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Dielectric Permittivity and Structure on Thin Ceramic Layers on Metal Surfaces

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Abstract
Research is focused on the synthesis of strontium titanate films and the deposition of sol on an aluminum support. Five layers of the stable sol were deposited on an aluminum support. Drying was carried out in a dryer at a temperature of 60°C. The finished sample was thermally treated in a laboratory furnace at 400°C with a delay of 10 minutes. The obtained pesultates were characterized by XRD and the relative dielectric permittivity was determined.

Keywords: sol-gel, $SrTiO_3$, conductivity, dielectric permittivity

1. Introduction

In modern industrial production and scientific and applied activity, various single-layer or multi-layer coatings, characterized by a number of functional properties [1-30], are used in a wide assortment of products: anti-corrosion, thermal, thermotechnical, magnetic, electrophysical, physicochemical, photoelectric, optical, catalytic, abrasive, adhesive, bioinert, bioactive, decorative, etc. The use of various thin-layer coatings ensures an increase in the technical indicators of the products and significantly expands the possibilities for their full use in a dynamic and aggressive operating environment [7,10,12,14,20-24,26,27,31].

The development of innovative and competitive products in the field of modern electronics [30] is a major factor for the successful functioning and development of industry, transport, energy, healthcare and other economic branches and public spheres. In the production of various electronic components, a standard technological stage is the deposition of thin layers in the course of the production cycle until the preparation of the final products [2].

During the extensive research activity carried out over a long period of time [1-31], a huge variety of experimental samples formed from binary or polycomponent thin-layer coatings (oxide, nitride, silicate, zirconate, titanate, aluminate, stannate and a number of others) were prepared deposited by various technological methods.

Standard and laboratory methods have been developed for preliminary preparation, modification and effective increase of the reactivity of the substrate [30,31] by applying various etching techniques and various surface technological treatment: chemical, thermal, plasma, mechanical and others. The role of the used deposition methods, the phase composition, the adhesion properties, the microstructural and mechanical characteristics [13,28,31] of the formed transition layers and the separated separate zones (between the coating and the substrate) in the formation of the final complex indicators of the experimental samples was traced.

The aim of the present work is to study the dielectric permittivity and structure of thin ceramic layers (titanate, stannate) with a registered thickness of about 1μm, deposited on the surface of metal experimental samples by applying the sol-gel method.

2. Experimental part and discussions

First, the aluminum pads were cleaned in 5% alkaline NaOH and then in 30% acidic HNO_3 solution and then rinsed in acetone for 30 minutes to remove the oil layer, primary oxidation and surface impurities.

The strontium titanate $SrTiO_3$(STO) sol was previously synthesized by a sol-gel method to obtain a stable sol. The starting precursors are $Sr(NO_3)$ strontium nitrate and titanium butoxide Ti(Bu) in a 1:1 ratio. The two solutions were homogenized independently of each other and mixed after 3 hours of homogenization. After mixing, DEA (diethanolamine) and AcAc (acetylacetone) are added as stabilizers. After obtaining a stable sol, proceed to the deposition of thin films by dipping method. 6 layers are deposited on the finished aluminum substrate. After each application, the sample is dried in a dryer at 60°C. After applying the last layer, the sample is annealed at 400°C in a laboratory furnace with a delay of 10 minutes. The material thus obtained is examined to determine the necessary indicators and possible applications. Structural characterization of STO thin films. Figure 1 shows the X-ray diffraction (XRD) patterns of STO films prepared. The films show a crystal pattern, with peaks corresponding to a cubic structure of the perovskite $SrTiO_3$ with space group Pm3m. The $Sr(NO)_3$/Ti(Bu) deposited film exhibits narrow peaks with higher intensity associated with superior crystal growth. The average crystallite size was calculated using the Scherer equation. From the structural analysis, the lattice distortion, ε, was further calculated from Eq. (1) This parameter describes the difference in atomic positions from the ideal crystal structure.

