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Sol-Gel Synthesis of Functional Nanostructured Materials for Electronic Devices

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Keywords: sol-gel method, ferromagnetics, semiconductors, non-volatile memory devices, perovskite structure, SBTN films, ZnO films, $Fe_xCo_yO_z$ films.

Abstract. The possibility of functional nanostructured materials for electronic devices synthesis by sol-gel method have been discussed such as ferroelectrics ($SrBi_2(Ta_xNb_{1-x})_2O_9$) , ferromagnetics ($Fe_xCo_yO_z$) and semiconductors (ZnO). The structural features of the surface (AFM), crystallization behavior (XRD) during the heating and properties of synthesized films are discussed. Achieved parameters suggest the possibility of using synthesized SBTN sol-gel films in non-volatile memory devices, semiconductors active ZnO layers in solar sells, ferromagnetics $Fe_xCo_yO_z$ films in microwave absorber covers.

Introduction

The intensive development of micro-and nano-electronics is the reason of great attention paid to the development of new types of functional materials (1-3). The search for new materials synthesys method is an actual problem. The literature describes many varieties of the synthesis of functional materials by sol-gel method. Sol-gel method is based on hydrolysis and polycondensation reactions of organometallic compounds or salts and then the direct transition «solution-sol-gel-oxide» [4,5].

Sol-gel films with the general formula ($SrBi_2(TaxNb_{1-x})_2O_9$) (SBTN-film) were synthesized by sol-gel method . Gelation took place under the effect of centrifugal force. The films were deposited on $Pt/TiO_2/BPSG/SiO_2/Si$ sublayers by spin-coating at different substrate speeds (500-1000 r/min) or by dip-coating. In order to achieve the desired thickness (200 - 300 nm) sol was applied 2-3 times followed by heat treatment of each layer at the temperature of 700 °C. Annealing of SBTN-films in order to form perovskite structure was made at 800 °C for 40 min. The structural features of the surface (fig. 1) (AFM), crystallization behavior (fig. 2) (XRD) during the heating and ferroelectric properties of synthesized films are investigated.

