Auto-combustion synthesis and characterization of perovskite-type LaFeO_3 nanocrystals prepared via different routes

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ABSTRACT

LaFeO_3 was prepared via simple, economical and environmentally friendly auto-combustion methods using different fuels, including citrate, urea, sucrose, egg whites, gelatin and chitosan. The prepared ferrites were systematically characterized by X-ray diffraction (XRD), Fourier transform infrared (FT-IR) spectroscopy, high resolution transmission electron microscopy (HRTEM), vibrating sample magnetometry (VSM) and electrical measurements to study the impact of the synthetic routes on the various properties. XRD showed the formation of a single orthorhombic phase, except for the samples prepared via egg white, gelatin and urea methods, which indicated a secondary $\text{La}_2\text{O}_2\text{CO}_3$ phase. The FT-IR and TEM studies confirmed the formation of the phase. Differential thermal analysis-thermogravimetry techniques (DTA-TG) were used to characterize the auto-combustion process up to ferrite formation. The obtained unsaturated magnetization for all of the samples suggested the presence of anti-ferromagnetic ordering in addition to weak ferromagnetic ordering. The egg white method showed higher magnetization (1.78 emu/g), while the urea and chitosan methods indicated lower magnetization (0.13 emu/g). The coercivity measurements confirmed the presence of ferromagnetic/anti-ferromagnetic interfaces with higher values than those reported in the literature. The AC-conductivity measurements indicated semiconducting characteristics and exhibited a change in the conduction mechanism from hopping to polaron conduction by increasing the temperature. LaFeO_3 prepared via the egg white method indicated an anti-ferromagnetic/paramagnetic transition at approximately 715 K. The dielectric measurements confirmed the AC-conductivity results and exhibited values higher than those reported in the literature.

1. Introduction

Lanthanum orthoferrite, LaFeO_3 , is an important ABO_3 perovskite type oxide, where A = rare earth element and B = 3d transition metal. The unit cell of LaFeO_3 consists of four formula units with Fe^{3+} ions surrounded by six O^{2-} ions in an octahedral coordination resulting in an orthorhombic structure with a $Pbnm$ space group [1]. Due to its attractive mixed ionic-electronic conductivity, LaFeO_3 has been proposed for many advanced technological applications, such as solid oxide fuel cells [2], oxygen sensors [3] and photocatalysts [4].

The FeO_6 octahedral units consist of two interpenetrating pseudocubic face-centered sublattices. The collinear arrangement of the Fe^{3+} ions in these two sublattices results in an antiferromagnetic interaction. The bulk LaFeO_3 exhibited antiferromagnetic behavior, with a very

high Neel temperature of 740 K and a very small spontaneous magnetization of $0.044 \mu_B/\text{Fe}$ [5]. On the other hand, an interesting observation is that most of the antiferromagnetic nanoparticles sometimes exhibit an increasing net magnetization, which is attributed to the presence of uncompensated surface spin [6]. Thus, the controlling of the size, morphology and crystallinity of LaFeO_3 , which are highly dependent on the preparation method, is expected to promote its ferromagnetic behavior.

Thus, improving of the synthesis of LaFeO_3 has garnered interest by many investigators. The old physical methods, such as solid-state reactions and ball-milling, are now avoided due to their many drawbacks that affect the size and purity of the products [7]. Therefore, many wet chemical methods, including hydrothermal [8], thermal decomposition [9], micro-emulsion [10], microwave plasma [11], electrospinning

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Fig. 1. XRD patterns of the precursors synthesized via the sucrose, chitosan and urea auto-combustion methods.

Fig. 2. XRD patterns of the calcined LaFeO₃ precursors synthesized via different routes.

Fig. 3. FT-IR spectra of the precursors synthesized via different methods.

[12], polymer pyrolysis [13], co-precipitation [14] and hot soap [5] have been investigated.

Wet chemical approaches face many experimental disadvantages, including the use of expensive reagents, small scale production, continuous monitoring of the pH and reactant composition, the need for calcining at high temperatures for long times and the negative environmental impacts. Recently, many sol-gel auto-combustion routes were developed for synthesizing such materials with highly active, stoichiometric and homogeneous yields [15–22]. These routes are simple, inexpensive, environmentally friendly and efficient. Additionally, no further calcination is required, since the heat generated during the reaction is enough for the complete formation of the products.

