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Energy conversion using copper modified carbon paste electrode in direct ethanol fuel cell

Sadiki Lamari Abdelmajid, sakina Touzara, Salah Eddine El 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

The copper modified carbon paste electrode (Cu-CPE) is designed and prepared by electro deposition of copper onto carbon paste surface for a direct ethanol fuel cell (DEFC). The morphology and structure of the catalyst layer were analyzed by MEB. The catalyst coating layer shows an alloy character. The results show that Cu-CPE is very active for the ethanol oxidation.

KEYWORDS

Ethanol electro oxidation;
Copper catalyst;
Alkaline media;
Electro deposition.

INTRODUCTION

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 derectly 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 complete with advanced batteries for powering mobile and portable electronic devices owing to their uniquely high specific energy[2]. However methanol is toxic for human 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 it's:

i Non-toxicity,
ii Natural availability,
iii Renewability
iv 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, Cu-CPE anode is prepared by electrodeposition copper catalyst layer onto carbon paste surface. The morphology and structure of the relative activities of the Cu-CPE anode were assessed by MEB. The relative activities of the prepared electrode were tested for ethanol oxidation reaction.

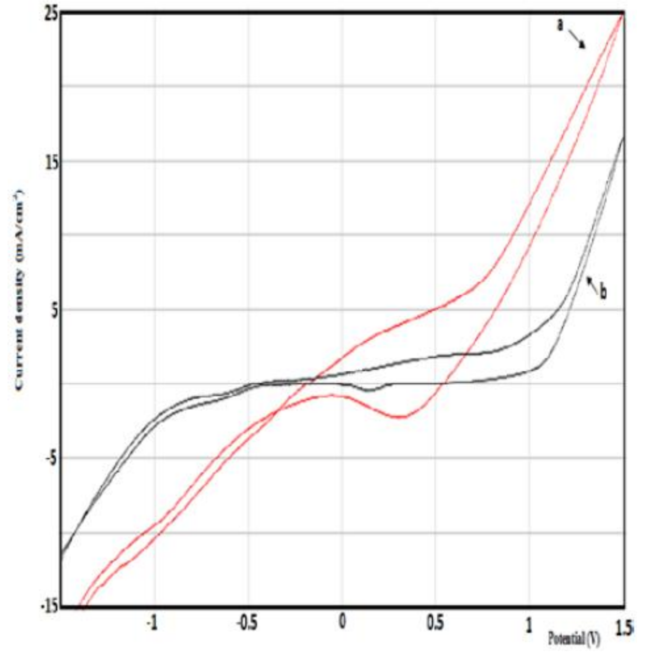

Figure 1: Cyclic voltammograms recorded in buffer solution at 100 mV/s, at b- carbon paste electrode, a- copper modified carbon paste electrode

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 (Cu-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. $CuSO_4$ 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 electrochemical sensor was developed by depositing the copper at fixed potential (0.1 V for 1 hour) onto the carbon paste electrode surface.

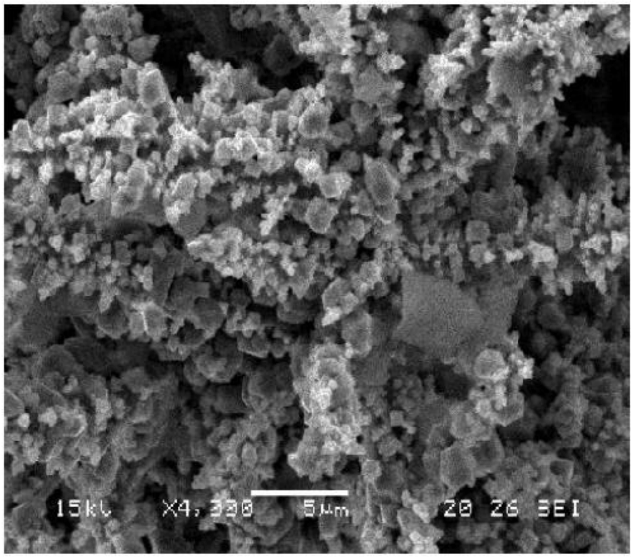

Figure 2: Scanning electron micrograph of Cu-CPE

RESULTS AND DISCUSSION

Characterization of prepared electrode

The cyclic voltammograms (CVs) of the copper modified carbon paste electrode (Cu-CPE) and carbon paste electrode (CPE) were recorded in the supporting electrolyte (0.1 M KOH) (Figure 1).

We can see that the shape of the cyclic voltammogram was modified in the presence of copper at CPE surface, suggesting that the carbon paste electrode was effectively modified by copper. The surface structure of copper modified carbon paste surface was observed using scanning electron microscopy (Figure 2). The film layer of copper was formed on the surface of carbon paste electrode; it was not disintegrated or detached from the surface when immersed in the buffer solution.

The Nyquist plots for the tested electrode Cu-CPE, in alkaline solution is presented in Figure 3. The locus of Nyquist plots is regarded as one part semi circle in Cu-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 Cu-CPE.