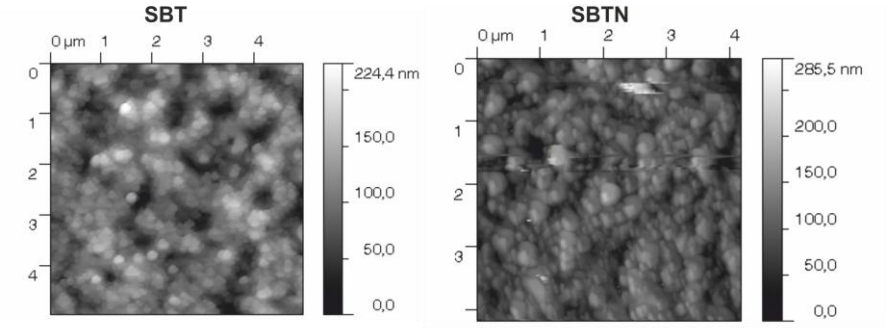


Fig. 1. AFM topography images of SBT, SBTN sol-gel films

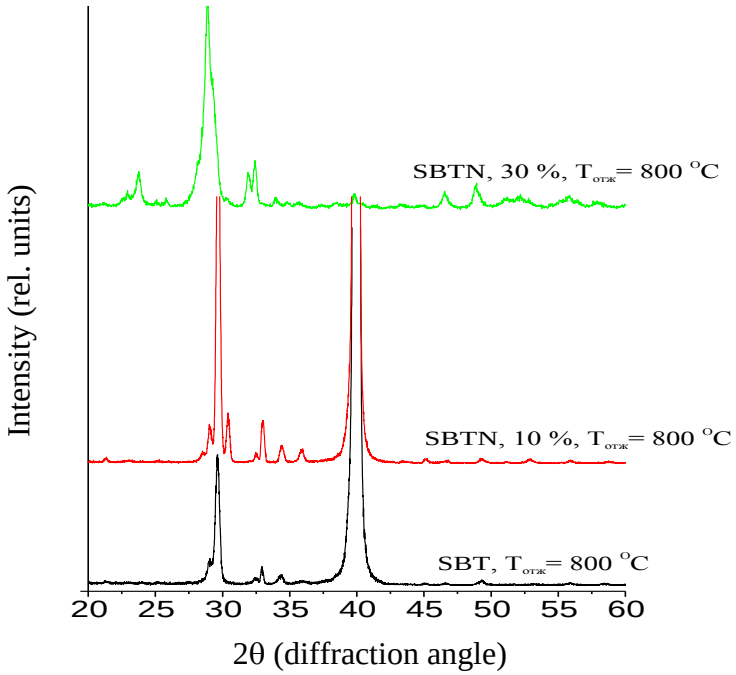
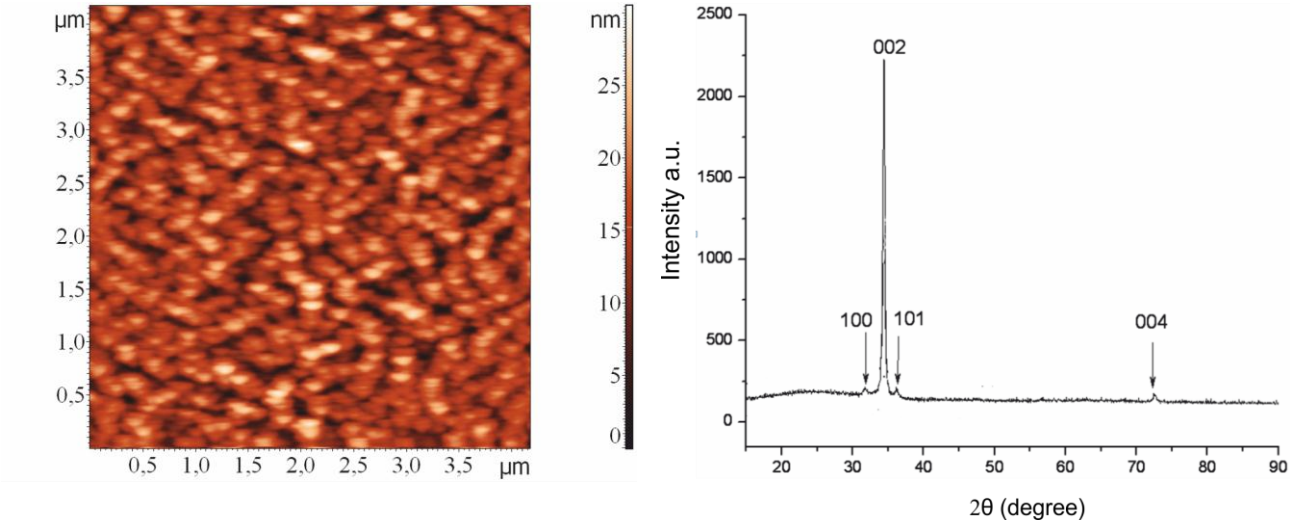


Fig. 2. XRD spectra of SBT, SBTN sol-gel films

It has been shown that the SBTN-films are suitable for using in FRAM (Ferroelectric Random Access Memory) devices because of high homogenity of the structure and of thickness, the comprehensible value of spontaneous polarization, low coercivity.

ZnO films were carried out by centrifugation. For manufacturing the precursor (sol), the required amount of zinc acetate filled into absolute isopropyl alcohol (or dimethylformamide or 2-methoxyethanol according to the sol type) and stirred. Then sol was stirred for 30 minutes. Sol was kept at the room temperature (22±2) °C for 2-3 days. Monoethanolamine was selected as the catalyst because of increase of the exposure time of to two days and ensure their stability during the month. After applying the sol onto the surface of glass, single crystal silicon etc , the samples were placed in the furnace and were heated stepwise at intervals of 20 °C to the temperature of 350 °C for 10 minutes. The process of applying and drying had been repeated until the desired thickness of the ZnO layers was achieved. AFM and XRD (fig. 3a, 3b) investigation confirmed the high homogeneity of the films and their suitability for use in solar sells.



a b

Fig. 3. AFM (a) and XRD spectrum (b) of ZnO:Al sol-gel films

For the manufacturing of RF absorbing materials the initial solutions have been prepared, one of which is alcohol-based, and the second - on the basis of tetraethylorthosilicate (TEOS). Then sol was kept at ambient temperature (22 °C) for 2-3 days, then into each of the solutions was added 20