Most of the auto-combustion processes cited in the literature for the preparation of LaFeO₃ use citric acid [15,18,19,22] or glycine [16,17,20,21] as fuel. Recently, other effective fuels, such as egg whites [23], gelatin [24], chitosan [25], urea [26] and sucrose [27], were successfully used for the efficient synthesis of ferrites. These types of fuels offer an environmentally friendly, fast and economic alternative for the preparation of such materials. The use of these different synthetic routes was found to affect the structural, electrical and magnetic properties [28].

The present study focuses on the preparation of LaFeO₃ perovskite nanocrystals through facile, economic and environmentally friendly sol-gel auto-combustion routes using different fuels, including egg whites, gelatin, citric acid, urea, chitosan and sucrose. The auto-combustion and ferrite formation processes were characterized using DTA-TG, XRD, FT-IR and TEM measurements. The magnetic and dielectric properties, as well as the AC-conductivity, were measured to study the effect of the different preparation routes on these properties and to suggest appropriate applications.

2. Experimental

2.1. Materials

All chemicals, including lanthanum nitrate hexahydrate (La(NO₃)₃·6H₂O), iron nitrate nonahydrate (Fe(NO₃)₃·9H₂O), citric acid (C₆H₈O₇), ammonium hydroxide (NH₄OH), low molecular weight chitosan and urea; (CO(NH₂)₂), were purchased from BDH and used as received. Gelatin powder was obtained from Fluke. Egg white extract was freshly prepared and commercial sucrose (C₁₂H₂₂O₁₁) was used as received.

2.2. Synthetic processes

The complete preparation processes have been reported in our previous works [23–28]. Generally, the citric acid, urea, egg whites, gelatin, chitosan and sucrose play a dual role. The first role is as a chelating agent to complex with Fe and La cations in the precursor solution, and the second role is as the fuel oxidized by nitrates during the auto-combustion process.

In the citrate sol-gel method [28], the stoichiometric amounts of entire metal nitrates were dissolved in a citric acid solution to form sol. The molar ratio of citric acid was equal to the molar ratio of both metal nitrates. The nitrate-citrate sol was then stabilized by adjusting the solution pH to approximately 7 using ammonium hydroxide. During this process, the mixture was vigorously stirred while keeping the temperature approximately 60 °C. The temperature was then raised to approximately 90 °C until the sol turned into viscous brown gel. By further evaporation of the gel, the gel frothed and turned into a dry gel, which automatically burnt in a self-propagation combustion and transformed into loose ash (as-synthesized precursor).

In the urea auto-combustion method, the urea to nitrate ratio required to release enough energy for the auto-combustion reaction was

Table 1
Structural and electro-magnetic data for LaFeO₃ system prepared via different routes.

Method	<i>a</i> , (Å)	<i>b</i> , (Å)	<i>c</i> , (Å)	<i>L</i> (nm)	<i>D</i> (nm)	<i>D_x</i> (g cm ⁻³)	<i>ν</i> ₁ (cm ⁻¹)	<i>ν</i> ₂ (cm ⁻¹)	<i>M_s</i> emu/g	<i>M_r</i> emu/g	<i>H_{C(gf)}</i>	<i>H_{C(df)}</i>	<i>σ</i> , (ohm ⁻¹ cm ⁻¹)
Citrate	5.558	7.862	5.554	38	35	6.64	559	344	0.56	0.07	222	277	3.0 × 10 ⁻⁶
Chito	5.565	7.864	5.540	37	39	6.65	563	343	0.13	0.03	703	987	1.3 × 10 ⁻⁵
Egg-white	5.563	7.870	5.560	51	54	6.62	561	345	1.78	0.51	235	252	9.0 × 10 ⁻⁶
Gelatin	5.550	7.855	5.690	28	29	6.50	567	360	1.76	0.14	119	137	7.6 × 10 ⁻⁶
Sucrose	5.553	7.843	5.560	24	22	6.66	565	340	0.36	0.04	150	215	7.4 × 10 ⁻⁶
Urea	5.520	7.850	5.800	31	33	6.41	563	338	0.13	0.01	101	328	4.8 × 10 ⁻⁶

