Applied Surface Science 554 (2021) 149530

Contents lists available at ScienceDirect

Applied Surface Science

journal homepage: www.elsevier.com/locate/apsusc

Full Length Article

Development of 3D open-cell structured Co-Ni catalysts by pulsed electrodeposition for hydrolysis of sodium borohydride

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ARTICLE INFO

Keywords:
Cobalt electrodeposition
Sodium-borohydride hydrolysis
Hydrogen production
Structured catalyst
Aluminum alloying/dealloying

ABSTRACT

Structured cobalt–nickel catalysts were synthesized by roughening the nickel-foam surface and electrodepositing cobalt onto it for application to sodium-borohydride hydrolysis. The catalysts were prepared by incorporating aluminum onto the nickel-foam surface, increasing the nickel-foam surface area by subsequently leaching the aluminum, and electrodepositing cobalt. The cobalt was chronoamperometrically electrodeposited under the optimal condition (-2.0 $V_{Ag/AgCl}$) to prevent local cobalt deposition on the substrate edge. Additionally, the cobalt was uniformly deposited onto the porous nickel foam by pulsed chronoamperometric electrodeposition wherein voltages were alternated from -2.0 to -0.3 $V_{Ag/AgCl}$, to electroplate and dissolve the cobalt, respectively. Although the resulting structured cobalt–nickel catalysts exhibited 1.5 times higher catalytic activity than the porous nickel foam, the cobalt content was only 0.57 wt% of the whole sample. In addition, the structured cobalt–nickel catalyst showed higher stability than the porous nickel foam even after ultrasonication as an accelerated durability test. Therefore, pulsed electroplating is an effective method of increasing both catalyst activity and durability.

1. Introduction

Over the last two decades, sodium borohydride ($NaBH_4$; SBH) has emerged as a promising material for chemically storing hydrogen (H_2) owing to its high gravimetric storage capacity (10.8 wt%), chemical stability, room-temperature nonflammability, and byproduct recyclability [1–3]. SBH hydrolysis with suitable catalysts can produce sufficient pure H_2 (>99%), even at room temperature, and H_2O is the only possible effluent gas.

As in many dehydrogenations, although precious metals such as platinum (Pt; \$31,783/kg_{Pt}) and ruthenium (Ru; \$8,504/kg_{Ru}) are the best metallic catalysts for SBH hydrolysis owing to their high catalytic activities [4,5], they may prevent the use of SBH hydrolysis for many H_2-generation applications. Therefore, nonnoble metals such as cobalt (Co; \$32/kg_{Co}) and nickel (Ni; \$17/kg_{Ni}) have attracted significant attention as alternatives to noble-metal catalysts [6,7]. Most recent studies on catalyst development for SBH hydrolysis have highlighted Co as an active metal because it shows the highest intrinsic catalytic activity among the nonnoble metals [8–12]. Specifically, Liu *et al.* [13] confirmed that Co is approximately 6.5 times more catalytically active than Ni in SBH hydrolysis. Furthermore, Walter *et al.* [14] reported that Co-based catalysts showed activities approximately 4.6 times higher than Ni-based ones in SBH hydrolysis. However, weak interactions between the Co active sites and the underlying ceramic supports and the high thermal gradient in the reactor often rapidly deactivate structured catalysts (*e.g.*, by Co detachment or $NaBO_2$ precipitation) and break catalyst pellets when H_2 is vigorously generated in SBH hydrolysis [15,16]. Hence, Co-based structured catalysts have been developed on metallic substrates showing sufficient thermal conductivity to increase the catalyst mechanical stability and alleviate the temperature gradient

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https://doi.org/10.1016/j.apsusc.2021.149530
Received 19 December 2020; Received in revised form 9 March 2021; Accepted 9 March 2021
Available online 13 March 2021