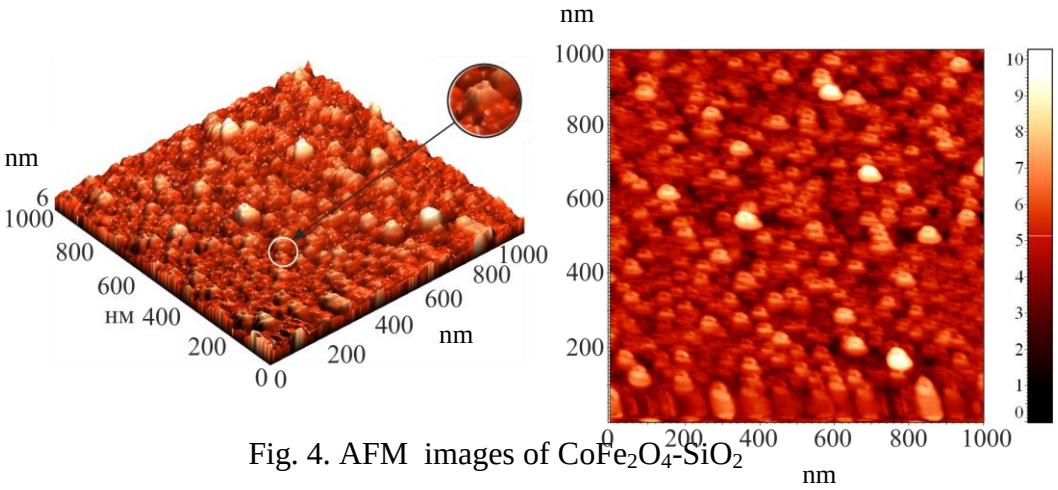


Fig. 4. AFM images of $CoFe_2O_4$-SiO_2

wt. % $Fe(NO_3)_2$ and 40 wt. % $Co(NO_3)_2$. Sol was applied on polished silicon wafers by spin coating deposition. After sol applying the plates were heat treated to 400 °C, 600 °C, 800 °C. The surface topography of microwave absorber coatings was studied by AFM (fig. 4). The influence of physico-chemical synthesis conditions on the frequency dependence of the attenuation and reflection of microwave absorbing sol-gel coatings have been investigated.

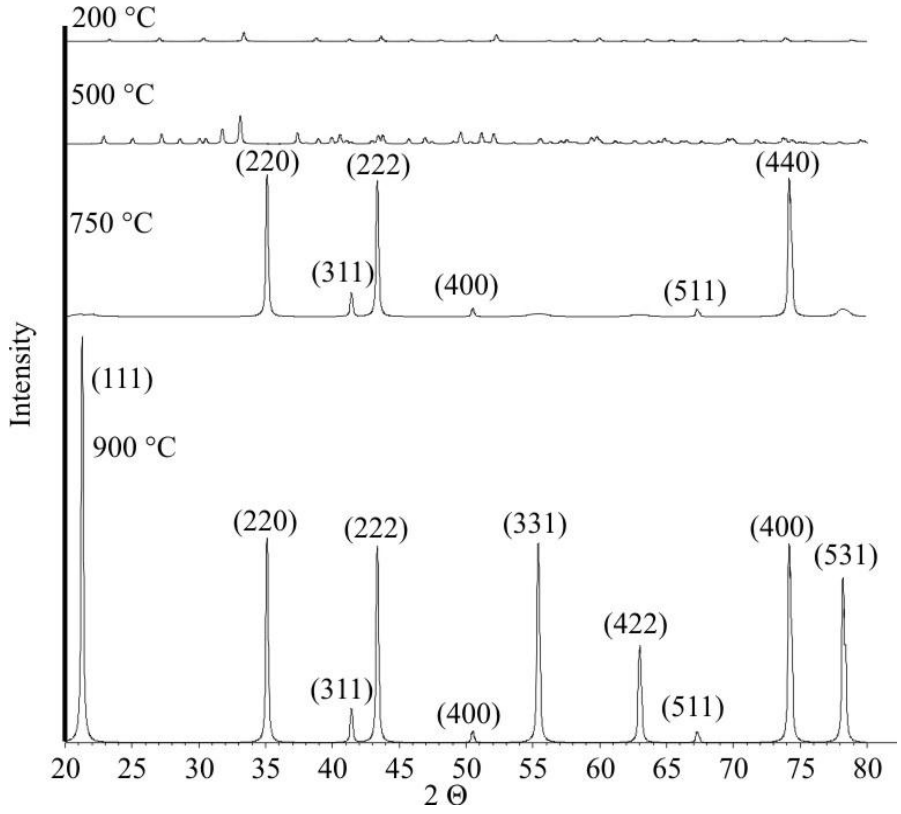


Fig. 5. X-ray spectrum $Fe_xCo_yO_z$-SiO_2-xerogels, synthesized by sol-gel method

