Preparation and characterization of (WO3:Co3O4) nano catalyst for fuel cell application

Haleemah J. Mohammed
Ministry of Science and Technology, Baghdad, Iraq
alhamdniya2003@yahoo.com.

Abstract This research focused on preparing the (WO3: Co3O4) nano catalyst by an electrochemical deposition technique; the electrochemical deposition cell consists of (WO3: Co3O4) electrode as an anode, mesh stainless steel electrode as a cathode and an aqueous solution as an electrolyte. (WO3: Co3O4) were grown on mesh stainless steel electrode, and XRD was used for characterization of nano catalyst; the topography properties were studied by atomic force microscopy (AFM), study the characterization of the electrochemical parameters. For this cell in terms of the impact of hydrogen volume on current, voltage, As well as the study of the effective results of the different concentration electrolyte arrangements extending from 0.14 M to 0.28 M KOH.

1 Introduction
The distinctive and desirable properties make the nanoparticles of metal oxide, and thin films an attractive candidate for materials science and their applications such as photocatalysts, photovoltaic, and fuel cells [1]. Photocatalysis refers to oxidation and reduction reactions on semiconductor surfaces by valence band holes, and conduction band electrons, Many metal oxides (SnO2, Co3O4, ZnO, MoO3, ZrO2, α-Fe2O3, WO3) [2,3]. One of the few stable oxides is Co3O4. Interest in as an effective photocatalyst has increased due to its important electronics, Chemical and magnetic properties. It is a p-type semiconductor [4,5], nanosheet Co3O4 has gained special attention over the past decades making it the anode electrode possible for the reaction of oxygen development in alkaline solutions[6], as for nano WO3, it was found to have great potential in energy transfer applications, so it attracted the attention of researchers. Also, due to the promising physical and chemical properties, as well as excellent electrical and optical properties [7]. Nanocomposite Co3O4: WO3 is characterized by high performance photocatalytic [8]. Not only has been surface surfaces that the nanoparticles possess, the nanostructures of the metal oxide catalyst, they produce nanoparticles of custom shape and size, and are also important in determining the surface geometry, exposure to faces, and the electronic structure of composite catalysts [9]. Furthermore, morphology has been found to have important effects on the catalytic properties of crystalline nanoparticles [10], the nano catalytic materials act as surface atoms or low-coordinate edges as active sites to stimulate and divide the water. This is effective for providing hydrogen and oxygen to fuel cells, and it involves two. The electrochemical reactions of the hydrogen (HER) and oxygen reaction (OER) [11,12]. Aim: To study the relation between for electrochemical factors during the preparation of nano catalyst for fuel cell application

2 Experimental
2.1. Preparation of nano catalyst (WO3:Co3O4).
Nano WO3 was mixed with Co3O4 and ethanol 2: 2; 2, respectively, and these materials were mixed by Sonicators Qsonica.LLC. Because of the properties these materials possess, they cannot be mixed
with any other mixer. Next, the mixture was placed in a 4 x 5 cm² mold. The mixture was left 4 hours and then placed in a drying oven at 200 °C for two hours. As shown in Figure 1.

![Figure 1. Membernece of nano catalyst (WO₃:CO₃O₄)](image)

2.2. **Preparation of Nano electrodes**

The desired electrode after attaching it to the negative electrode, the other electrode nano (WO₃: Co₃O₄) connected to the positive electrode of the power supply (5.1V and 0.60A), the coating solution was added an aqueous solution, its black coating layer of nano (WO₃: Co₃O₄) atoms were produced. After the coating was completed, it has been cleaned with deionized water and dried. As shown in Figure 2.

![Figure 2. Electrochemical deposition](image)

2.3. **Preparation of hydrogen gas unit**

The electrolysis cell consists of two cylinders, the first cylinder in which the cell HHO (The chemical name is her oxyhydrogen), is placed. As shown in Figure 3a. These electrodes were electrodes made of stainless steel, these electrodes were immersed in an electrolyte solution (KOH). and for the other cylinder, water is placed. As shown in Figure 3b.

![Figure 3a, HHO electrodes cell](image) ![Figure 3b, The electrolysis cell](image)

2.4. **Design of fuel cell**

The nanocatalyst (WO₃:Co₃O₄) to electrodes were used. Made for this purpose, with an area (4.5x4) cm² and thickness 0.1 cm. Three holes for entering the first and second hydrogen to introduce oxygen and the third to release water vapor. As shown in Figure 4.
3. Results and discussion

3.1. XRD Measurement

The XRD patterns of (WO$_3$:Co$_3$O$_4$) nano catalysts are prepared, there is an obvious sharp WO$_3$ (002) plane at $2\theta$ = 19.66°. showed a series of diffraction peaks at 20 of 44.40°, 54.14°, and 61.87°. The XRD patterns for the characteristic reflections for Co$_3$O$_4$ showed a series of diffraction peaks at 20 of 20.06°, 29.404° and 37.84°, are often assigned to (111), (220) and (311) planes was present in a polycrystalline form. Indicating that the Co$_3$O$_4$ particles are covered on the surface of the WO$_3$ particles with greater space. As shown in Figure 5.

