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Short Communication

Enhancing future technologies: Sol-Gel synthesis of $Sr_{0.6}Ag_{0.4}MnO_3$ manganite perovskite

Faouzia Tayari[1]*, Kais Iben Nassar[1,2] and Majdi Benamara[1,3]

[1]I3N-Aveiro, Department of Physics, University of Aveiro, 3810-193, Aveiro, Portugal

[2]CICECO – Aveiro Institute of Materials, Department of Chemistry, University of Aveiro, Santiago University Campus, Aveiro, Portugal

[3]Laboratory for Building Energy Materials and Components, Swiss Federal Laboratories for Materials Science and Technology (Empa), Überlandstrasse 129, 8600 Dübendorf, Switzerland

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***Corresponding author:** Faouzia Tayari, I3N-Aveiro, Department of Physics, University of Aveiro, 3810-193, Aveiro, Portugal, E-mail: Faouziatayari12@gmail.com

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Abstract

The research successfully produced $Sr_{0.6}Ag_{0.4}MnO_3$, a silver strontium manganite with the desired perovskite crystal structure, using the sol-gel technique. Extensive analysis revealed its notable characteristics, indicating potential uses across various fields. X-ray diffraction showed the compound's tetragonal structure at room temperature, affirming its stability. Morphological and chemical assessments confirmed the material's consistency and evenness, with crystallites averaging 27 nm (from XRD) and 90 nm (from SEM). The material displayed a ferro-paramagnetic transition at 375 K, suggesting suitability for magnetic applications, alongside a slight drop in electrical resistance under a magnetic field, hinting at potential magnetoresistive properties for electronic devices. In terms of dielectric properties, particularly at low frequencies, the material demonstrated a high dielectric constant and low tangent loss, indicating its potential for electrical components. Overall, these findings position $Sr_{0.6}Ag_{0.4}MnO_3$ as a versatile material with promising applications in magnetism, electronics, and electrical components.

Introduction

Perovskite materials, known for their versatile properties, have attracted scientific interest in diverse technological applications. Among them, $SrMnO_3$ (SMO) stands out for its unique electrical and magnetic behaviors. Researchers are exploring perovskite doping, including substituting ions like Ag into SMO, to enhance its properties further. SMO, with its ABO_3 crystal structure, displays paraelectric behavior and antiferromagnetic ordering. Its response to mechanical strain is particularly intriguing, as controlled strain can induce ferroelectric properties and alter its magnetic behavior [1-3]. This study focuses on $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticles, aiming to understand how Ag doping affects their structural, electrical, dielectric, and magnetic properties. Limited research exists on these nanoparticles, especially regarding the influence of doping concentration. The study reports the hydrothermal synthesis of $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticles, highlighting their single-phase structure, uniform distribution, high electrical conductivity, and enhanced ferromagnetic behavior at room temperature.

Experimental work

The synthesis of $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticles involved a meticulous sol-gel process with precursors including strontium nitrate, silver nitrate, and manganese II chloride tetrahydrate. The mixture underwent dissolution in nitric acid, heating, gel formation, and calcination, followed by crushing and pressing into circular pellets at varying temperatures. Characterization of the synthesized samples utilized advanced techniques such as X-ray diffraction, scanning electron microscopy, transmission electron microscopy, energy-dispersive X-ray analysis, magnetometry, and impedance analysis to explore structural, morphological, compositional, magnetic, and electrical characteristics comprehensively [4].

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Results and discussion

The X-ray Diffraction (XRD) patterns of the $Sr_{0.6}Ag_{0.4}MnO_3$ sample displayed the crystalline structure, confirming its perovskite nature (Figure 1). Analysis of the powder XRD pattern revealed diffraction peaks indexed within the tetragonal perovskite structure with the space group I4/mcm. Utilizing the Rietveld method with the Fullprof program indicated no secondary phases, affirming the material's single-phase nature [5-8]. The agreement between calculated and measured intensities suggested robust crystallization. Additionally, Scherrer's equation was employed to determine the crystallite size, yielding a value of 27 nm.

$$D_{XRD} = \frac{K.\lambda}{\hat{a}.COS\ \grave{e}}$$

The SEM analysis of annealed $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticles at 1000 °C revealed irregular fine particles prone to agglomeration, indicative of the mechanical alloying process [9]. The SEM images displayed a particle size of 90 nm (Figure 2a), consistent with XRD data. Additionally, SEM coupled with EDX technology confirmed the presence of all elements within the compound, affirming its stoichiometry. Interestingly, the grain size observed in SEM images appeared larger than calculated by the Scherrer formula, suggesting multiple small crystallized grains within each observed grain (Figure 2b).

Magnetization, a key property in perovskite materials with the ABO_3 crystal structure, was investigated in this study over a temperature range of 0 to 400 K. The results, depicted in Figure 3, revealed a notable increase in magnetization at approximately 375 K, indicating a transition from paramagnetic or antiferromagnetic to ferromagnetic states (Figure 3). In the ferromagnetic phase, magnetic moments align parallel, leading to net magnetization and the emergence of ferromagnetism [10-12]. Conversely, above 375 K, the material displays paramagnetic or antiferromagnetic behavior due to disordered or anti-aligned magnetic moments. The observed ferromagnetic transition has significant implications for potential applications, akin to transitions seen in other materials like barium titanate and strontium titanate at Curie temperatures of 393 K and 105 K, respectively.