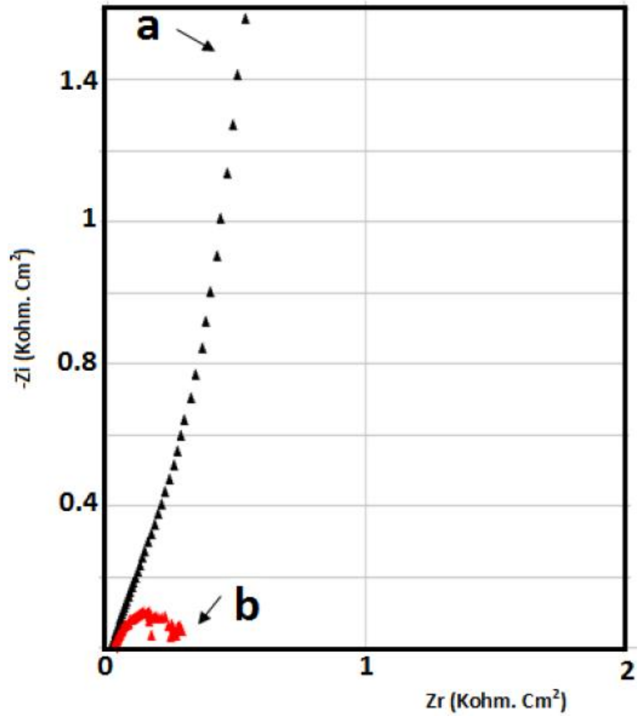

Figure 3: Electrochemical impedance spectroscopy recorded for, a- carbon paste electerode and b- Cu-CPE electrode, in 1M KOH solution.

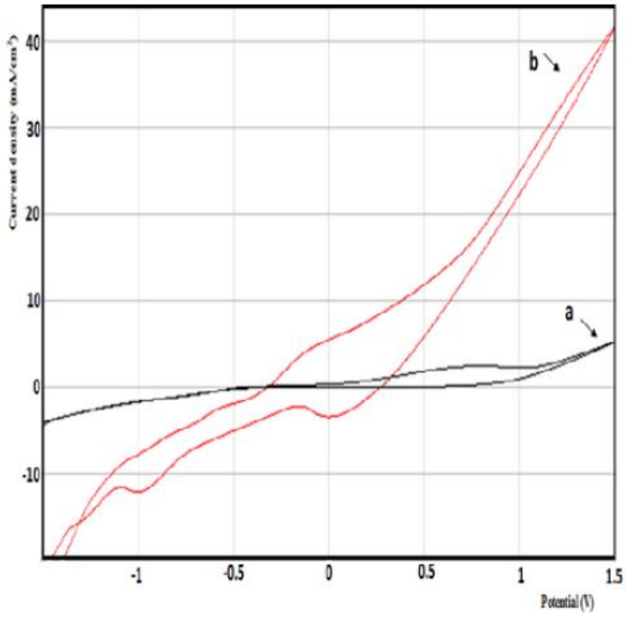

Figure 5: Steady state cyclic voltammograms of a- carbon paste electrode and b- Cu-CPE in 0.1 M KOH + 0.12 M ethanol, scan rate 100 mV.s^{-1}, room temperature

Ethanol oxidation

Figure 4 compares the transient curves recorded, successively, at carbon paste electrode (curve a) and at copper modified carbon paste electrode (curve b), in 0.1M KOH containing 0.12 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 400 mV for Cu-CPE (Figure 5). The Cu-CPE showed much better electrochemical activity and stability than carbon paste electrode.

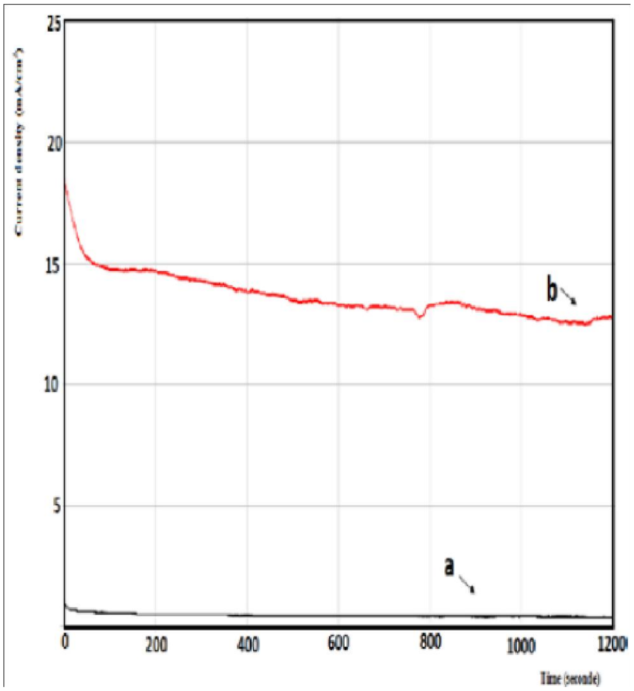

Figure 4: Chronoamperometry curves of a-Carbon paste electrode and b- Cu-CPE for ethanol oxidation, in 0.1M KOH