calculated based on the total reducing and oxidizing valencies of urea and the nitrates, respectively [29]. The oxidizing valence of La(NO₃)₃ = 3 + 3(0+(-6)) = -15 and of Fe(NO₃)₃ = 3 + 3(0+(-6)) = -15. On the other hand, the reducing valence of urea CO(NH₂)₂ = 4+(-2)+2(0+2(+1)) = +6. Hence, 1 mol of La(NO₃)₃ and 1 mol of Fe(NO₃)₃ require 5 mol of urea (-15+(-15)+6n = 0 where n = moles of urea). The calculated stoichiometric amount of urea was added to a solution containing an appropriate amount of dissolved metal nitrates under vigorous stirring at approximately 90 °C. After the water was completely evaporated and the solution became sufficiently thick, the hot plate temperature was raised to the maximum value. The formed gel initiated auto-combustion accompanied by the evolution of a large amount of heat and gas and the formation of voluminous ash. The powder obtained was collected and denoted the as-synthesized precursor.

In the egg white [23] and gelatin methods [24], the same processing technique was followed. The aqueous egg white solution was freshly prepared by mixing 60 ml egg white extract with 40 ml distilled water. The gelatin aqueous solution was prepared by dissolving 10 g gelatin in 100 ml distilled water under vigorous stirring. The aqueous egg white or gelatin solution was then added to a stoichiometric amount of metal nitrates under continuous stirring without any need for adjusting the pH. The gel precursors that formed were evaporated until an auto-combustion reaction, accompanied by the evolution of a dense gas, started. The obtained loose solids (as-synthesized precursor) were then collected.

In the chitosan method [25], the chitosan (1.6 g) was dissolved in 100 ml acetic acid (3%, v/v). The solution was then added to the stoichiometric nitrate solution under vigorous stirring at 60 °C. The pH was adjusted to approximately 7 using an ammonium solution. The formed gel was then evaporated until the complete combustion occurred, and a foamy powder was obtained (as-prepared precursor). In the sucrose method [27,28], the dissolved sucrose (12 g in 100 ml water) was added to the appropriate ratio of metal nitrates under constant stirring until a homogeneous solution was obtained. The pH was then adjusted to 7 using NH₄OH, and the temperature was raised to 90 °C. The sticky gel that formed was evaporated until auto-combustion propagated with the formation of loose powder (as-synthesized precursor).

To increase the crystallinity, all of the as-synthesized precursors obtained using the different methods were calcined in a muffle furnace at 500 °C for 1 h. The as-synthesized precursor obtained using the urea auto-combustion method was further calcined at 700 °C for 1 h to remove secondary phases and obtain single-phase crystals.

2.3. Techniques

The thermal behaviors (DTA-TG) of the gel precursors (before auto-combustion processes) in air were determined using a Perkin Elmer thermal analyzer up to 700 °C at a heating rate of 5 °C min⁻¹.

The crystalline phases of the as-prepared precursors were characterized using a Bruker D8 Advance X-ray diffractometer operated at 40 kV and 25 mA with a CuKα irradiation source.

Fourier transform infrared spectra were measured in the range 800–300 cm⁻¹ using a Perkin Elmer instrument and KBr pellet technique.

The morphology was monitored using an FEI Titan ST TEM equipped with a field emission gun (FEG) operating at 300 keV.

The magnetic properties were measured at room temperature using a vibrating sample magnetometer (VSM-9600 M Lakeshore) up to an applied magnetic field of 20 kOe.

The AC-conductivity and dielectric properties (as a function of frequency (100 Hz–5 MHz) and temperature up to 750 K) were obtained using a two-probe method and a Hioki LCR high tester 3531.

