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№ 6229

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Fatma Aydın Ünal

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August 5, 2021

1st International Conference on Applied Engineering and Natural Sciences

https://www.icaens.com/

November 1-3, 2021, Konya, Turkey

Synthesis of undoped TiO_2 and Co doped TiO_2 photoelectrode powders for dye-sensitized solar cells

Fatma Aydın Ünal

Department of Metallurgical and Materials Engineering, Faculty of Engineering, Alanya Alaaddin Keykubat University, Turkey
ORCID ID 0000-0002-0031-0047

(fatma.aydin@alanya.edu.tr)

***Abstract* –** Although many parameters affect the efficiency of Dye Sensitized Solar Cell (DSSC), one of the main components of the cell, photoanode materials, comes first among the parameters that most affect the cell performance. The most common titanium dioxide (TiO_2) is used as the semiconductor layer for photoanode materials, which directly provides some of the high performance achieved in DSSC. Different types of elements are used while modifying the TiO_2 photoanode. Depending on the type of elements used, certain properties of the TiO_2 photoanode are improved and more efficient use of incoming light is ensured. In this paper, the ionic radius of Co^{+2}(0.74 Å) was chosen because it is close to the ionic radius of Ti^{4+}(0.60 Å). In this study, the synthesis of undoped TiO_2 and Co doped TiO_2 compounds as photoanode material in a DSSC was made. Undoped TiO_2 powders and Co doped TiO_2 powders were synthesized via the sol-gel method. Here, 5 wt % Co metal was doped to TiO_2. SEM/EDX and particle size analyzes of the synthesized TiO_2 powders were performed and the results were compared. It was observed that the powders were successfully synthesized by EDX analysis. Particle size distribution analysis showed that undoped TiO_2 had smaller particle size than Co-doped TiO_2.

Keywords – TiO2, sol-gel, synthesis, powder, DSSC

I. INTRODUCTION

Photovoltaic cells convert light from the sun directly into electrical energy. Among the photovoltaic technologies, Dye Sensitive Solar Cell (DSSC) is one of the alternative technologies that are cheap and suitable for development [1]. Although many parameters affect the efficiency of dye-sensitized solar cells, one of the main components of the battery, photoanode materials, comes first among the parameters that most affect the cell performance [2]. The most common TiO2 (titanium dioxide) is used as the semiconductor layer for photoanode materials, which directly provides some of the high performance achieved in dye-sensitized solar cells [3]. Although it is possible to use materials such as ZnO, SnO2 and Nb2O5 as a semiconductor layer, TiO2 is abundant in the market, relatively inexpensive, non-toxic, easy to synthesize, wide band gap, high specific surface area, relatively high power conversion efficiency [4]. Being chemically and mechanically stable is the main reason why this compound is preferred as photo anode material in this study. In addition, TiO2, which has strong catalytic activity and stability of electron/hole pairs, is the most widely used photocatalysis. TiO2 has the task of creating a surface area for the dye to be adsorbed, accepting the electron from the excited dye and transmitting the incoming electron to the conductive glass surface in dye sensitive solar cells [5,6].

In recent years, it is seen that studies on metal doping to pure TiO2 have increased rapidly in the literature [7-9]. Since the additives affect the internal structure properties of TiO2, they reduce the particle growth of TiO2 during the process, allowing smaller nanoparticles to be obtained. Therefore, as metal-doped TiO2 will have more surface area, it absorbs more dye and increases the

efficiency of the dye-sensitized solar cell. In particular, cationic additives prolong the absorption of visible light and increase the high temperature stability of anatase phase TiO2. This increases the photocatalytic activity of TiO2[10]. Different types of elements are used while modifying the TiO2 photoanode[11]. Depending on the type of elements used, certain properties of the TiO2 photoanode are improved and more efficient use of incoming light is ensured.

In this paper, the ionic radius of Co+2(0.74 Å) was chosen because it is close to the ionic radius of Ti4+(0.60 Å) [12]. In this study, the synthesis of undoped TiO2 and Co (5 wt %) doped TiO2 was carried out by sol gel method. SEM/EDX and particle size analysis of undoped TiO2 and Co-doped TiO2 were compared.

II. MATERIALS AND METHOD

2.1 Sample preparation

2.1.1 Preparation of pure TiO2 powders

90 ml of 2-propanol was placed in a beaker and mixed with a magnetic stirrer for 5 minutes. 10 ml of distilled water was added dropwise to this mixture for 15 minutes. To this mixture of purified water and propanol, 15 ml of titanium tetraisopropoxide (TTIP) was added dropwise over 40 minutes. After the addition, it was allowed to mix in a magnetic stirrer for another 5 hours. It was then dried in an oven at 90oC for 10 hours. It was calcined for 4 hours at 450oC for homogeneity and nanoparticle size. As a result of calcination, the color of pure TiO2 was obtained as white (Fig. 1a) [9].

