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A nanoporous palladium-nickel alloy with high sensing performance towards hydrogen peroxide and glucose

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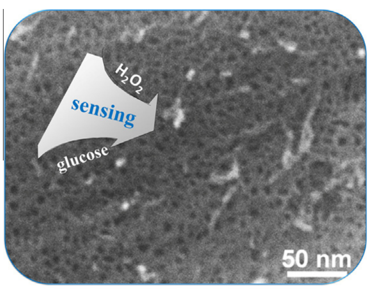
GRAPHICAL ABSTRACT



Nanoporous PdNi alloy

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ABSTRACT

The nanoporous (NP) PdNi alloy is easily fabricated by one-step mild dealloying of PdNiAl precursor alloy in NaOH solution. Characterized by the nanoporous network architecture with the ligament size as small as 5 nm, NP-PdNi alloy exhibits higher electrocatalytic activity towards the oxidation of H_2O_2 and glucose compared with NP-Pd and Pd/C catalysts. The electrochemical sensor constructed based on NP-PdNi alloy shows high sensing performance towards H_2O_2 and glucose with a wide linear range, long-term stability, and fast amperometric response. Moreover, NP-PdNi alloy exhibits high resistance towards Cl^- poisoning as well as good anti-interference towards ascorbic acid, urci acid, and dopamine. This work provides a simple and green route to construct highly active and sensitive electrochemical sensor for detecting H_2O_2 and glucose.

1. Introduction

Hydrogen peroxide (H_2O_2) as an intermediate plays a fundamental role in many reactions, such as an antiseptic or disinfectant agent, a bleaching agent, and a cleaning agent [1–4]. Glucose detection is vital in diabetes management, wastewater treatment, food industries, and environmental monitoring [5–8]. Consequently, development of highly sensitive, accurate, and selective method for determination of H_2O_2 and glucose is of significant importance in food, pharmaceutical, industrial, and environmental analyses. Different analytical methods for the detection of H_2O_2 and glucose have been reported, such as colorimetric assay, fluoroimmunoassay, and electrochemiluminescence [9–11]. Among these methods, electrochemical sensors based on electrooxidation of small molecules have gained remarkable attention owing to the advantages of convenient operation, fast response time, and low cost [12–15]. In recent years, advanced nanomaterials modified electrodes have attracted much attention as the platform for the H_2O_2 and glucose electrochemical sensor. Anu Prathap et al. developed a simple nonenzymatic H_2O_2 and glucose sensor based on CuO nanostructures modified electrode, finding unique electro-

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chemical sensing performance for H_2O_2 and glucose detections [6]. The nanomaterial is indeed successful in achieving high electrochemical activity as the platform to construct the electrochemical sensor. Therefore, the design of highly efficient nanostructured materials with controllable preparation is much important in order to maximize the entire advantages of electrochemical sensors.

Among various nanostructured materials, palladium (Pd) nanostructured materials have attracted considerable interests due to their high electrocatalytic efficiency, the relatively cheaper price, and abundant yielding [16–18]. Especially, incorporation of other transition metals into Pd can further improve its electrochemical performance by changing its electronic structure as well as correlating the ligand effect and strain effect. Thus, great attentions have been paid to explore highly active Pd-based catalysts for various electrochemical detections. Nickel(Ni) as one of the 3d metals shows a dramatically synergistic effect to enhance the electrochemical activity of Pd [19–23]. Shen et al. synthesized PdNi catalysts by simultaneous reduction method using $NaBH_4$ as reductant, finding high oxidation activity towards ethanol in alkaline solution [24]. Zhang et al. synthesized carbon-supported PdNi nanoparticles by controlling coreduction of $PdCl_2$ and Ni $(NO_3)_2$, finding excellent ascorbic acid sensing capability [25]. However, these preparation methods usually involve the reduction of various Pd precursors with organic agents and the excessive use of surfactants, which may cause undesired environmental issues. Consequently, it is essential to develop a simple and highly effective method to fabricate PdNi bimetallic nanostructure in high through-put under mild conditions.