3. Results and discussion

3.1. Structural characterization

3.1.1. X-ray diffraction

X-ray diffraction is considered an effective way to investigate the crystallinity and crystal structure of materials, as well as to confirm their purity. Fig. 1 shows the X-ray diffraction patterns of the as-synthesized precursors prepared via the sucrose, chitosan and urea auto-combustion methods. The patterns show the successful formation of the single-phase LaFeO₃ perovskite structure for the precursor obtained via the sucrose method, while those synthesized via the chitosan and urea auto-combustion methods indicate low crystallinity and secondary phases, respectively. X-ray diffraction of the other as-synthesized precursors indicated similar patterns to that obtained using the sucrose method.

Fig. 2 shows the X-ray diffraction patterns of the calcined precursors. Upon calcination, all of the samples exhibited diffraction patterns with more intense peaks, indicating a high degree of crystallinity. On the other hand, the absence of any secondary phases confirmed the formation of a single-phase LaFeO₃ perovskite. An exception occurred for the samples synthesized via the egg white, gelatin and urea methods, in which a very small amount of lanthanum oxide carbonate (La₂O₂CO₃) secondary phase was observed. This phase mainly formed on the surfaces of the LaFeO₃ particles due to chemisorption of CO₂ gas at ambient temperature with the formation of carbonate ions [10,20].

The observed reflection planes, (101), (121), (220), (202), (141), (240), (143) and (204), can be assigned to the orthorhombic LaFeO₃ crystalline phase in accordance with the JCPDS card file No. 37-1493. The lattice parameters (*a*, *b*, *c*), as well as the theoretical densities of the synthesized orthoferrites, were calculated using equations (1) and (2) from [30] and are summarized in Table (1).

$$\frac{1}{d^2} = \frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2} \quad (1)$$

$$\rho = \frac{ZM}{N(abc)} \quad (2)$$

where *h*, *k*, *l* are the reflection planes, *d* is the interlayer spacing calculated using the 2θ value and Bragg's equation, *Z* is the number of atoms in the unit cell of the orthorhombic phase, *M* is the molecular weight of LaFeO₃ and *N* is Avogadro's number. The obtained values were found to agree well with those reported in the JCPDS card (*a* = 0.5572 nm, *b* = 0.7848 nm, *c* = 0.5543 nm and *ρ* = 6.638 g cm⁻³).

Fig. 4. TEM images of the calcined LaFeO_3 precursors synthesized via different routes.

The obvious broadening of the diffraction peaks indicates the nanocrystalline characteristics of the synthesized powders. The crystallite sizes L were calculated using the well-known Scherrer's equation (3) and are summarized in Table (1).

Fig. 5. DTA-TG curves of the different gel-precursors in air. Heating rate = 5 °C min⁻¹.

Fig. 6. Room temperature hysteresis loops for LaFeO₃ prepared via different routes.

$$L = \frac{k\lambda}{\beta \cos \theta} \quad (3)$$

where k is a constant equal 0.94, β is the full width of diffraction peak at half maximum (FWHM), λ is the wavelength (1.5406 Å) and θ is the Bragg angle. The measured crystallite sizes range between 24 and

51 nm. The perovskite prepared via the sucrose method has the lowest crystallite size, while that prepared using the egg white method has the highest.

3.1.2. FT-IR spectra

The FT-IR spectra of the calcined LaFeO₃ precursors prepared using different methods were measured in the frequency range 700–300 cm⁻¹ and are displayed in Fig. 3. Two broad absorption peaks approximately 560 and 340 cm⁻¹ were detected, which are the characteristic bands of orthorhombic LaFeO₃. The band approximately 560 cm⁻¹ (ν_1) can be attributed to the Fe–O stretching vibration that is characteristic of FeO₆ octahedral groups, while that approximately 340 cm⁻¹ (ν_2) is due to the bending or deformation modes of Fe–O–Fe [10,20,31]. The slight shifts in the positions of the bands can be correlated to the observed slight changes in the calculated lattice parameters (Table 1).