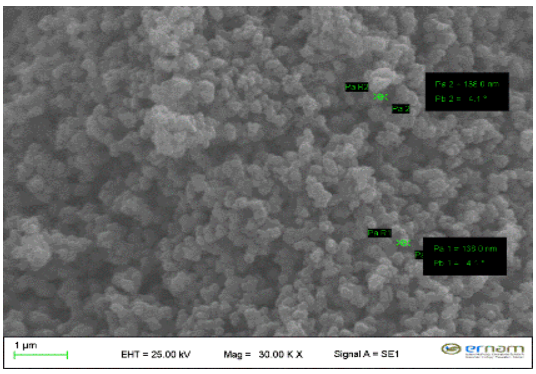
2.1.2 Preparation of cobalt-doped TiO2 powders

90 ml of 2-propanol was placed in a beaker and mixed on a magnetic stirrer. A Co(NO3)3·6H2O solution was prepared for the stoichiometric ratio calculated for 5 wt % dop treatment in a separate beaker. This prepared solution was slowly added to 2-propanol over 30 minutes. To this mixture, 15 ml of titanium tetra isopropoxide (TTIP) was added dropwise over 40 minutes. This final mixture was allowed to stir for a further 5 hours in a magnetic stirrer. Then the obtained gel was dried in an oven at 90 °C for 12 hours. This dried gel was calcined for 4 hours at 450 oC for homogeneous and nanoparticle size. As a result of calcination, light green colored Co-doped TiO2 powder was obtained (Fig. 1b).

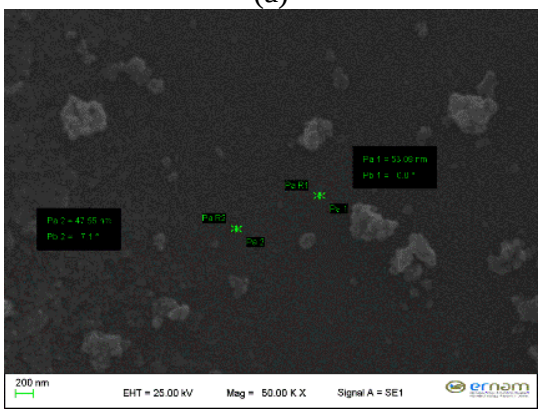
(a) (b)

Fig. 1. Photograph of synthesized (a) undoped TiO2 and (b) Co doped TiO2 powders.

III. RESULTS

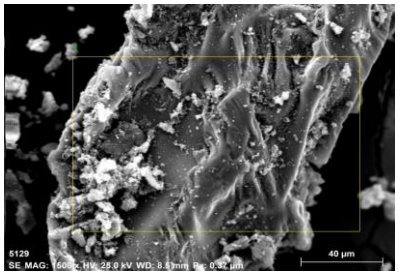


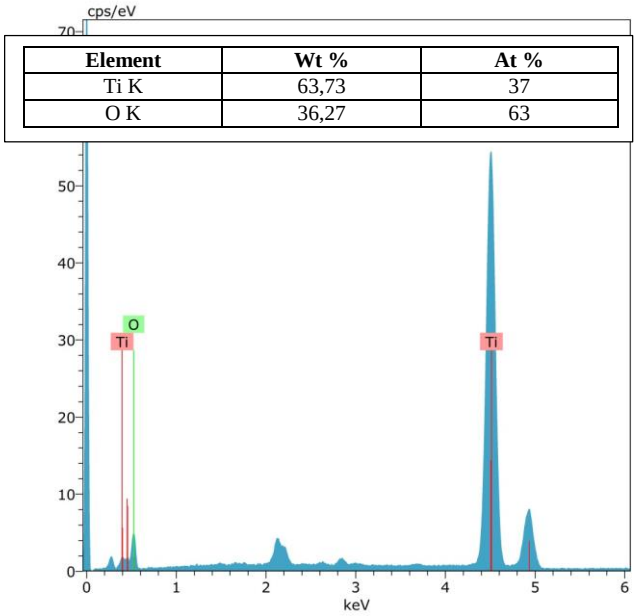
(a)



(b)

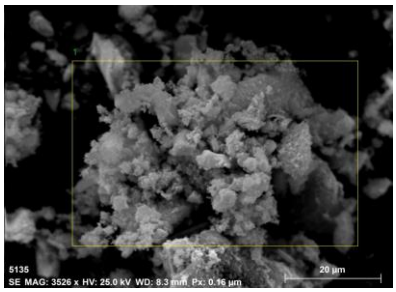
Fig. 2. SEM Micrographs of (a) undoped TiO2 and (a) (5 wt %) Co doped TiO2 powders.

