

# Synthesis, Determination of the Structure and Electrochemical Performance of the Palladium-Cobalt Alloy Catalyst Based on the Graphene for usage in the direct alcohol fuel cells with ethanol fuel

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## Abstract

In this study, Palladium-Cobalt alloy catalyst was synthesized based on the graphene, and its structure was evaluated by scanning electron microscopy, transmission electron microscopy, and X-ray diffraction tests. The results of structural tests showed that the average of particles of the synthesized catalyst was 70 nm in size, and the particles were regularly throughout the catalyst samples, and their accumulations were low. The electrochemical performance of the palladium-cobalt alloy catalyst was assessed in the ethanol oxidation at an alkaline medium into a three-electrode system. The results showed that the synthesized catalyst had significant activity in terms of the peak density of the high flux and low initiation potential in the electrochemical oxidation of the ethanol. Also, the synthesized catalyst showed excellent stability against the poisoning caused by ethanol oxidation products.

**Keywords:** Alcohol Fuel Cells; Palladium-Cobalt Alloy Catalyst; Three-Electrode System

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## 1. Introduction

The tremendous human need for energy sources has always been a principal problem in human life, and efforts to achieving the endless source of energy have been considering as the long-term of human aspirations. Given the fact that the amount of energy consumption in the world and the limited resources of fossil fuels has increased, it cannot rely upon presence resources of energy (1). Nowadays, the use of new energy sources has been considered due to the concerns about warming, population growth, advancement in technology, as well as, the quick decreases of the oil resources in the world. During recent years, fueled cells have been considered as a promising choice to provide future energy needs with the scarcity of environmental

pollutions. The target of cells is to immediately convert the stored energy in chemicals toward more efficient energy, such as electrical energy. Fuel cells have different types, including hydrogen cell, alcohol cell, solid oxide, phosphoric acid, and molten carbonate. Today, direct alcohol fuel cells are considered as sources of providing energy for portable applications (2). Similar to any developing technology, fuel cells have several challenges in the advance path, in addition to having numerous benefits. One of the most important challenges in the field of the fuel cells is the expensive cost and performance of the used catalyst layer in them. The subject of the present study is to improve the electrocatalyst medium and the type of used electrocatalyst in the anodic of alcohol fuel cells. Various alcohols such as methanol, ethanol,

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ethylene glycol, and glycerol have a high volumetric density of energy and used as fuel in the alcohol fuel cell. Since the oxidation process of mentioned alcohols hardly takes place on the platinum and platinum alloys, and on the other hand, due to the high cost of platinum and its alloys, various studies have been performed to designing and synthesis the new catalytic structures for the anodic section of the alcohol fuel cells which are without platinum. In this study, catalysts of cobalt-palladium were synthesized, and its electrochemical performance was evaluated in the reaction of ethanol oxidation.

## 2. Experimental section

The methodology was based on three parts:

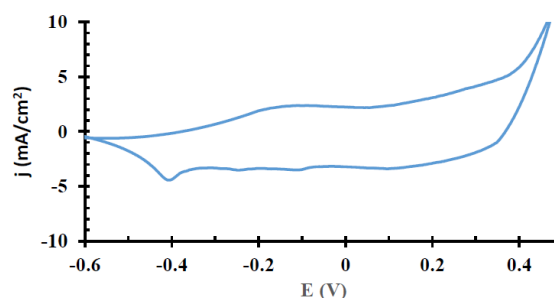
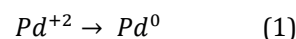
- 1) Synthesis of Palladium-Cobalt alloy catalyst: A solution containing 25 mg of graphene and 25 cc of ethylene glycol was added to a solution containing 12 g of palladium chloride (PdCl<sub>2</sub>) and 19 g of cobalt acetate dissolved in ethylene glycol. Then, hydrazine hydrate (5 cc) was added to the mentioned solution under argon gas; Eventually, the final solution was placed in the furnace at 222 °C.
- 2) Palladium-cobalt catalyst based on the graphene (2 mg), isopropyl alcohol (1 cc), distilled water (1 cc) and 0.20 cc of Nafion solution 5% was placed for 5 minutes under ultrasound waves. The obtained homogeneous solution was transferred on the surface of the glassy carbon electrode with a 0.0314 cm<sup>2</sup> area by a sampler.
- 3) Catalyst structure detection tests: The structure of synthesized catalyst powder was evaluated by various tests, including SEM-FE, XRD, and TEM tests. The electrochemical performance of the catalyst in the reaction of ethanol oxidation was estimated by a three-electrode test.