Recently, nanoporous (NP) bimetallic structures have attracted great attention in the application of electrochemical sensing because their bicontinuous nanoscale skeletons and interconnected hollow channels are favourable for easy mass transport and high electron conductivity [26–30]. Nanoporous materials prepared by dealloying have the advantages of extremely clean metal surface, controllable and simple preparation, and excellent reproducibility [31–33]. In our previous work, it has been reported that NP-PdNi alloy was simply fabricated by a straightforward dealloying from the ternary PdNiAl source alloy in NaOH solution. It is found that NP-PdNi show superior electrocatalytic activity towards oxygen reduction reaction with higher specific and mass activities as well as higher methanol tolerance compared with Pt/C catalyst [32]. In current work, it is interesting to explore the sensing ability of NP-PdNi alloy as the platform for the electrochemical detection of H_2O_2 and glucose. On the basis of the unique electroxidation activity towards H_2O_2 and glucose, NP-PdNi alloy shows promising application potential to construct highly sensitive and stable electrochemical sensors.

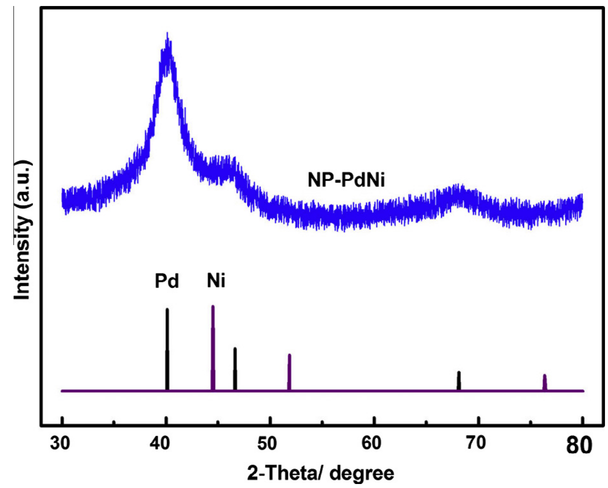

Fig. 2. XRD patterns of the dealloyed NP-PdNi sample. The standard patterns of Pd (JCPDS 65-2867) and Ni (JCPDS 65-2865) are attached for clear comparison.

2. Experimental

$Pd_{15}Ni_5Al_{80}$ and $Pd_{20}Al_{80}$ alloy foils with a thickness of 50 μm were prepared by refining respective pure (>99.9%) Pd, Al, and Ni metal in an arc furnace, followed by melt-spinning under an

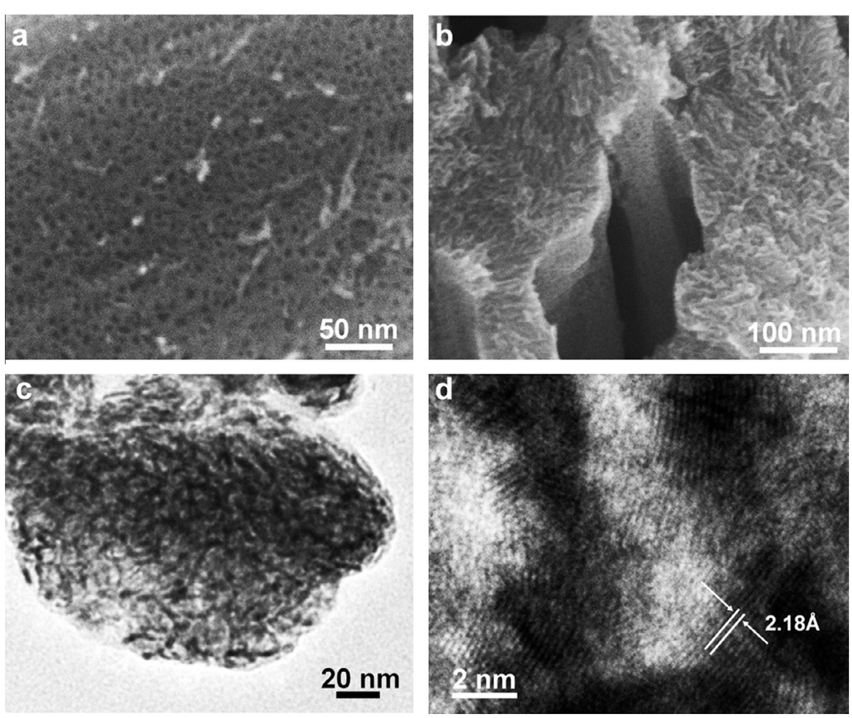

Fig. 1. SEM (a) and (b), TEM (c) and HRTEM (d) images of the resulted samples by dealloying $Pd_{15}Ni_5Al_{80}$ alloy in 0.5 M NaOH solution for 48 h at room temperature.