

Anion-exchange-membrane water electrolysis based on Nickel ferrite catalysts for the oxygen evolution reaction (O-8H-V)

Angela Capri^{1*}, Irene Gatto¹, Carmelo Lo Vecchio¹, Stefano Trocino¹, Alessandra Carbone¹, Vincenzo Baglio^{1**}

¹ Institute for Advanced Energy Technologies "Nicola Giordano" - CNR-ITAE, Via S. Lucia sopra Contesse 5 - 98126 Messina, Italy

(*) Pres. author: angela.capri@itae.cnr.it

(**) Corresp. author: vincenzo.baglio@itae.cnr.it

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1. Introduction

The need to find some innovative strategies to develop new energy technologies is a priority since the use of fossil fuels has become unsustainable. Hydrogen is a promising vector for the storage and transport of energy from renewable sources. Water electrolysis is considered a sustainable production method if powered by renewable sources because it does not produce direct carbon emissions [1].

Electrocatalytic oxygen reduction/evolution reactions (ORR/OER) are essential for renewable energy conversion and storage devices such as electrolyzers and fuel cells [2][3]. Still today, some of the leading research lines are aimed at obtaining electrocatalysts characterized by high stability, high activity, high efficiency, economically sustainable and, at the same time, PGM-free [4].

Until now, alkaline electrolysis is the technology that shows the greatest potential. In an alkaline electrolytic cell, the electrodes are in contact with an alkaline solution, generally potassium hydroxide. The high hydroxide concentration influences both cell performance and conductivity, but this technology suffers from low productivity and high maintenance costs associated with the caustic electrolyte. In the last few years, a growing interest has been tied to a system based on anion exchange membranes (AEM) due to their high selectivity, low resistance, and high current density obtained [5][6]. At the cathode, the water is split to form H₂ releasing hydroxide anions, which pass through the membrane and are oxidized at the anode producing O₂. For the latter reaction, good prospects are associated with electrocatalysts based on transition metal oxides that show good conductivity and stability under the conditions of use. This work reports the synthesis and use of a NiFe₂O₄ spinel deposited directly on a commercial anion exchange membrane (FAA3-50 by FumaTech).

2. Experimental

NiFe₂O₄ was obtained by a liquid-phase method, at atmospheric pressure, via the so-called oxalate route [7]. The brown precipitate obtained was then filtered under vacuum and dried in an oven at 80°C overnight. Then it was calcined at 350°C, in air, for 2h.

Anodes were prepared mixing for 30 minutes, under sonication, an exact amount of the catalysts with 20 wt.% of ionomer. The obtained ink was then applied by spray coating technique directly onto the FAA3-50 membrane, with a loading of 3 mg/cm², forming a catalyst-coated membrane (CCM). Cathodes were made using a commercial Platinum on carbon. The ink was deposited by spray coating technique onto the Sigracet 25-BC Gas Diffusion Layer (SGL) to obtain a gas diffusion electrode (GDE) with 0.5 mg/cm² Pt/C. Ni felt was coupled to the CCM (at the anode side) for all the tests performed.

The CCM and cathodes were previously exchanged in a 1M KOH solution for 1h before assembling them.

The crystallographic structure and morphology of the catalyst powder were investigated by X-ray diffraction (XRD) and Scanning Electron Microscopy (SEM). The XRD pattern of the sample was obtained by a Bruker D8 Advance diffractometer (Bruker, Billerica, MA, USA), scan type: Coupled TwoTheta/Theta, measurement range: 5–80°, step size: 0.010° in 0.1 s, Voltage: 40 kV, Current: 40 mA, Anode: Cu (k α 1: 1.54060 Å, k α 2: 1.54439 Å). The obtained spectrum was compared with reference peaks for the spinel structure. Scanning electron microscopy (SEM) analysis was carried out employing a Philips XL-30-FEG scanning electron microscope. The analyses were performed with an accelerating voltage of 20 kV and a spot width of 3.

Electrochemical characterizations were carried out in a temperature range between 30 - 60°C at atmospheric pressure. Electrochemical measurements were realized out using a potentiostat-galvanostat device PGSTAT302N equipped with an FRA module (Autolab). I-V curves were performed at a scan rate of 5 mV/s. An alkaline solution (KOH 1M) was supplied by a peristaltic pump to the anode section of the single cell, with a flow rate of 5 ml/min.

3. Discussion

The crystalline structure was analyzed by XRD, confirming the spinel structure. Figure 1 shows the XRD pattern of the sample, with broad peaks indicating very small

crystallite size (less than 3 nm). The inset of Figure 1 shows the SEM micrograph, which reveals a porous structure.

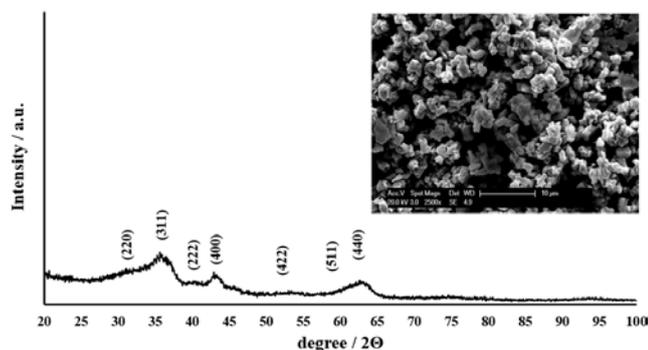


Figure 1 XRD pattern of the NiFe₂O₄ sample, with the Miller indexes. The inset shows a SEM image.

Electrochemical tests were carried out increasing the temperature in a range between 30°C and 60°C. At 2.2 V, current density values equal to 1.6 A/cm², 2.17 A/cm², 2.69 A/cm² and 3.0 A/cm² were obtained, respectively, which are higher than those reached using noble metal catalysts (not shown).

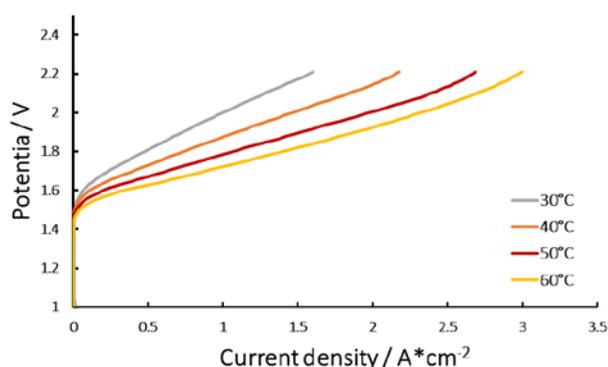


Figure 1 Polarization curves, at different temperatures, of the cell based on NiFe₂O₄ catalyst at the anode.

4. Conclusions

A nano-sized nickel-ferrite sample was synthesized and used as an electrocatalyst for anion exchange membrane (AEM) water electrolyzers. The application of the ink directly on the membrane resulted in a homogeneous coating. The electrolyzer showed good activity for the oxygen evolution reaction (OER) and proper durability (not shown here). A comparison with commercial noble metal catalysts (IrO₂) showed, at the same temperature and cell configuration, higher current density values. It is also believed that this system can be easily further improved. Particularly relevant, at 60°C, is the value of 3.0 A/cm² recorded at 2.2 V.

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