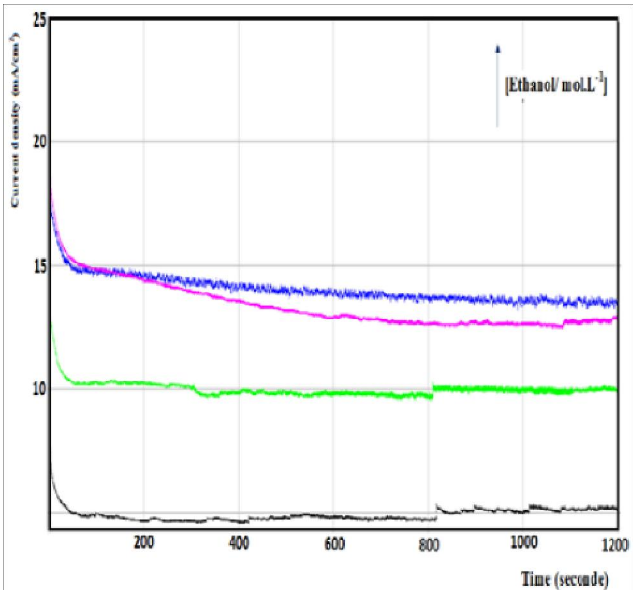

Figure 6: Influence of ethanol concentration on oxidation current density

The ethanol concentration on fuel cell performance has a positive effect. An increase on ethanol concen-

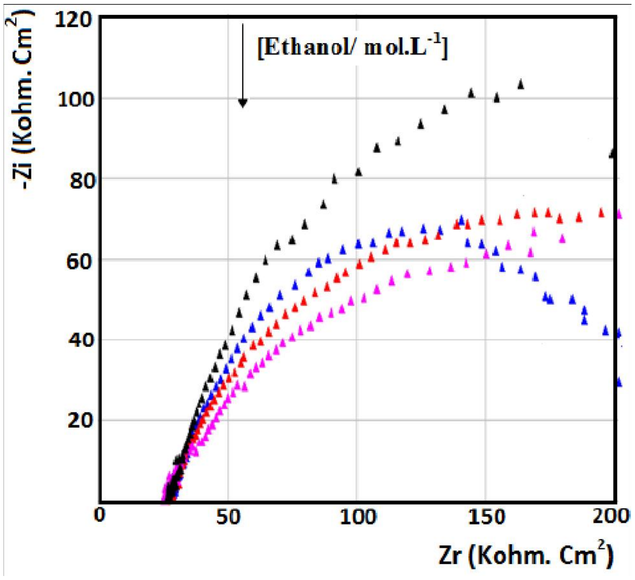

Figure 7: Effect of ethanol concentration on the electrochemical impedance spectroscopy

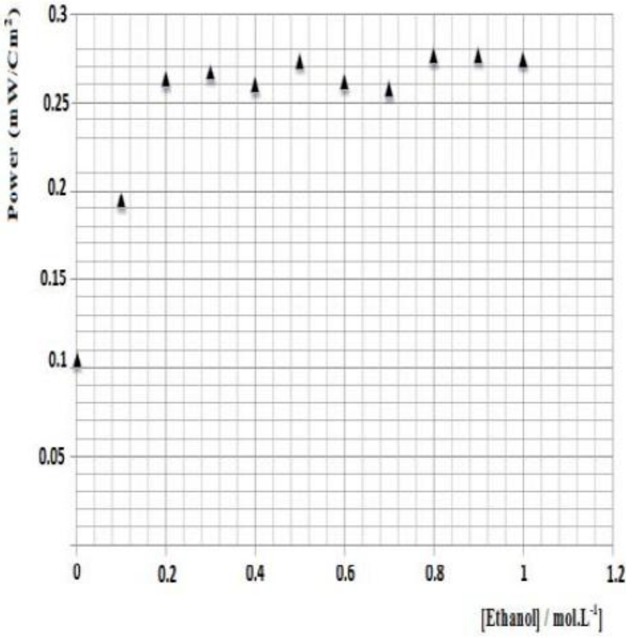

Figure 8: Influence of ethanol concentration on power density

tration 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 effect of the concentration of ethanol was also investigated by spectroscopy Impedance. We note that the diameter of the semi circle down gradually as the concentration of ethanol increases. This shows that the oxidation reaction is intense for the high concentration of ethanol (Figure 7).

The results presented in Figure 8, show that increase of ethanol concentration leads to increase in cell performance.

CONCLUSION

Low ethanol crossover is essential to improve the performance of DEFCs and achieve higher power densities.

In this work, the effect of ethanol concentration, and the effect of addition of copper onto carbon paste electrode were studied.

In this work the maximum power density, 0.3 mW/cm^2, was obtained using copper modified carbon paste electrode.

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