ECCS 2025 Conference

The 3rd International Electronic Conference on Catalysis Sciences

23–25 April 2025 | Online

MDPI

Gold Nanoparticle-Modified Nickel-Iron Coatings for Efficient Sodium Borohydride Electrooxidation

Huma Amber*, Aušrinė Zabielaitė, Irena Stalnionienė, Birute Šimkūnaitė-Stanynienė, Aldona Balčiūnaitė, Jūratė Vaičiūnienė, Loreta Tamašauskaitė-Tamašiūnaitė, Eugenijus Norkus

Center for Physical Sciences and Technology (FTMC), Saulėtekio Ave. 3, Vilnius, Lithuania

INTRODUCTION & AIM

- Sodium borohydride ($NaBH_4$) is an attractive hydrogen storage material due to its high hydrogen content and stability.
- Direct borohydride fuel cells (DBFCs) offer great potential, but their performance is limited by the slow kinetics of $NaBH_4$ electrooxidation.
- Nickel-iron (NiFe) alloys are cost-effective and electrochemically active in alkaline media.
- Gold nanoparticles (AuNPs), when integrated with NiFe, introduce synergistic effects that can improve reaction kinetics, stability, and surface reactivity.
- **Research Objective:** To design, synthesize, and evaluate AuNP-decorated NiFe coatings on a flexible copper-coated polyimide (Cu/PI) surface as efficient, durable electrocatalysts for $NaBH_4$ electrooxidation.

FABRICATION OF CATALYSTS

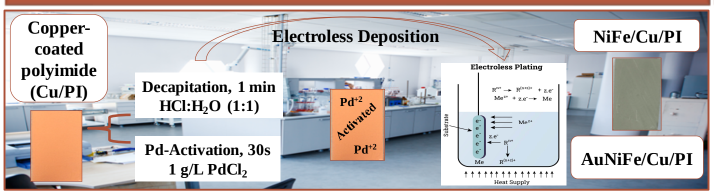

Table 1. Composition of plating baths and deposition parameters.

Coatings	Composition of plating bath, mol L^{-1}						Deposition conditions		
	$NiSO_4$*7H2O	$FeSO_4$*7H2O	EDTA	Sodium Malonate	Morpholine Borane	Glycine	T, °C	*t*, min	Solution pH
$Ni_{80}Fe_{20}$/Cu/PI	0.14	0.001	0.05	0.1	0.2	0.2	60	5	7
$AuNi_{80}Fe_{20}$/Cu/PI 1mM Au (1 min)	0.14	0.001	0.05	0.1	0.2	0.2	60	5	7

SEM & EDX ANALYSIS

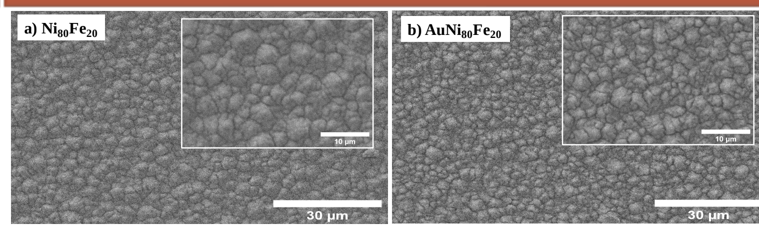

Fig. 1. SEM images of the $Ni_{80}Fe_{20}$ **(a)** and $AuNi_{80}Fe_{20}$ **(b)** coatings on Cu/PI surface.

Table 2. Composition of $Ni_{80}Fe_{20}$ and $AuNi_{80}Fe_{20}$ coatings deposited on Cu/PI surface via EDX analysis.

Catalyst	Element, wt%		
	Au	Ni	Fe
$Ni_{80}Fe_{20}$/Cu/PI	-	96.16	3.84
$AuNi_{80}Fe_{20}$/Cu/PI	16.29	82.10	1.60

RESULTS & DISCUSSION

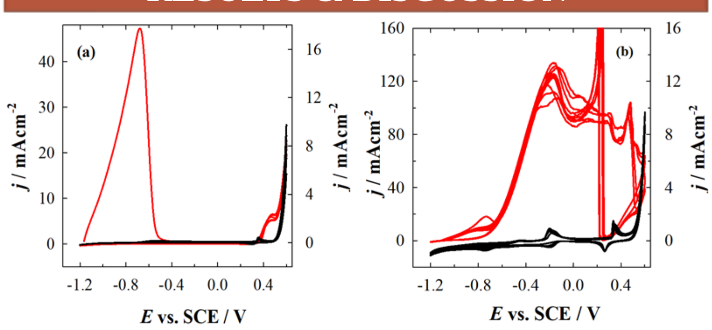

Fig. 3. CVs of $Ni_{80}Fe_{20}$/Cu/PI **(a)** and $AuNi_{80}Fe_{20}$/Cu/PI **(b)** catalysts recorded in 1 M NaOH and 0.05 M $NaBH_4$ + 1 M NaOH at 10 mV s^{-1}, T = 25°C.

