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INVESTIGATION OF THE TECHNOLOGY FOR OBTAINING THIN COATINGS OF VANADIUM PENTOXIDE FOR THE PRODUCTION OF SMART WINDOWS

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Preliminary Note – Prethodno priopćenje

This article deals with the doping of vanadium pentaoxide with tungsten in various quantities and obtaining coatings used in the production of “smart windows” from the resulting melt. The properties of the obtained coatings were determined using X-Ray diffraction (XRD) and scanning electron microscope (SEM). The thermo-optical properties, namely solar reflectance and IR emittance, were investigated and were correlated with the doping tungsten effect in thin vanadium oxide films.

Keywords: coating, vanadium pentoxide, tungsten alloy, smart windows, X-Ray research (XRD, SEM, EDS)

INTRODUCTION

Over the past few years, many researchers [1-3] have studied various ways of obtaining thin vanadium oxide coatings, as well as both their physical and chemical properties. During the production of packaging materials from vanadium oxides, oxygen gas was supplied to the spraying machine and mixed with inert gases (such as argon). Oxygen reacts with vanadium atoms in the melt to form vanadium oxide, which is used as a coating. This method is called reactive magnetron spraying [4]. During the process, the conditions of the packaging process, such as the oxygen flow rate and the temperature of the material from which the packaging is made, are carefully monitored [5-7]. The main reason that prompted many such scientific studies is the advantage of using vanadium in the production of various “smart windows.”

Due to the presence of many phases of vanadium oxide and the unique optical properties of its different phases, this material is currently used in many industries.

For example, while V_2O_5 is used as a catalyst in electrochromism and in the manufacture of optical equipment, VO_2 is used as a “smart window” and a switching device [4]. Scientific and technical interest in the optical and thermo-optical properties of tungsten-alloy vanadium oxides used in the production of smart windows is growing. The main reason for this increase in interest is the specifics of the optical properties of vanadium coating, which is often alloyed with variable valence metals. That is, these alloy coatings, which are made on the surfaces of glass windows, have the property of “regulating” the sun’s rays when used to construct buildings. The mechanism of the “regulatory” property of such sunlight can be explained by the following phenomenon. During alloying with tungsten, vanadium oxide is partially filled with d-orbitals and form a complex chemical structure. Under the influence of this, the nanoparticle coating applied to the surface of a glass window forms the properties of metal bonds and the variability of optical conductors. Under the influence of a small increase in the temperature that occurs in the packaging materials when the sun goes down, the electrons move from the lower d-Orbital to the higher-energy free orbital, resulting in the formation of conductive electrons and space in the packaging structure [8].

As shown in many articles [8], vanadium dioxide is frequently used in packaging processes. Therefore, the use of vanadium pentaoxide in the research process and knowledge of the properties of the resulting packaging structure [8] is of great scientific interest. As a result, the purpose of this article is to describe the properties of packaging made from a mixture obtained by alloying vanadium pentaoxide with tungsten anhydride.

EXPERIMENTAL DETAILS

Vanadium pentoxide and metallic tungsten were used to produce the films, and the purity of vanadium and tungsten oxide used was 99,98 %. Before carrying out all experimental work, the ITO glass plates used were washed with soap solution and 96,0 % ethyl alcohol for 20 minutes in an ultrasonic bath and rinsed with

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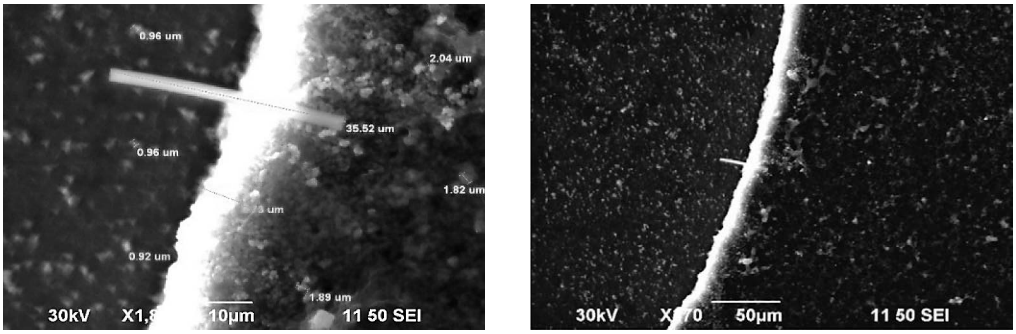

(a) (b)

Figure 1 SEM images of the morphology of the coating surface

deionized water. The electrical resistance of the ITO glasses was 8,0 ohms/cm^2.

The magnetron sputtering unit MAGNA TM-200-1 was used to produce thin films of V_2O_5. The power of the magnetron varied in the range of 100–500 watts.