## 3. Results and discussion

### 3.1 Results of cyclic voltammetry (CV) test

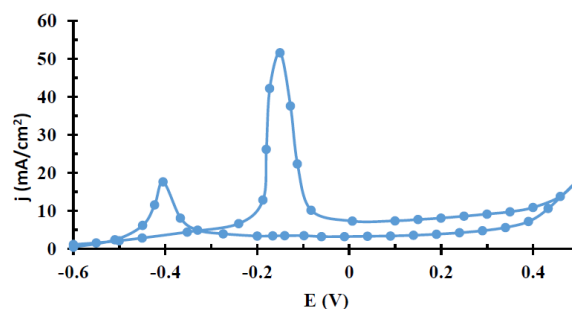
In cyclic voltammetry, the scan process starts from the initial potential. After reaching the potential to the final value, in order to reach the potential to the initial state, it is done on the contrary direction of the scan process. For comparing the electrochemical activity level and the stability of the catalysts in an alkaline medium, a cyclic voltammetry method was used into a potassium hydroxide solution 1 M. After preparing the electrodes, from each electrode in the mentioned solution were tested equal to 150 continuous cycles to determine the effect of base electrolyte concentration on the reaction of the electrode. Figure 1 was performed under the absence of ethanol fuel. The results of the chart show that the forward reaction was happened due to the presence of palladium oxide, and subsequently, palladium oxide converted to the palladium at the

backward reaction. At backward reaction, we observed a peak at -0.4 V, which was related to the reduction of palladium oxide.

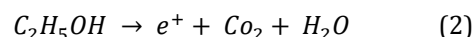


**Figure 1.** Catalyst cyclic voltammogram of Pd-Co/Gr into a KOH solution 1 M with scanning speed equal to 50 mV.s<sup>-1</sup>

In figure 2 ethanol was used as fuel, which causes ethanol to be placed on the surface of the catalyst, and the oxidation reaction was taken place.



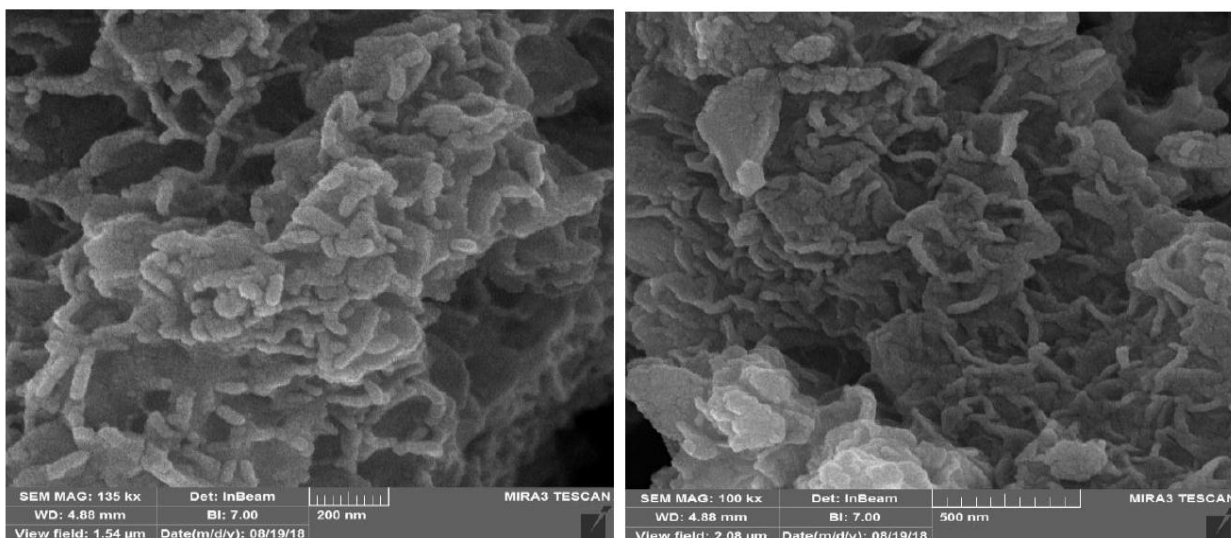
**Figure 2.** Catalyst cyclic voltammogram of Pd-Co/Gr into a KOH 1 M and ethanol 2 M solutions with scanning speed equal to 50 mV.s<sup>-1</sup>



