

Electrocatalytic activity of Ni modified carbon paste electrode in direct ethanol fuel cells

Sadiki Lamari Abdelmajid, Salah Eddine Ei Qouatli, Abdelilah Chtaini*

Equipe d'Electrochimie Moléculaire et Matériaux Inorganiques, Université Sultan Moulay Slimane, Faculté des Sciences et Techniques de Béni Mellal, (MAROC)

E-mail: a.chtaini@usms.ma

ABSTRACT

Investigations on systems using Ni modified carbon paste electrode (Ni-CPE) electrocatalysts for ethanol oxidation in alkaline solution. The relative activities of the Ni-CPE catalyst were assessed. The results show that this electrode is active for the ethanol oxidation. The prepared electrode shows a considerable performance in direct ethanol fuel cell.

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KEYWORDS

Fuel cell;
Ethanol;
Electrocatalyst;
Modified electrode;
Power density.

INTRODUCTION

The performance of direct ethanol fuel cell is still limited by the electrocatalysts available for ethanol oxidation.

Fuel cells have been identified as a promising power source for transportation and portable electronic devices, since they convert the chemical energy of a fuel directly into electrical energy; have low emissions and absence of moving parts. The Direct Ethanol Fuel Cell is an electrochemical device which converts the energy through chemical reactions: electrooxidation of ethanol, into electrical energy. The demand for energy, coupled with concerns about environmental pollution and growing fossil fuel costs have created a great need for clean and efficient power sources^[1]. Both direct methanol fuel cells and direct ethanol fuel cells have been projected to be strong candidates to compete with advanced batteries for powering mobile and portable electronic devices owing to their uniquely high specific energy^[2]. However methanol is toxic for hu-

man beings is easily volatile and inflammable as well as non-renewable^[3-5]. Among the other alcohols available, ethanol appears as an attractive and promising fuel due to its:

1. Non-toxicity,
2. Natural availability,
3. Renewability
4. Higher power density

Based on that, direct ethanol fuel cells (DEFCs) appear as more attractive technologies than direct methanol fuel cells (DMFCs)^[6-8].

The performance of direct ethanol fuel cells (DEFCs) is still limited by the electrocatalysts available for ethanol oxidation, which are mostly based on expensive noble metals such as platinum or its alloys^[9-12].

Past research on the development of DEFCs has focused mainly on the so-called PEM DEFCs that use PEM as the electrolyte, a Pt-based catalyst on the anode, and a pure Pt catalyst on the cathode^[13-14].

In this work, Ni-CPE anode is prepared by electrodeposition nickel catalyst layer onto carbon paste surface. The morphology and structure of the relative

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activities of the Ni-CPE anode were assessed by TEM. The relative activities of the prepared electrode were tested for ethanol oxidation reaction.

EXPERIMENTAL SECTION

Apparatus

Electrochemical experiments were performed using a voltalab potentiostat (model PGSTAT 100, Eco Chemie B. V., Utrecht, The Netherlands) driven by the general purpose electrochemical systems data processing software (voltalab master 4 software).

All the electrochemical experiments were performed in a standard one-compartment three-electrode cell. The reference electrode was SCE and the counter electrode was platinum. All electrode potentials were referred to this reference electrode. The working electrode was copper modified carbon paste electrode (Ni-CPE).

Reagents and solutions

All chemicals were of the highest quality. Graphite powder (spectroscopic grade RWB, Ringsdorff-Werke GmbH, Bonn-Bad Godesberg, Germany) was obtained from Aldrich and was used without further purification. NiSO_4 was obtained from Merck chemicals. Deionised water was used to prepare all solution. Electrolytic solution is 0.1 M KOH.

Preparation of the modified electrode

The carbon paste unmodified was prepared by adding paraffin oil to carbon powder and thoroughly hand-mixing in a mortar and pestle. The resulting paste was packed into the electrode and the surface was smoothed. The electrocatalyst electrode (Ni-CPE) was developed by depositing the nickel at fixed potential (0.1 V for 1 hour) onto the carbon paste electrode surface.

RESULTS AND DISCUSSION

Characterization of prepared electrode

The cyclic voltammograms (CVs) of the unmodified carbon paste electrode (CPE), and Ni-CPE were recorded in the supporting electrolyte (0.1M KOH solution). The change of the CVs shapes (Figure 1), before and after modification, is a major sign that the

carbon paste electrode was, effectively, modified with Ni.