The examination of conductivity variation with alternating current (AC) frequency provides valuable insights into the charge transport mechanism and interactions among charge carriers. In Figure 4, the variation of this physical quantity concerning angular frequency at different temperatures is depicted. The conductivity spectra validate the existence of two distinct contributions: one at low frequencies, attributed to grain boundaries, and the other at high frequencies, associated with the grains. At low frequencies, conductivity maintains a constant and uniform profile, progressively increasing with

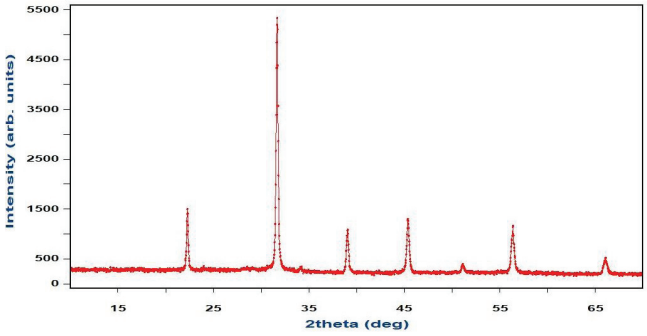

Figure 1: Powder XRD patterns of $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticle.

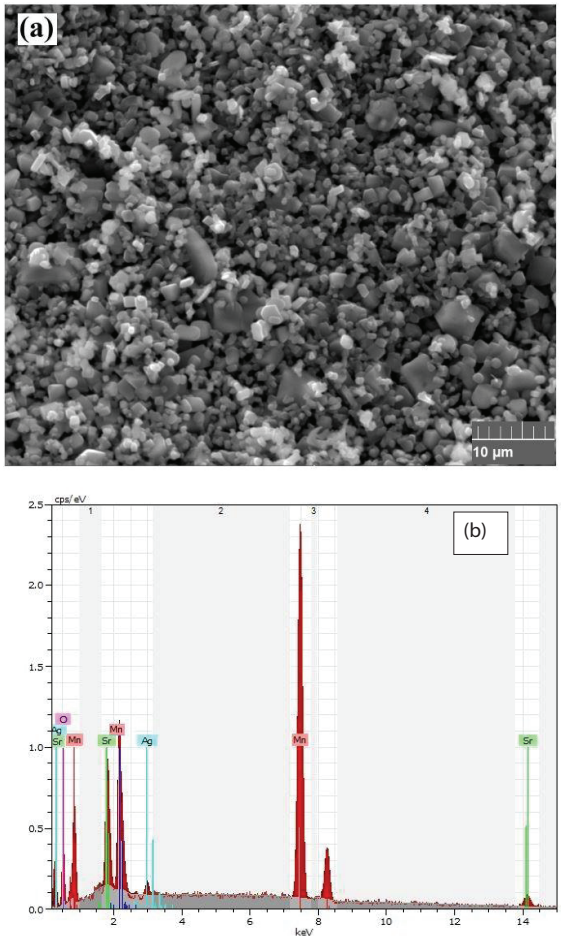

Figure 2: Image SEM (a) and EDX spectra (b) of $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticle at room temperature.

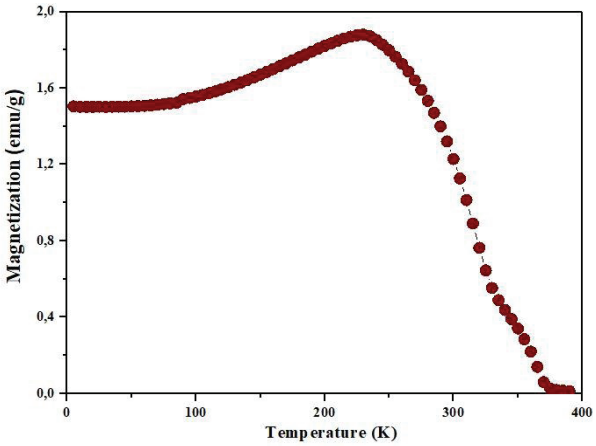

Figure 3: Variation of the magnetization as a function of temperature for $Sr_{0.6}Ag_{0.4}MnO_3$ nanoparticle.

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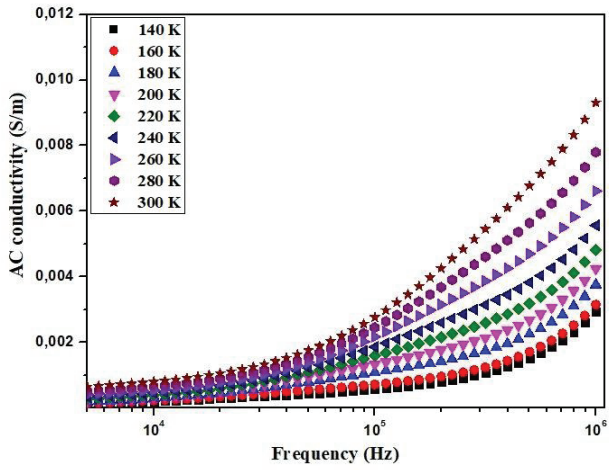

Figure 4: Variation of AC conductivity with frequency.

temperature, indicating the activation of thermal conduction processes within the material [13].

Conclusion

In summary, the sol-gel synthesis of $Sr_{0.6}Ag_{0.4}MnO_3$ perovskite resulted in a high-quality, monophasic material with a well-defined crystal structure (I4/mcm). Structural and morphological analyses confirmed purity and revealed a crystallite size of approximately 27 nm. Magnetic investigations demonstrated a distinctive ferro-paramagnetic transition at 375 K, showcasing its magnetic responsiveness. With its unique combination of magnetic and electrical properties, alongside its well-defined structure, $Sr_{0.6}Ag_{0.4}MnO_3$ emerges as a promising candidate for various high-tech applications, including energy storage and electronics. This study significantly advances our understanding and exploration of perovskite materials tailored for diverse technological applications.

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