



Structural, electrochemical and optical comparisons of tungsten oxide coatings derived from tungsten powder-based sols

Dilek Işık^a, Metin Ak^b, Caner Durucan^{a,*}

^a Department of Metallurgical and Materials Engineering, METU, 06531 Ankara, Turkey

^b Department of Chemistry, Pamukkale University, 20017 Denizli, Turkey

ARTICLE INFO

Article history:

Received 13 July 2008

Received in revised form 24 June 2009

Accepted 24 June 2009

Available online 2 July 2009

Keywords:

Electrochromic coatings

Peroxtungstic acid

Tungsten oxide

ABSTRACT

Tungsten trioxide (WO₃) electrochromic coatings have been formed on indium tin oxide-coated glass substrates by aqueous routes. Coating sols are obtained by dissolving tungsten powder in acetylated (APTA) or plain peroxotungstic acid (PTA) solutions. The structural evolution and electrochromic performance of the coatings as a function of calcination temperature (250 °C and 400 °C) have been reported. Differential scanning calorimetry and X-ray diffraction have shown that amorphous WO₃ films are formed after calcination at 250 °C for both processing routes; however, the coatings that calcined at 400 °C were crystalline in both cases. The calcination temperature-dependent crystallinity of the coatings results in differences in optical properties of the coatings. Higher coloration efficiencies can be achieved with amorphous coatings than could be seen in the crystalline coatings. The transmittance values (at 800 nm) in the colored state are 35% and 56% for 250 °C and 400 °C-calcined coatings, respectively. The electrochemical properties are more significantly influenced by the method of sol preparation. The ion storage capacities designating the electrochemical properties are found in the range of $1.62\text{--}2.74 \times 10^{-3}$ (mC cm⁻²) for APTA coatings; and $0.35\text{--}1.62 \times 10^{-3}$ (mC cm⁻²) for PTA coatings. As a result, a correlation between the microstructure and the electrochromic performance has been established.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

The production of electrochromic devices and the enhancement of their functional properties have been the subject of a number of researches over the last two decades; and research in this field is expanding as possibilities and applications for electrochromic devices are recognized. Electrochromic devices have broken new ground in energy-saving applications, display devices and screens for visual appliances; while other technological applications of electrochromism include architectural windows, automobile sunroofs and mirror glazes.

Electrochromic devices are composed of several layers of coatings on a solid substrate that are capable of undergoing repeated coloring and bleaching operations through the onset of an applied potential. The technological commercialization of electrochromic devices is somewhat hindered by the costly processing methods and elaborate device integration. The selected coating technique itself can also be a limiting factor in the production of devices on a larger scale. All these factors should be considered when choosing an effective and feasible

coating process. Several techniques are available for the application of electrochromic coatings, including sputtering [1], chemical vapor deposition [2,3], electron beam deposition [4], thermal evaporation [5], and pulsed spray pyrolysis [6]. Sol-gel approaches have been also explored for making electrochromic coatings. There are several advantages to this processing method. As an aqueous route, it is an economic, fast and effective production method when compared to other techniques and may offer reproducibility in terms of coating thickness, crystallinity and composition [7,8]. Finally, sol-gel enables the use of variety of different precursors, allowing modifications to chemical and microstructural properties. Among the available sol-gel precursors, the most preferred are chlorides [9,10] and peroxo complexes [7–13].

Tungsten trioxide (WO₃) is one of the most commonly used cathodic electrochromic components [14] due to the large difference in contrast between its bleached and colored states, high ion storage capacity and availability. As an inorganic material it is thermally stable and is also highly resistant to weathering when compared to some organic electrochromic analogues [15–17]. Various tungsten precursors, such ethoxides (W(OEt)₆) [18], chlorides (WCl₆, WOCl₄) [9,10] and peroxo complexes [7,8,11–13] have been employed in the making of tungsten oxide by sol-gel. Tungsten ethoxides are expensive and sensitive to water, limiting their utilization in commercial production [19]. Similarly, chlorides have limited use, as their processing requires

* Corresponding author.

E-mail addresses: e145342@metu.edu.tr (D. Işık), metinak@pamukkale.edu.tr (M. Ak), cdurucan@metu.edu.tr (C. Durucan).