3.1.3. Morphology characterization

The morphology of the LaFeO₃ synthesized via different routes was examined using TEM to characterize the microstructures and define the particle sizes. High-resolution TEM (HRTEM) analysis and selected area electron diffraction (SAED) were carried out to confirm the crystallinity of the materials and identify the crystal structure. Fig. 4 shows the TEM, HRTEM and SAED images for the different perovskites. The TEM

Fig. 7. Relationship between $\ln\sigma$ and the reciprocal of the absolute temperature as a function of the applied frequency for LaFeO_3 prepared via different routes.

images (Fig. 4a) exhibit worm-like particles with a regular morphology and average sizes (D) that agree well with those estimated through XRD measurements (Table 1). An exception occurred for the LaFeO_3 prepared via the citrate method, in which hexagonal-like particles with sharp boundaries were observed. Generally, the particles are agglomerated (with an exception for the LaFeO_3 prepared via the egg white method). However, the grain boundaries of the particles are obviously distinguishable.

The SAED patterns (Fig. 4b) show discontinuous diffraction rings with sharp spots, indicating polycrystallinity. The major rings could be indexed, in agreement with the XRD results, to the reflection planes (101), (002), (220) and (221) of the orthorhombic LaFeO_3 phase (JCPDS card file No. 37-1493). No diffraction rings that could be attributed to secondary phases were detected. Fig. 4d illustrates the magnification of a portion of the HRTEM image (Fig. 4c), marked by the white square, from which clearly resolved lattice fringes are present. The measured regular interplanar spacings of 0.39 and 0.28 nm are consistent with (101) and (121) reflection planes of orthorhombic LaFeO_3 (where the peak at 22.7° is a convolution of the reflection planes (101) and (002), while that located at 32.23° is a convolution of the reflection planes (121) and (200) [22,32]). This finding agrees well with the XRD results and confirms the formation of an orthorhombic LaFeO_3 phase.

3.2. Thermal decomposition behavior of gel precursors and LaFeO_3 formation

DTA-TG measurements were carried out for the gel precursors (complexes formed by water evaporation prior to auto-combustion) to characterize the decomposition processes and following LaFeO_3 phase formation. Fig. 5 displays the DTA-TG thermographs of the different precursors in air. From the figure, it is clear that all of the decomposition processes proceed through many decomposition TG steps. These steps are evident by the DTA peaks. Generally, the first steps are accompanied by endothermic DTA peaks and are assigned to the dehydration of the gel precursors, while the following steps are accompanied by exothermic DTA peaks and are attributed to the nitrate-fuel auto-combustion processes.

The TG curves showed an almost constant weight loss at approximately 500°C for all of the precursors, except for those prepared via the citrate and chitosan methods. These constant weight losses imply the effective formation of the LaFeO_3 phase during auto-combustion. On the other hand, referring to the previous XRD results (Fig. 1), the energy released during auto-combustion appeared to be inadequate for the formation of well-crystalline single phase LaFeO_3 and that further calcination processes are needed.

Fig. 8. Relationship between the real part of the dielectric constant (ϵ') and the absolute temperature as a function of the applied frequency for LaFeO_3 prepared via different routes.

The expected stoichiometry of the exothermic decomposition reactions for LaFeO_3 formation can be expressed by the following equations:

Citrate method:

Urea method:

Sucrose method:

The stoichiometric representations for the other methods (egg white, gelatin and chitosan methods) appeared to be very complicated due to the high molecular weight and the unknown composition of these complexing agents (egg whites and gelatin are composed of many amino acids linked via peptide bonds, and chitosan is a polysaccharide).

3.3. Magnetic properties

The magnetic properties of LaFeO_3 synthesized via different methods were characterized using VSM measurements. Fig. 6 shows magnetic hysteresis loops measured at room temperature up to a magnetic field strength of 10 kOe. From the figure, it is evident that the synthesized LaFeO_3 displayed sizable hysteresis loops, in contrast to the linear relationship observed for bulk LaFeO_3 [33], indicating ferromagnetic ordering. The unsaturation of the magnetization even up to high magnetic fields (20 kOe) indicates mainly an anti-ferromagnetic ordering beside weak ferromagnetic ordering. This behavior has also been reported for other prepared LaFeO_3 [18,34,35].