Figure 5 shows the X-ray pictures of the studied $Fe_xCo_yO_z$ nanoparticles obtained at different temperatures. On the basis of the obtained X-ray pictures using the Powder Cell program we calculated the packing density for the synthesized matrixes depending on the temperature. It follows from Table 1 that at low temperatures (200-300 ^{0}C) the nanoparticles are characterized by the cubic symmetry. The nanoparticles consisting of ferrum and cobalt oxides were formed after the heat treatment at the temperature of 200-300 ^{0}C. The packing density of the simple cubic cell, as is known, does not exceed 55 %. The transition from one crystalline phase to the other, having the packing density of 81,5 %, occurs during the heat treatment at the temperature range of 300-600 ^{0}C.

The sol-gel films also can be manufactured with relief film surface for use as holographic concentrator in solar cells. Solar cells using holographic concentrators have such advantages as the

lightness and the minimum of thickness. Also the advantage of holographic solar cells is the selection of the light frequencies, leading to high efficiency of photovoltaic cells without overheating ("thermal" part of the spectrum misses photocell). Such type of solar cells do not require turning mechanism. The holographic solar cells compared with solar panels without concentrators require 50-85% less silicon to produce one watt. In this case, the holographic solar sells is much cheaper then large mirrors or lenses.

Organic-inorganic optical layers thicker than 1 μm with a relief surface were synthesized by sol-gel method on the surface of the glass substrates (Fig. 6). The height of one step is about 5 μm.

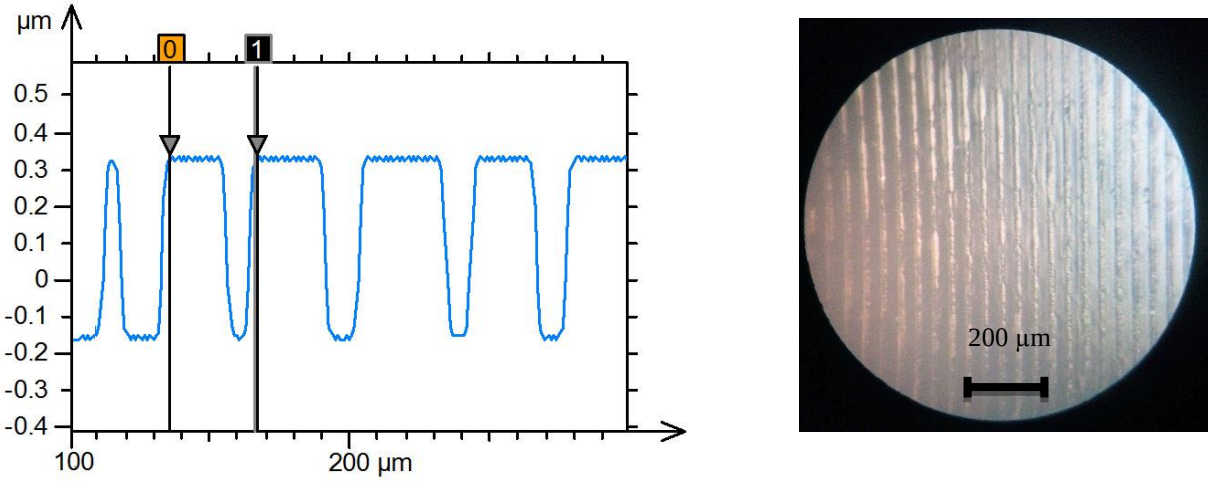


Fig. 6. The surface topography and the micrograph of the sol-gel film with relief surface

The application of sol-gel method will provide holographic concentrators replacing expensive solar cells by relatively cheap optical systems.

Summary

It has been shown that the use of sol-gel method allows to synthesize the functional nanostructured materials (ferroelectrics ($SrBi_2(Ta_xNb_{1-x})_2O_9$), ferromagnetics ($Fe_xCo_yO_z$) and semiconductors (ZnO)) for electronic devices with required properties. The sol-gel method also allows to fabricate optical films thicker than 1 mkm with relief film surface for use as holographic concentrator in solar cells.

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