A typical EDX spectrum is shown in Figure 2 the atomic ration of Ni (electrodeposited onto carbon paste electrode) is about (40%). The characteristic peak of Ni can not be found in Figure 2. It indicates that CPE is almost fully covered by the Ni catalyst layer.

The Nyquist plots for the tested electrode Ni-CPE, in alkaline solution is presented in Figure 3. The locus of Nyquist plots is regarded as one part semi circle in CNI-CPE electrode (curve b), but in carbon paste electrode (curve a), the plot was not perfect semi circle. This feature had been attributed to frequency dispersion of interfacial impedance, and corrosion resistance of carbon paste electrode better than Ni-CPE.

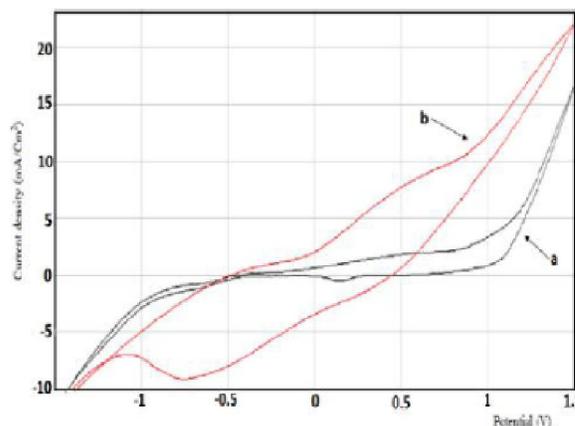


Figure 1 : Cyclic voltammograms recorded in electrolytic solution at 100 mV/s, at a- carbon paste electrode, b- nickel modified carbon paste electrode.

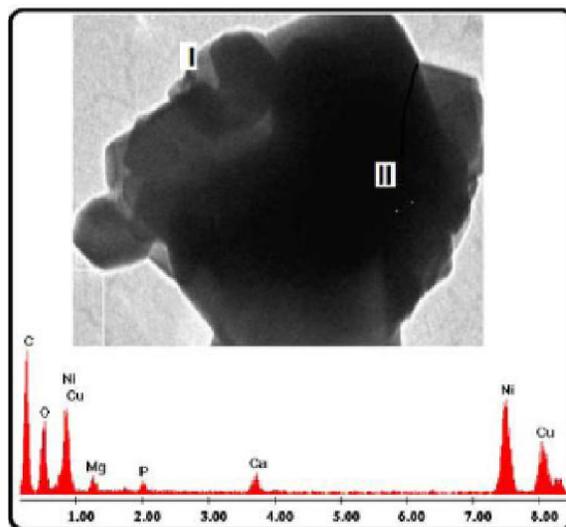


Figure 2: EDX spectra analysis of the Ni-CPE scanning electron micrographs of the cross-section of Ni-CPE anode: II: Ni and I: CPE catalyst.

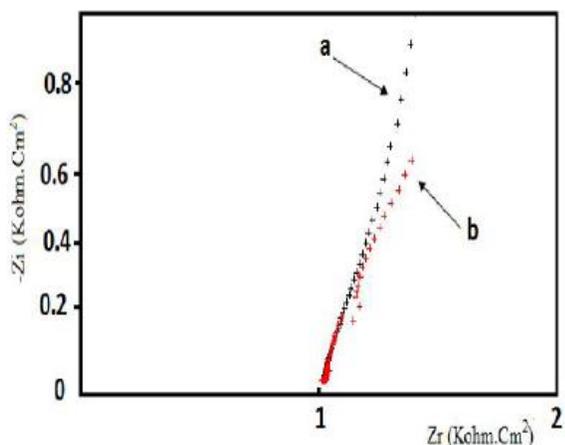


Figure 3: Electrochemical impedance spectroscopy recorded for CPE (curve a) and Ni-CPE (curve b), in 1M KOH solution.

Ethanol oxidation

Figure 4 compares the transient curves recorded, successively, at carbon paste electrode (curve a) and at nickel modified carbon paste electrode (curve b), in 0.1M KOH containing 0.24 mol/L ethanol. It is clearly seen that carbon paste electrode has little activity of ethanol oxidation. The onset potential of ethanol oxidation is observed at around 500 mV for Ni-CPE (Figure 5). The Ni-CPE showed much better electrochemical activity and stability than carbon paste electrode.

