Gold nanoparticle–modified nickel–rhenium alloy coatings as advanced anode materials for sodium borohydride–water reduction fuel cells

Aušrinė Zabielaitė, Huma Amber, Aldona Balčiūnaitė, Loreta Tamašauskaitė-Tamašiūnaitė, Birutė Šimkūnaitė-Stanynienė, Jūratė Vaičiūnienė, Eugenijus Norkus

INTRODUCTION

Sodium borohydride ($NaBH_4$) is considered a promising alternative fuel for direct liquid fuel cells due to its high energy density and convenient handling. The development of efficient electrocatalysts for the borohydride oxidation reaction (BOR) is therefore of considerable interest. In this study, flexible nickel-rhenium (Ni_xRe_y) binary alloy coatings were successfully deposited on thin substrates (stainless steel mesh or polyimide film) using a simple, cost-effective electrodeless method using sodium hypophosphite as a reducing agent. To further improve the catalytic performance, the electrodes were modified with gold nanoparticles by galvanic displacement, yielding AuNPs-Ni_xRe_y/SSM catalysts. The research results indicate that AuNPs-Ni_xRe_y/SSM catalysts are promising flexible anode materials for high-performance BOR-HER fuel cells.

FABRICATION OF CATALYSTS

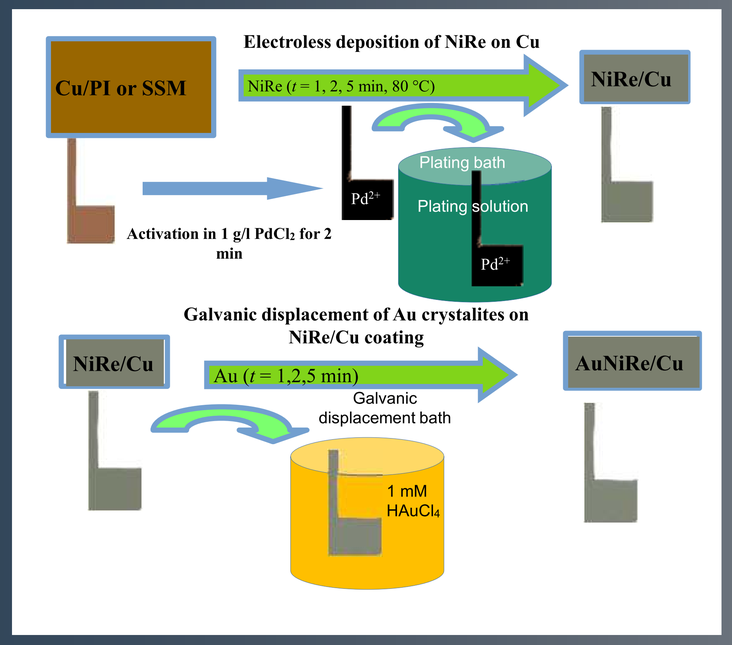

Figure 1. Scheme of deposition process of the AuNiRe catalyst on copper electrode or stainless-steel mesh (SSM).

SEM Analysis

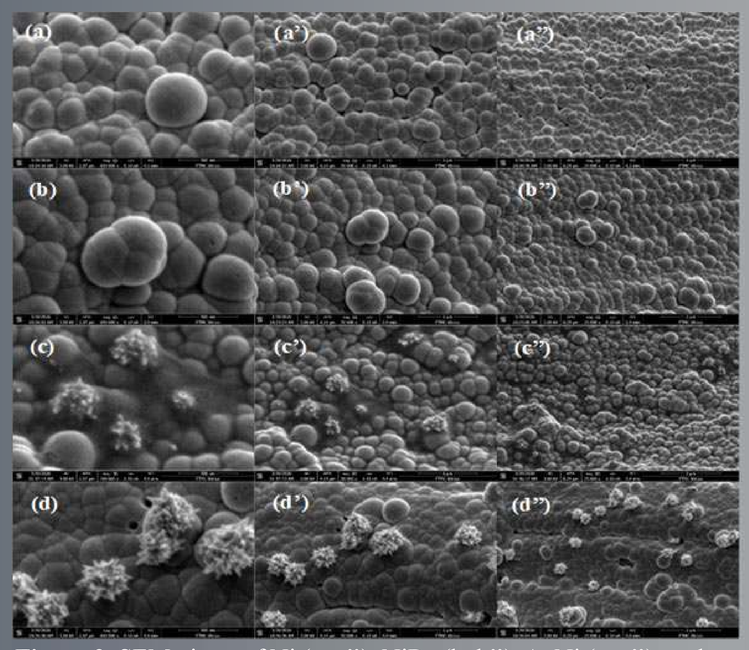

Figure 2. SEM views of Ni (a–a''), NiRe (b–b''), AuNi (c–c''), and AuNiRe (d–d'').

