

Hydrogen is a future energy carrier for both stationary and motive power generation. Water splitting offers a clean and sustainable way to produce hydrogen, as water is an almost inexhaustible renewable source and the water splitting process is not as energy-intensive as steam reforming. However, in order to achieve a high water splitting efficiency, an electrocatalyst for the hydrogen evolution reaction (HER) is crucially needed to render a high current at low overpotentials. Platinum (Pt) has so far been the most efficient and commonly used electrocatalysts for HER. But it is not practical and economically viable to use Pt for large-scale application because of its high cost and scarcity. Therefore, developing earth-abundant and low cost HER catalysts having comparable activity and stability as Pt is highly desired [1]. Very recently, transition metal phosphides (TMPs), such as Ni_2P, CoP, MoP, FeP, etc., have emerged as a new class of catalysts which show sufficiently high electrocatalytic activity and excellent stability toward HER in acidic electrolytes [2,3].

In this work, we report a facile route to the growth of nickel phosphide (Ni_2P) nanoneedles on commercially available nickel (Ni) foam, which involves direct phosphorization of Ni foam under solvethermal conditions using red phosphorous as a precursor [4]. This results in the formation of well-defined Ni_2P nanoneedles on the entire surface of the Ni foam (see Figure 1a). The electrocatalyic performance of the as-fabricated Ni_2P/Ni electrode was evaluated by linear scan voltammetry (LSV) and electrochemical impedance spectroscopy (EIS) in 0.5 M H_2SO_4. A cathodic current as high as 42 mA cm^{-2} was observed at an overpotential of 200 mV, and to afford a current density of 20 mA cm^{-2} only a small overpotential of 162 mV is needed (see Figure 1b). The EIS result reveals that the charge transfer resistance of the Ni_2P nanoneedles is 143.2 Ω, close to that of the Pt foil (104.4 Ω). Moreover, the Ni_2P/Ni also exhibits reasonably good stability due to the protection of a continuous $Ni_{12}P_5$ layer underneath the nanoneedles. The observed good electrocatalytic performance of the Ni_2P/Ni can be attributed to the unique 3D porous feature of the Ni foam, which is not only beneficial for the mass transfer of the electrolyte and release of H_2 gas bubbles, but also greatly facilitates the electron transport in the overall electrode. The Ni_2P nanoneedles supported on Ni foam reported in this work hold substantial promise for use as efficient and low-cost cathodes in electrolyzers.

References

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Figures

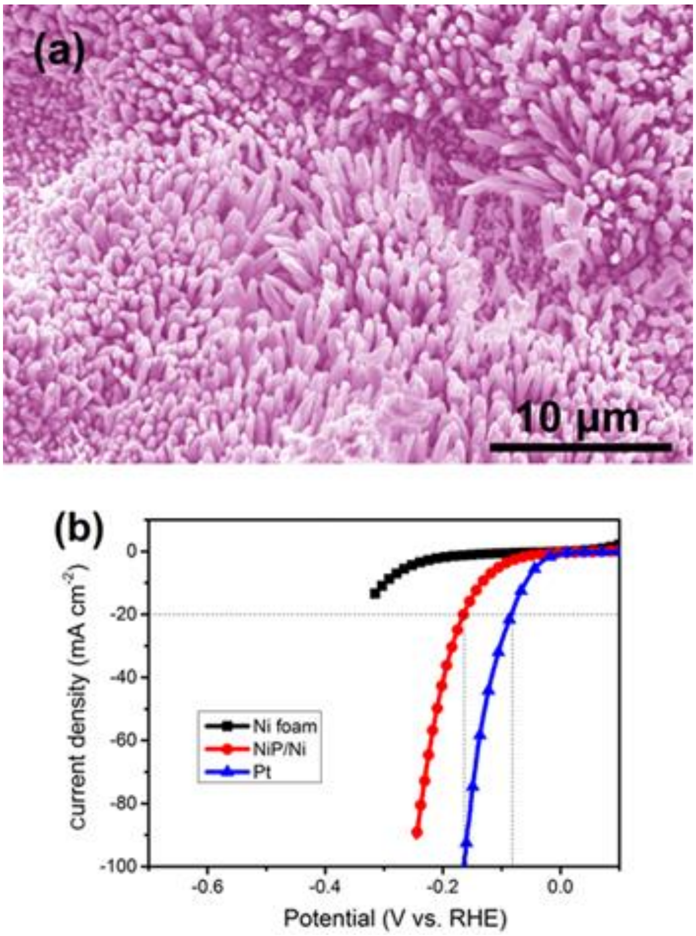

Figure 1: (a) A representative SEM image showing the nickel phosphide nanoneedle arrays grown on the ligament of the nickel foam and (b) comparison of the polarization curve of NiP/Ni with that of the Ni foam and Pt foil recorded in 0.5 M H_2SO_4 at a scan rate of 10 mV s^{-1}.