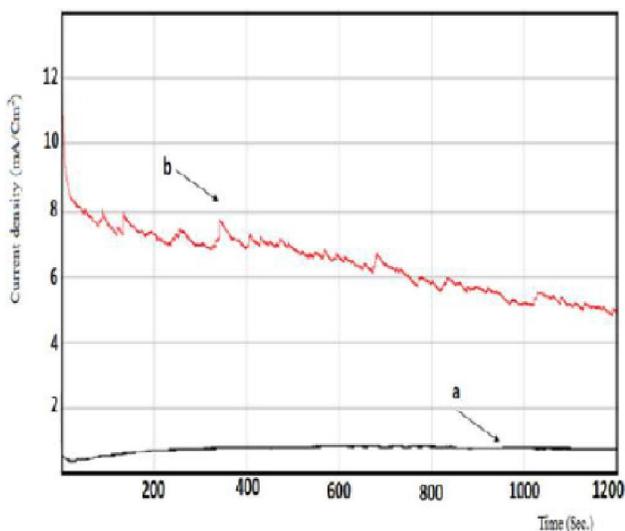


Figure 4: Chronoamperometry curves of a-Carbon paste electrode and b- Ni-CPE for ethanol oxidation, in 0.1M KOH.

The ethanol concentration on fuel cell performance has a positive effect. An increase on ethanol concentration will lead to an increase on the coverage of the electrocatalyst, increasing the ethanol oxidation reaction, and to an increase of current density (Figure 6).

The results presented in Figure 7, show that increase of ethanol concentration leads to increase in cell performance.

The effect of ethanol concentration on fuel cell performance usually, have two different effects, a positive and a negative one:

- (1) An increase on ethanol concentration will lead to an increase on the coverage of the electrocatalyst, increasing the ethanol oxidation reaction, and to increase of the oxidation current density;

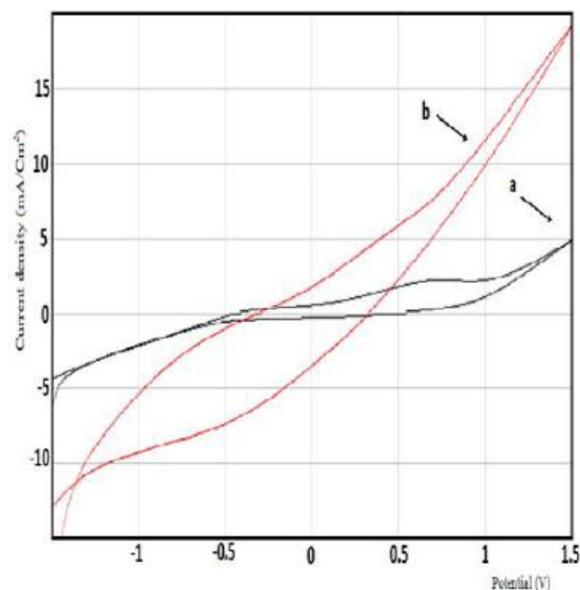


Figure 5: Steady state cyclic voltammograms of a- carbon paste electrode and b- Ni-CPE in 0.1 M KOH + 0.24 M ethanol, scan rate 100 mV.s⁻¹, room temperature.

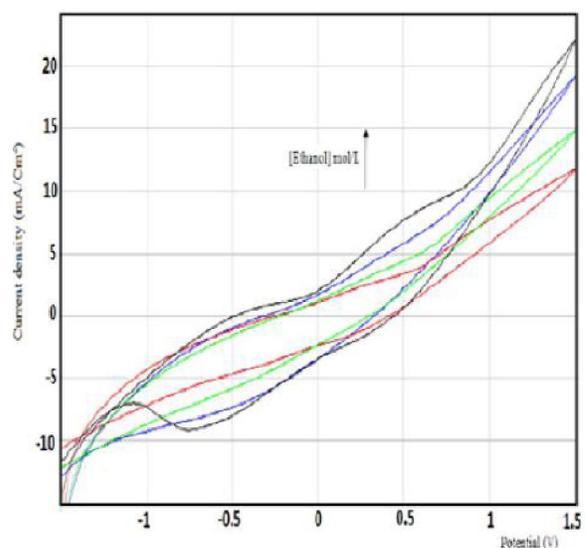


Figure 6 : Influence of ethanol concentration on oxidation current density.