$$\varepsilon = \beta\ \theta/4\ \tan \qquad (1)$$

Meanwhile, the dislocation density, δ, represents the presence of defects in the material and is calculated using equation (2),

$$\delta = 1/D2 \qquad (2)$$

D represents the crystallite size previously calculated from XRD patterns. From these analyses, it was found that the $Sr(NO_3)$/Ti(Bu) deposited sample showed the highest crystallite size and the lowest lattice distortion and dislocation (Fig. 1)

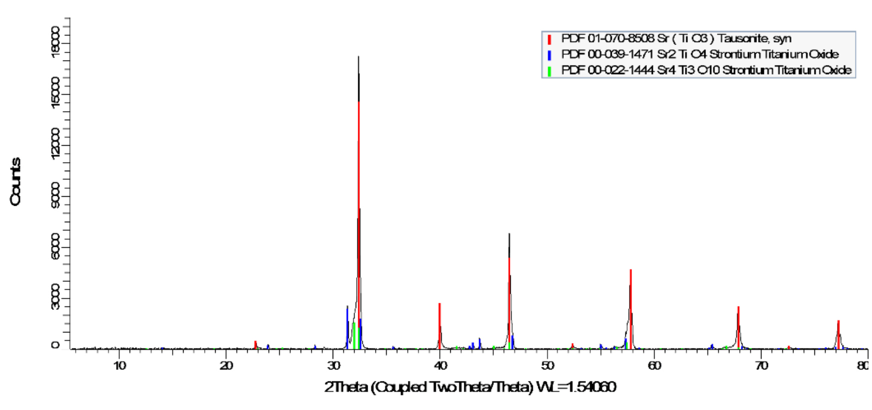

Fig. 1. $SrTiO_3$ film deposited on an aluminum support

The relative permittivity of the material as a function of temperature was also determined. The result is shown in fig. 2

The relative permittivity (ε_r) of the material shows its energy storage capacity when a potential is applied across it. It is related to the macroscopic properties like polarization or capacitance. For circuit miniaturization, usually one employs a high ε_r material.

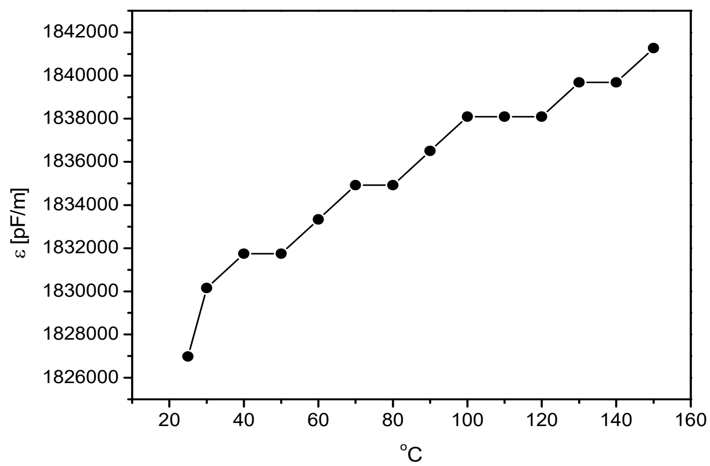

Fig.2 Dielectric permittivity of $SrTiO_3$ deposited on an aluminum support

In the studies carried out in this way, the relative dielectric permittivity has a relatively higher result compared to the synthesis of powdered material in the traditional solid phase synthesis.

3. Conclusion

As a result of the conducted research, the following conclusions can be drawn: Synthesis of a strontium titanate phase with high dielectric permittivity during sol synthesis by the sol-gel method. Aluminum plates were prepared by chemical treatment and deposition of the sol solution by dip coating. X-ray analysis of the deposited coatings is presented and the dielectric constant is determined. The material may find application in the development of dielectrics for supercapacitors.

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