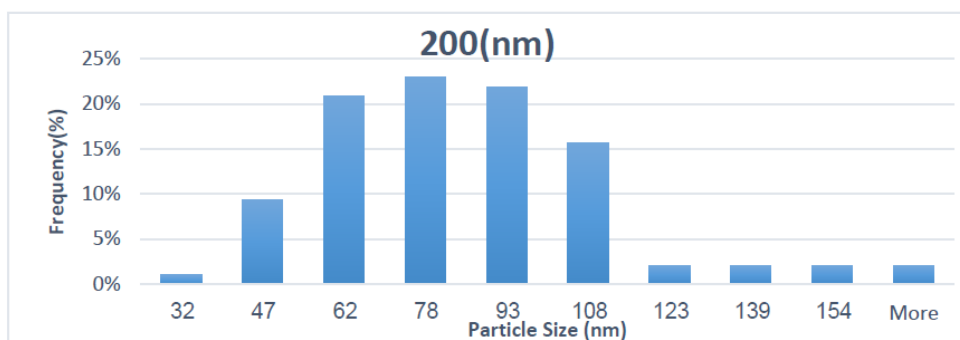
In this chart, the amount of peak flux (*j<sub>p</sub>*) and the onset potential (*E<sub>onset</sub>*) are equal to 53 mA.cm<sup>2</sup> and -0.23 V, respectively. Also, the peak potential (*E<sub>p</sub>*) is equal to -0.15 V. On this basis, it is clear that the activity of the catalyst is better when the onset potential and the peak potential are lower, and the peak flux is higher. These results indicate that the catalyst in this study shows the electrochemical activity in the oxidation of ethanol.

### 3.2 Results of Scanning Electron Microscopy (EF-SEM) analysis

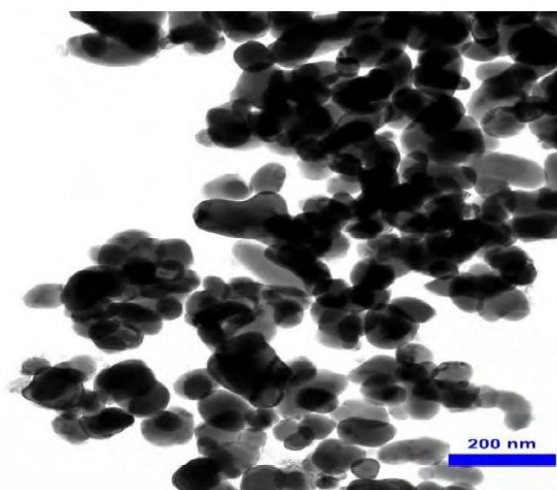
The images of analysis of the EF-SEM showed that palladium-cobalt catalyst particles were distributed almost homogeneously on graphene medium and the size of particles was evaluated in nm scale.



**Figure 3.** FE-SEM images of palladium-cobalt catalysts with a zoom of 200 and 500 nm



**Figure 4.** TEM particle size distribution related to palladium-cobalt catalysts with a zoom of 200 nm



**Figure 5.** The TEM image of a catalyst sample in a zoom of 200 nm

### 3.3 Results of Transmission Electron Microscopy (TEM) analysis

In the TEM test, a catalyst sample was used at a zoom of 200 nm, and the chart of distribution of the catalyst particle size was determined. According to

the above images, it can be concluded that the catalyst particles were homogeneously distributed in all over the sample, and their particle size was about 80 nm.

#### 4. Conclusion

The functional goal of this study is synthesizing and investigating the performance of a new alloy catalyst in the field of alcohol fuel cells. The use of palladium-cobalt alloy based on the graphene accelerates the kinetics of the anodic oxidation reaction of simple alcohols in an alkaline environment of the electrochemical system of three electrodes. Also, the application of this alloy enhances the efficiency of energy and output power in the anode section of direct alcohol fuel cells. The results of this study can be used in the field of the fuel cells at research centers, all industries

including transportation industry, military, petrochemical, power plants, especially in the New and Renewable Energy Organization, and all of the transferable electrical product industries such as mobiles, chargers, etc.

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