Comparative Electrochromic Properties of \( \text{V}_2\text{O}_5 \), \( \text{Ta}_2\text{O}_5 \) and \( \text{V}_2\text{O}_5-\text{Ta}_2\text{O}_5 \) Thin Films deposited by Sol–Gel Spin Coating Method

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Abstract: In this study, Electrochromic \( \text{V}_2\text{O}_5 \), \( \text{Ta}_2\text{O}_5 \) and \( \text{V}_2\text{O}_5-\text{Ta}_2\text{O}_5 \) thin films were deposited by Spin Coating Method on FTO glasses. As deposited films were annealed at 400ºC for 2 hours. Structural and Electrochromic properties of them were evaluated by using X-ray diffraction, Scanning Electron Microscopy and Cyclic Voltammetry measurements. The results of the films compared and the best electrochromic structure was investigated.

Keywords — \( \text{V}_2\text{O}_5 \), \( \text{Ta}_2\text{O}_5 \), Spin Coating, Electrochromic.

I. INTRODUCTION

Electrochromic (EC) smart windows are able to vary their throughput of visible light and solar energy by the application of an electrical voltage and are able to provide energy efficiency and indoor comfort in buildings [1]. Vanadium Pentoxide (\( \text{V}_2\text{O}_5 \)) has both electrochromic and photochromic properties and its optical absorption occurs during transition of \( \text{V}^{4+} \rightarrow \text{V}^{5+} \) [2].

It is reported that \( \text{V}_2\text{O}_5 \) thin films can be synthesized variety of techniques such as PVD, Electron Beam Evaporation, Magnetron Sputtering, PLD, CVD, Spray Pyrolysis, Sol-Gel Spin Coating etc. [3]. \( \text{Ta}_2\text{O}_5 \) has a very low coloration coefficient but it has electrochemical stability over the acidic electrodes for higher pH values [4]. Also it is reported that Ta doped \( \text{V}_2\text{O}_5 \) exhibit excellent cyclic stability [5].

It is reported that \( \text{Ta}_2\text{O}_5 \) can be deposited by various techniques such as CVD, E-beam evaporation, Sputtering, Anodic oxidation, Spin coating etc. [6]. Among them, Spin Coating is versatility and cost effective technique for large scale production [7].

In this study, \( \text{V}_2\text{O}_5 \), \( \text{Ta}_2\text{O}_5 \) and \( \text{V}_2\text{O}_5-\text{Ta}_2\text{O}_5 \) thin films were deposited by simple spin coating technique. Structural and Electrochromic properties of as deposited films were evaluated and compared.

II. EXPERIMENTAL PROCEDURE

The thin films were deposited on FTO coated glass substrates by Spin Coating Technique using \( \text{Ta}_2\text{O}_5 \) powder and Ethanol, Vanadium oxotrisopropoxide and Ethanol precursors for \( \text{Ta}_2\text{O}_5 \), \( \text{V}_2\text{O}_5 \) thin films respectively and mixed precursor of \( \text{Ta}_2\text{O}_5 \) powder-vanadium oxotrisopropoxide-Ethanol for \( \text{V}_2\text{O}_5-\text{Ta}_2\text{O}_5 \) thin films.

The films were prepared by using 3000 rpm rotation speed for 30 s and heated at 125º C for 5 minutes each spinning process. The spinning process was repeated 5 times for each sample. After deposited process, the films were annealed at 400ºC temperature for 2h.

The crystal structure of the films was identified by X-ray diffraction (XRD) measurements. The surface morphology of the films was characterized by Scanning Electron Microscopy (SEM). Electrochromic properties of the films were determined by Cyclic Voltammetry.

III. RESULTS

XRD patterns of \( \text{V}_2\text{O}_5 \), \( \text{Ta}_2\text{O}_5 \) and \( \text{V}_2\text{O}_5-\text{Ta}_2\text{O}_5 \) thin film have been given in figure 1. According to Fig.1, because of synthesized very thin \( \text{Ta}_2\text{O}_5 \) thin film, It has been observed that weak peak of its (001) plane corresponding to orthorhombic structure as previously reported in literature [8].

When XRD pattern of \( \text{V}_2\text{O}_5 \) thin film is evaluated, it has been seen that if the FTO peaks are ignored, peak of the (101) plane is the sharpest peak corresponding to the diffraction peak at 2 theta value of 21.26º.

We have clearly observed that the XRD peaks of \( \text{V}_2\text{O}_5 \) thin film consist with orthorhombic crystal structure as reported in literature [9, 10]. It has been shown that XRD peaks of \( \text{V}_2\text{O}_5-\text{Ta}_2\text{O}_5 \) thin film consist with both \( \text{V}_2\text{O}_5 \) crystal structure and \( \text{Ta}_2\text{O}_5 \) crystal structure.
In figure 3, Cyclic Voltammetry measurements of the thin films deposited Spin Coating Method have been evaluated. The solution for intercalation and de-intercalation processes was prepared by adding 50 ml of 1 molar H₂SO₄. The CV analysis are measured at scanning rates of 100 mV/ between -2V and 2V.

According to CV analysis, it is clear that Ta₂O₅-V₂O₅ thin film show different electrochromic properties than others and it has not any peak according to CV analysis. However, it has good coloration during cyclic voltammetry scanning. V₂O₅ thin film has a peak which emerged sharper than Ta₂O₅ thin film. Moreover, because V₂O₅ thin film has larger area trough sweep voltage, it is better electrochromic performance than Ta₂O₅ thin film. However, V₂O₅ has been exposed chemical corrosion in solution.
IV. CONCLUSIONS

As a result, in this study $\text{V}_2\text{O}_5$, $\text{Ta}_2\text{O}_5$ and $\text{V}_2\text{O}_5$-$\text{Ta}_2\text{O}_5$ thin films were synthesized by using simple solution-based economical Spin coating Method. Characteristics of the films were evaluated. Although deposited all of the films can be used in electrochromic applications, it is obvious in CV results that $\text{V}_2\text{O}_5$-$\text{Ta}_2\text{O}_5$ films has better electrochromic performance than $\text{Ta}_2\text{O}_5$ thin film and it is not exposed chemical corrosion in $\text{H}_2\text{SO}_4$ solution unlike $\text{V}_2\text{O}_5$ thin film.

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REFERENCES