EDX Analysis

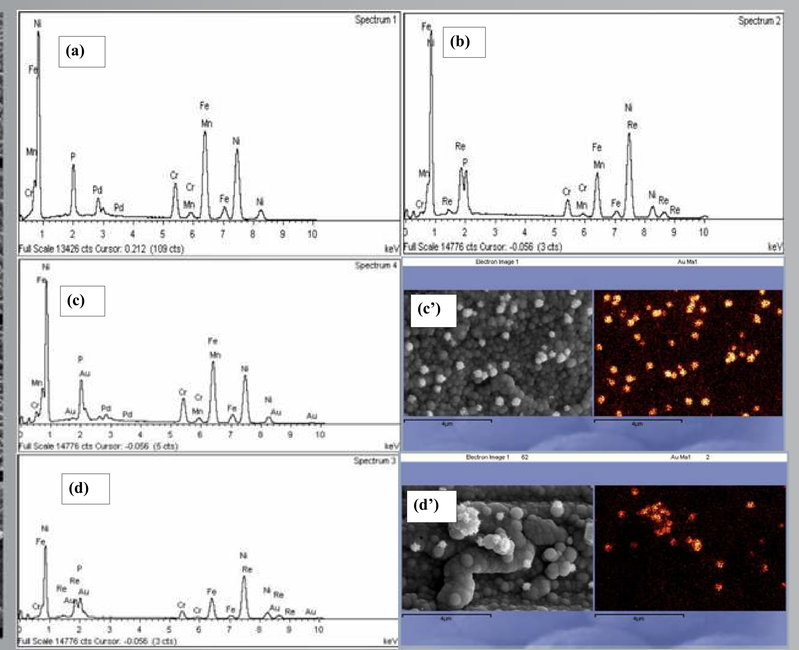

Figure 3. The EDX analysis data.

BOROHYDRIDE OXIDATION

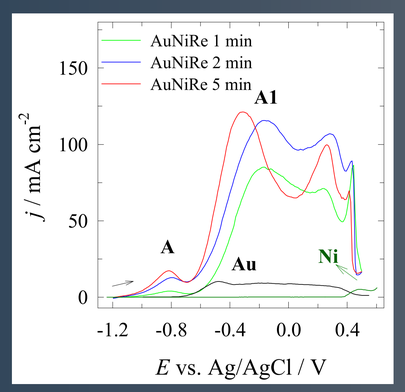

Figure 4. LSVs of Au (solid line), Ni (dark green line), and AuNiRe catalysts recorded in a 0.05 M $NaBH_4$ + 1 M NaOH solution. The deposition time of Au crystallites on the NiRe catalysts was 1 (green line), 2 (blue line), and 5 (red line) minutes.

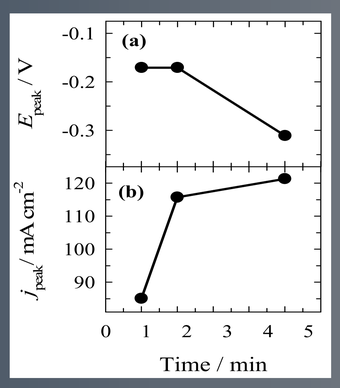

Fig. 5. Dependence of sodium borohydride oxidation peak potential (a) and current density (b) values on the deposition time of Au crystallites on the NiReP/Cu catalysts.

HYDROGEN EVOLUTION

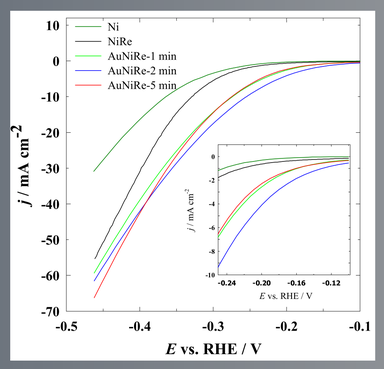

Fig. 6. LSVs recorded on Ni, NiRe, and AuNiRe catalysts in Ar-saturated 1 M KOH at 2 mV s^{-1}.

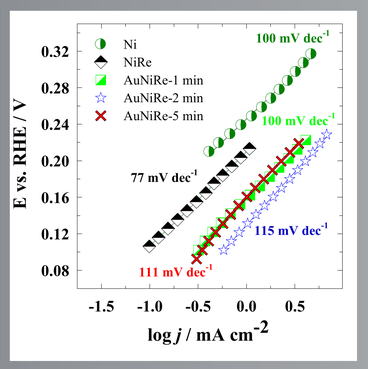

Fig.7 The corresponding Tafel slopes on the same catalysts.

Table 1. Quantitative results of atomic concentration of selected elements on the basis of EDX presented in Figure 3.

Sample	Elements, at%							
	Au	Ni	P	Re	Fe	Cr	Mn	Pd
Ni–P	–	40.74	11.88	–	33.55	9.95	0.66	3.22
Ni–Re–P	–	55.07	12.26	7.15	19.32	5.81	0.39	–
Au–Ni–P	1.62	39.92	12.71	–	33.56	9.91	0.64	1.65
Au–Ni–Re–P	1.26	59.20	10.63	5.87	17.61	5.09	0.34	–

Table 2. η_{10} mV in 1 M KOH.

Catalysts	η_{10} mV in 1 M KOH
Ni	360
NiRe	327
Au 1 min	271
Au 2 min	252
Au 5 min	270

CONCLUSIONS

The as-prepared Au-NiRe catalysts exhibited a higher electrocatalytic activity toward the BOR as compared with that of a bulk Au and NiRe electrode, and seem to be a promising anodic material for BOR-HER fuel cells.

It was found that the catalyst AuNiRe-2 min shows the highest current density and gives the lowest overpotential of 252 mV for HER to reach a current density of 10 mA cm^{-2} in 1 M KOH.

CONTACT
Center for Physical Sciences and Technology, Vilnius, Lithuania
ausrine.zabielaite@ftmc.lt

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