![Figure 5. X-ray diffraction analysis of (WO$_3$:Co$_3$O$_4$)](image)

3.2. AFM Measurement

The surface morphology of the nano catalyst (WO$_3$:Co$_3$O$_4$) has been verified using AFM analysis that is fully focused on the nano scale characterization. Surface morphology of the catalytic layers revealed the presence of a sponge-like structure when the current density increases, where nano crystalline can be seen and distributed throughout the entire surface, as well as Analysis of the morphology of the catalyst Porous under varying current density conditions. The network was obtained very highly spaced, randomly oriented and highly correlated of pores. However, the increase in the current density of small pores requires showing forms, leading to an increased catalyst porosity. As shown in Figures 6a,b, the better results for morphology and roughness of the nano catalyst (WO$_3$:Co$_3$O$_4$), because the reason is in a perfect crystal structure. This result was supported by XRD measurements, which exhibited a smaller grain size. It was found that the average grain size was 50 nm.
3.3. The Effect of the Electrochemical Parameters to the Volume of Hydrogen Gas:

It has been studied the size of hydrogen. It is clear that when the variation of the volume with increasing time for constant voltage (6.2) V, as shown in table 1, and Figure 7, addition, the increase in the concentration of electrolyte solution leads to an increase in the number of energy carriers, which in turn increases the hydrogen production, as shown in table 2, and figure 8, which correspond to the data for these papers [13].

Table 1. Show the relationship between the volume of gas with current

| Time (min) | Voltage (V) | Current (A) | Volume of H (ml) |
|------------|-------------|-------------|-----------------|
| 10         | 6.2         | 0.5         | 0.6             |
| 15         | 6.2         | 1.3         | 1.7             |
| 20         | 6.2         | 1.9         | 2.8             |
| 25         | 6.2         | 2.2         | 4.8             |
| 30         | 6.2         | 2.5         | 7.3             |
| 35         | 6.2         | 3.0         | 10.4            |
| 40         | 6.2         | 3.4         | 13.9            |

Figure 7. The relationship between Volume of hydrogen and Current

Figure 6a. Surface morphology of nanocatalyst WO₃:Co₃O₄.

Figure 6b. Granularity normal distribution of nano catalyst (WO₃:Co₃O₄).
Table 2. Shows the concentration Potassium hydroxide with Voltage and Volume of hydrogen

| Concentration KOH (M) | Voltage (V) | Time (min) | Volume of H (ml) |
|-----------------------|-------------|------------|-----------------|
| 0.14                  | 2.5         | 10         | 3               |
| 0.18                  | 3.4         | 15         | 4.6             |
| 0.22                  | 4.6         | 20         | 8.2             |
| 0.25                  | 5.3         | 25         | 10.6            |
| 0.28                  | 6.2         | 30         | 12.8            |

Hydrogen gas, As described above, has been pumped into the cell via the anode of the catalyst (WO$_3$:Co$_3$O$_4$). The resulting electrons have transferred to the anode, which is separated from the cathode by a nano catalyst (WO$_3$:Co$_3$O$_4$). Then the electrons are transferred from the anode through the outer circuit to the cathode. This transfer occurs due to the difference between the anode and cathode electrodes. Oxygen reduction in the cathode occurs using the transported electrons, protons and molecular oxygen [14], To obtain a voltage of 1.56 volts by the fuel cell, As shown in Figure 9.

4 Conclusions

The results showed an improved X-ray diffraction pattern. All the materials involved in the manufacture of the cell electrolysis are simple primary materials and cheaply available in the local market. fuel cell developed so that (WO$_3$:Co$_3$O$_4$) used as a catalyst and a coating material to the cell to accelerate the process of interaction as well as increase the surface area to the electrodes. This study found that the increase in the current increases the current. volume of hydrogen.

**NOT:** The preparation of nano CO$_3$O$_4$, as well as nano WO$_3$, have not been presented because they
References

[1] P-J. A. Rodriguez, M. Fernandez-Garcia. 2007. *Wiley Interscience*, New York. pp. 79–119.
[2] Carp O, Huisman CL, Reller A. 2004. *Progress in Solid State Chemistry*;32:33-177.
[3] Kabra K, Chaudhary R, Sawhney RL.2004. *A Review. Industrial & engineering chemistry research*.43:7683.
[4] Di Zu, Haiyang Wang, Sen Lin, Gang Ou, Hehe Wei, Shuqing Sun & Hui Wu ,2019. *Nano Research* volume 12, pages 2150–2163.
[5] Li, Y.; Tan, B.; Wu, Y. 2008. *Nano Lett*. 8, 265–270.
[6] Zhang, W., Sherrill, P., Minett, A.I., Razal, J.M., Chen, J. 2010. *Energy Environ. Sci*. 3, 1286–1293.
[7] Huang K, Zhang Q, Yang F and He D .2010 . *Nano Res*. 3 281–7.
[8] Makhlouf, S. A. 2002. *J. Magn. Magn. Mater.*.246, 184–190.
[9] Y. Xia, Y. Xiong, B. Lim, S.E. Skrabalak. 2009. *Angew. Chem. Int. Ed*. 48 .60-103.
[10] L. Hu, Q. Peng, Y. Li, Selective .2008. *JACS*, 130 . 16136-16137.
[11] A. K. Geim, K. S. Novoselov. 2007. *Nat. Mater.*. 6, 183.
[12] T. F. Jaramillo, K. P. Jorgensen, J. Bonde, J. H. Nielsen, S. Horch, I. Chorkendorff. 2007.*Science*, 317, 100.
[13] Wendt, H., & Plzak, V. 1991. *Kerntechnik*, 56(1), 22–28.
[14] Sara Faulkner.2017. *The University of Queensla*