The formation of thin films of vanadium oxide on the surface of ITO glass by magnetron deposition proceeded in the mode of operation of an energy source at direct current. The deposition process was accompanied by feeding a (2,95·10^{-5} millibars) mixture of argon (99,95 %) and oxygen (99,92 %) into a chamber with a high vacuum. The elimination of oxides from the surface of the metal target was achieved by pre-spraying the material in argon plasma for 15–25 minutes. The physical atomization of vanadium took place when accelerated ions of sputtering argon gas bombarded the surface of a vanadium target, the purity of which was 99,98 %, followed by the reaction of vanadium atoms torn from the target surface with reactive oxygen gas. The supply of argon and oxygen gases was carried out through channels of independent gas intakes with controllers of a mass gas flow meter. Alloying of vanadium oxide with tungsten was carried out from 0,25 % to 0,75 %.

The process of magnetron deposition of vanadium oxide on a conductive glass was started when the argon gas pressure reached 0,6 Pascal, while the reaction oxygen gas was supplied until 10 % of the argon in the reactor chamber was reached.

X-ray studies were carried out using a Panalytical Epsilon 4. Energy-dispersive spectroscopy (EDS) analysis was performed on the basis of a MIRA 3 TESCAN scanning probe microscope with energy dispersive prefixes for microprobe analysis.

RESULTS AND DISCUSSION

After applying layers to create a V_2O_5 coating, the surface consists of microspheres, the average size of which varies from 0,9 to 2,0 microns (Figure 1 (a, b)). When applying thin films in the amount of 5 cycles, the average size of the particles evenly distributed on the surface of the sample did not increase.

Figure 2 shows the X-ray spectrum of the composite nanolayer and demonstrates the main peaks characteristic of the structure of the composite product of vanadium pentoxide and tungsten. Figure 2 also shows the absence of crystalline phases of film and signifies that the as-deposited films are amorphous in nature.

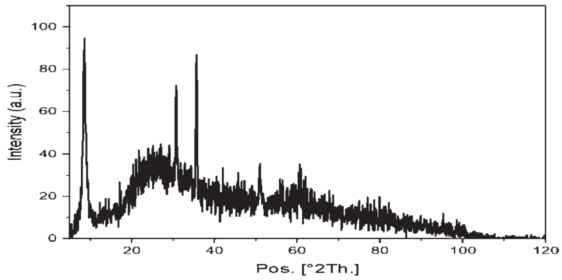

Figure 2 XRD of the synthesized nanocomposite sample

Table 1 shows some optical properties of the samples in order to determine the possible of practical application of the obtained coatings. As Table 1 indicates, the coating that consists of only vanadium pentoxide reflects only 18,0 % of the sun's rays; when doped with 0,75 % tungsten, the percentage of reflection increased

Table 1 **Optical properties of the obtained coatings.**

№	Components of the coating	W Doping level, %	IR emittance / %	Solar reflectance / %
1	V_2O_5	-	16	18
2	V_2O_5+W	0,25	29	26
3	V_2O_5+W	0,50	37	31
4	V_2O_5+W	0,75	48	36

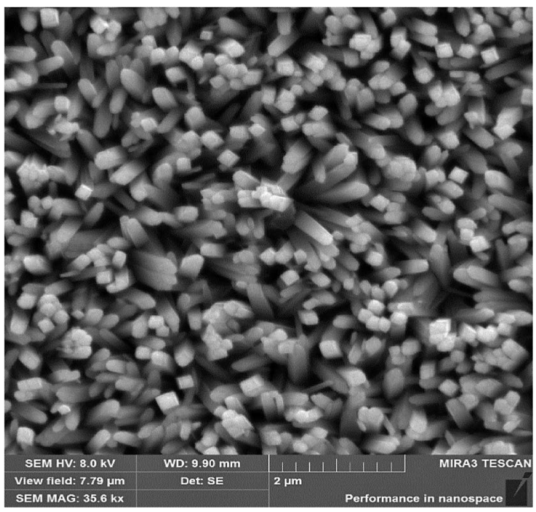

Figure 3 SEM image of the sample surface

to 36%. The properties of reflection of infrared rays were also studied. According to the research results, when alloying tungsten pentoxide with 0,25 % to 0,75 %, the degree of reflection of infrared rays increased from 29 % to 48 %.

The addition of the tungsten metallic phase to a thin vanadium oxide film shows a decrease in the sheet's resistance value. The morphology of the sample obtained at 0.75 percent doping was studied by scanning electron microscopy Tescan (Figure 3).

A uniform array of coating structures consisting of rods with a diameter of 170–200 nm was directed mainly perpendicular to the substrate.

CONCLUSION

The present study experimentally investigated the effect of doping of tungsten in thin vanadium oxide films. By alloying vanadium pentaoxide with tungsten in the amounts of 0,25, 0,5, and 0,75 percent, the optical properties of the resulting coating were determined. The physio-chemical properties of the various coatings obtained were obtained, and it was determined that a 0,75 percent tungsten additive was effective in the production of «smart windows»

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