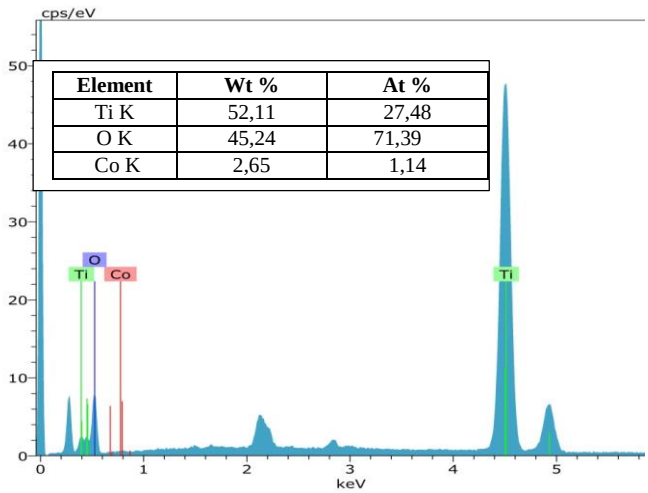




Element	Wt %	At %
Ti K	63,73	37
O K	36,27	63

(a)

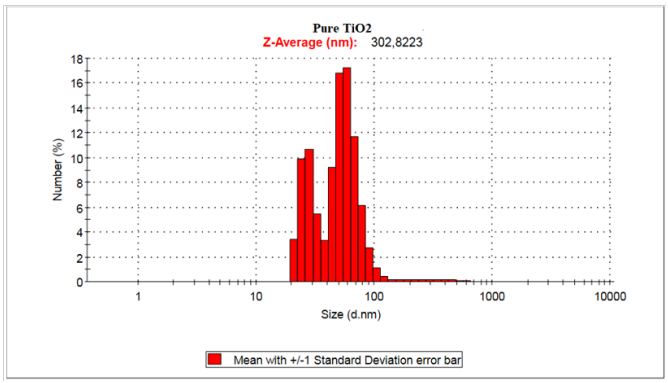




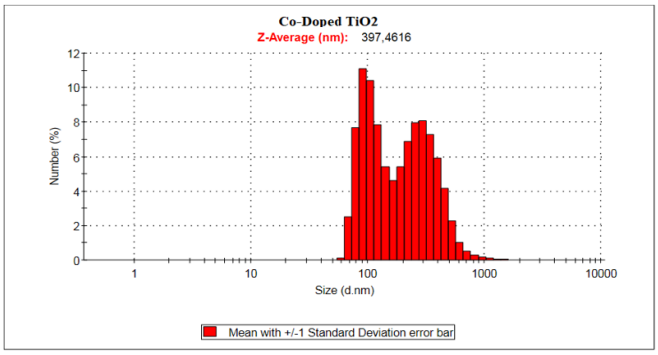
Element	Wt %	At %
Ti K	52,11	27,48
O K	45,24	71,39
Co K	2,65	1,14

(b)

Fig. 3. EDX analyses of (a) undoped TiO2 and (b) (5 %) Co doped TiO2 powders.



(a)



(b)

Fig. 4. Particle size distribution graphics of synthesized powders (a) pure TiO2, (b) 5 % Co doped TiO2 powders.

Figure 1 shows the pictures of the synthesized pure TiO2 (a) and Co-doped TiO2 (b)powders. As can be seen, pure TiO2 powder is white in color, while the color of Co-doped TiO2 powder is light green. Figure 2 shows SEM images of (a) undoped TiO2 and (a) (5 wt %) Co-doped TiO2 powders. Figure 2.a shows the SEM morphological structure of pure TiO2 powders. Powders have a fairly homogeneous particle size. In Figure 2.b, it is seen that the Co-doped TiO2 particles are slightly larger than the undoped TiO2 particles.

Figure 3 shows EDX images of un-doped TiO2 and 5 wt % Co-doped TiO2 powders. While Ti wt is 63.73% in un-doped TiO2, O wt is 36.27 %. Co-doped TiO2 was obtained with a ratio of Ti 52.11 wt %, O wt 45.24 % and Co 2.65 wt %.

In Figure 4, particle size distribution analyzes of un-doped TiO2 and Co-doped TiO2 powders are given.

IV. DISCUSSION

The morphological structure and chemical analyzes of the powders synthesized in SEM/EDX analyzes were examined. It is seen that the powders show a homogeneous distribution in their morphological

structures. In addition, it is seen that Co contribution to TiO2 has been successfully made in EDX analyzes. Considering the particle size distribution analysis, it was determined that the synthesized undoped TiO2 had a particle size distribution of 302 nm, while the Co-doped TiO2 had a particle size of 397 nm.

V. CONCLUSION

In this study, undoped TiO2 and Co-doped TiO2 were synthesized according to the sol gel method and the analysis results were compared. The structures of the powders obtained as a result of the synthesis were elucidated by SEM/EDX analysis. Accordingly, it was observed that the powders had a homogeneous morphology and showed a homogeneous distribution. It was observed that Co-doped TiO2 was successfully synthesized at a rate of 2.65 % by weight. Particle sizes of undoped TiO2 and Co-doped TiO2 powders were determined as 302 nm and 397 nm, respectively, by particle size distribution analysis. In the continuation of the study, it is recommended to compare the photocatalytic activities of the synthesized powders and to use them as photoanode material in dye-sensitized solar cells.

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