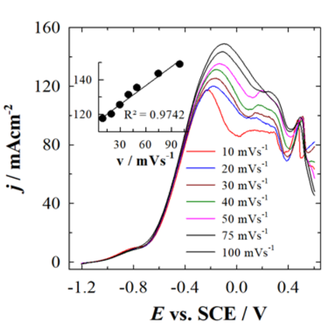

Fig. 4. LSVs of $AuNi_{80}Fe_{20}$/Cu/PI catalysts recorded in 0.05 M $NaBH_4$ + 1 M NaOH at different potential scan rates, T = 25°C.

Table 3. Fuel cell parameters of $NaBH_4$-H_2O_2 employing $Ni_{80}Fe_{20}$/Cu/PI and $AuNi_{80}Fe_{20}$/Cu/PI anode catalysts.

Catalysts	T (°C)	Peak Power Density (mW cm^{-2})	Current Density at Peak Power Density (mA cm^{-2})	Cell Voltage at Peak Power Density (V)
$Ni_{80}Fe_{20}$/Cu/PI	25	73.1	112.3	0.65
	35	80.0	122.9	0.65
	45	85.9	132.0	0.65
	55	93.6	143.9	0.65
$AuNi_{80}Fe_{20}$/Cu/PI	25	89.7	137.9	0.65
	35	100.0	153.7	0.65
	45	114.1	175.4	0.65
	55	126.3	194.2	0.65

Acknowledgement

This research was funded by a grant (No. P-MIP-23-467) from the Research Council of Lithuania.

RESULTS & DISCUSSION

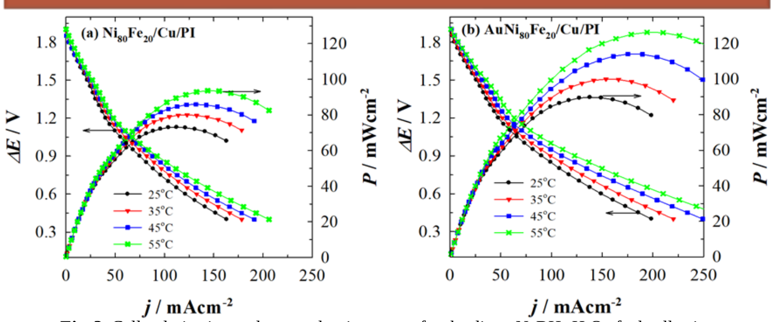

Fig. 2. Cell polarization and power density curves for the direct $NaBH_4$-H_2O_2 fuel cell using $Ni_{80}Fe_{20}$/Cu/PI **(a)** and $AuNi_{80}Fe_{20}$/Cu/PI **(b)** catalysts as the anodes/cathodes with anolyte consisting of 1 M $NaBH_4$ and 4 M NaOH and 5 M H_2O_2 and 1.5 M HCl catholyte at different temperatures.

CONCLUSION

In this study, NiFe coatings were successfully synthesized via electroless deposition on Cu/PI surface and subsequently modified with AuNPs through galvanic displacement to enhance their electrocatalytic performance in $NaBH_4$ electrooxidation. The structural and morphological characteristics of the coatings were examined using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX), confirming the successful formation of a NiFe alloy matrix and the presence of dispersed AuNPs. Electrochemical characterization, including cyclic voltammetry (CV) and linear sweep voltammetry (LSV), demonstrated that the $AuNi_{80}Fe_{20}$ coatings exhibited significantly improved catalytic performance compared to unmodified $Ni_{80}Fe_{20}$ coatings. The electrooxidation of $NaBH_4$ has been observed to occur at more negative potential values and to yield higher current densities (Fig. 3 and .4). The electrocatalysts were subjected to further evaluation in a DBFCs configuration, where the $AuNi_{80}Fe_{20}$ anode showed a superior power density of 89.7 mW cm^{-2} at room temperature under alkaline conditions, while the $Ni_{80}Fe_{20}$ anode exhibited 73.1 mW cm^{-2} (Table 3. and Fig.2). The enhanced performance is attributed to the synergistic interaction between the highly active AuNPs and the conductive NiFe matrix, which collectively promote efficient borohydride oxidation and electron transfer. This work presents a novel, cost-effective, and highly active anode engineering strategy for DBFC, with a focus on NiFe-based materials in the field of catalytic $NaBH_4$ electrooxidation and other hydrogen-based energy systems.