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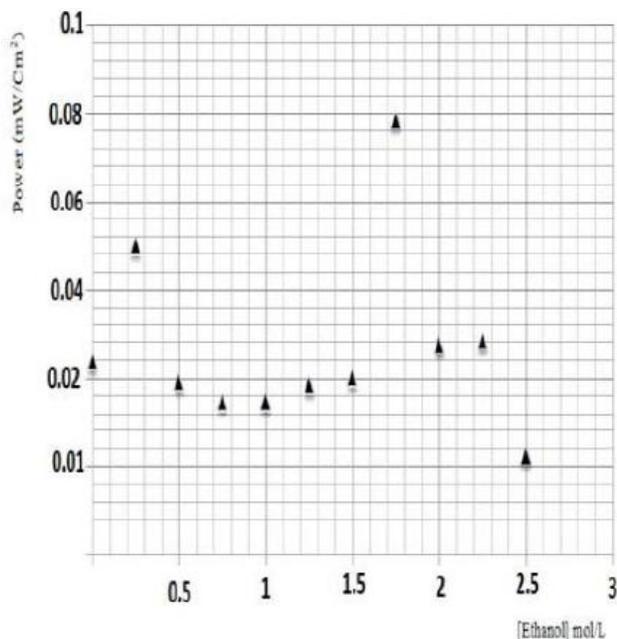


Figure 7 : Influence of ethanol concentration on power density

- (2) From a certain concentration of ethanol, the total active sites were occupied by the ethanol molecule, which leads to the deterioration in performance of the fuel cell.

CONCLUSION

Based on the obtained results and discussion, it is concluded that Ni-CPE based catalyst shows good promises to improve the activity of oxidation reaction of ethanol in alkaline media, and the effect of ethanol concentration was studied.

High ethanol concentrations achieve lower fuel cell performance.

REFERENCES

- [1] W.Du, K.Mackenzie, F.Daniel, N.Milano, A.Deskins, D.Su, X.Teng; *ACS Catal*, **2**, 287-297 (2012).
 [2] S.Y.Shen, T.S.Zhao, J.B.Xu, Y.S.Li; *J.Power Sources*, **195**, 1001-1006 (2010).
 [3] W.J.Zhou, B.Zhou, W.Z.Li, Z.H.Zhou, S.Q.Song, G.Q.Sun, Q.Xin, S.Douvartzide, M.Goula, P.Tsiakaras; *J.Power Sources*, **126**, 16-22 (2004).

- [4] C.Lamy, A.Lima, V.Lerhun, F.Delime, C.Coutanceau, J.M.Leger; *J.Power Sources*, **105**, 283-296 (2002).
 [5] K.Sundmacher; *Ind.Eng.Chem.Res*, **49**, 10159-10182 (2010).
 [6] F.Achmad, S.K.Kamarudin, W.R.W.Daud, E.H.Majlan; *Appl.Energy*, **34**, 1681-1689 (2011).
 [7] X.U.A.Faghri; *J.Power Sources*, **226**, 223-240 (2013).
 [8] A.Faghri, Z.Guo, Allp; *Therm.Eng.*, **28**, 1614-1622 (2008).
 [9] K.Y.Chan, J.Ding, J.Ren, K.Y.Tsang; *J.Mater.Chem.*, **14**, 505-516 (2004).
 [10] H.Wang, Z.Jusus, R.J.Behm; *J.Phys.Chem.*, **B108**, 19413-19424 (2004).
 [11] F.Figier, S.Rousseau, C.Coutanceau, J-M.Leger, C.Lamy; *Top.Catal.*, **40**, 111-121 (2006).
 [12] G.Siné, D.Smida, M.Limat, G.Foti, C.Comminellis; *J.Electrochem.Soc.*, **154**, B170-B174 (2007).
 [13] E.Antolini; *J.Power Sources*, **1**, 1-12 (2007).
 [14] N.Fujiwara, K.Fridrich, U.Stimming; *J.Electroanal Chem.*, **472**, 120-125 (1999).