Bulk LaFeO_3 is well known to be antiferromagnetic, since its magnetic structure is composed of two interpenetrating pseudocubic face-centered FeO_6 octahedral units with a collinear arrangement, and there is no magnetic interaction between the nonmagnetic La^{3+} ions and Fe^{3+} ions [33]. However, increasing the surface area by reducing the particle size results in a fundamental change in the magnetic ordering due to the generation of uncompensated surface spins [13].

The different magnetic parameters, including saturation magnetization (M_s), coercivity (H_c) and remanent magnetization (M_r), were estimated and are summarized in Table 1. The egg white method showed a higher magnetization value (1.78 emu/g), while the urea and chitosan methods indicated a lower value (0.13 emu/g). In comparison to the

Fig. 9. Relationship between the imaginary part of dielectric constant (ϵ'') and the absolute temperature as a function of the applied frequency for LaFeO_3 prepared via different routes.

literature, the present measured values are lower than the value of 3.3 emu/g for LaFeO_3 nanoparticles synthesized via sol-gel reported by Shen et al. [18]. On the other hand, the values presented here are comparable to or higher than the values for the samples prepared via ball-milling (0.44 emu/g) [36] or electrospinning (0.9 emu/g) [12] methods.

This difference in the magnetization values reflects the impact of the utilized synthetic method and particle size on the resulting magnetic properties. These synthetic conditions may affect the cation distribution of ions among A- and B-sites, surface uncompensated spins [37] or spin canting along the c-axis [38].

The coercivity values, calculated at increasing field ($H_{c(f)}$) and decreasing field ($H_{c(df)}$) (inset of Fig. 5 as a typical curve and Table 1), indicated a shift in the hysteresis loop, which confirmed the presence of ferromagnetic/anti-ferromagnetic interfaces [34]. Generally, all of the samples showed higher coercivity values than of those in the literature [13,34], and the chitosan method resulted in the highest value.

3.4. Electrical properties

The electrical properties of the synthesized ferrites were characterized via their AC-conductivity (σ_{ac}) and dielectric properties; viz. dielectric constant (ϵ') and dielectric loss (ϵ'') as a function of temperature and frequency. Fig. 7 shows the AC-conductivity versus reciprocal temperature as a function of frequency, while Figs. 8 and 9 display the

changes in the dielectric constant and dielectric loss as a function of frequency with temperature.

Generally, increasing the frequency at lower temperatures enhances electron hopping among different charge carriers and helps to liberate trapped charges from their trapping centers. At high temperatures, the excess thermal energy generated initiates lattice vibrations, which overcomes the frequency effect by scattering the charge carriers. This result illustrates the frequency dependence of the conductivity at low temperatures and the frequency independence at higher temperatures (Fig. 7). This result also suggests the predominance of a hopping conduction mechanism at low temperatures, which changes to polaron conduction at higher temperatures [28].

The slight decrease observed in the conductivities by increasing the temperature from ambient up to approximately 450 K could be attributed to the loss of surface adsorbed water [27,28,39]. The gradual changes in the slopes of the conductivity vs. reciprocal temperature plots towards higher conductivities by increasing the temperature indicates semiconducting characteristics for all of the synthesized perovskites. Table 1 summarizes the conductivity values measured at 500 K and 500 kHz for the different perovskites. The highest conductivity value was obtained for the LaFeO_3 prepared via the chitosan method.

For the LaFeO_3 prepared via the egg white method, the change in the slope started at about 620 K and resulted in a bend at approximately 715 K. This change could be attributed to the transition from anti-ferromagnetic to paramagnetic behavior by increasing the temper-

ature. The Neel temperature obtained at approximately 715K agreed well with that reported for LaFeO_3 in the literature [35]. No such transition was observed for the other LaFeO_3 prepared using the other methods.

The dielectric properties (Figs. 8 and 9) showed a gradual decrease in the ϵ' and ϵ'' values when increasing the frequency, which can be considered normal ferrite behavior [28]. This behavior is attributed to insufficient time for the dipoles to catch up with fast changes in the electrical field. The obvious increase in the dielectric values by increasing the temperature could be assigned to the enhancement of polarization by increasing the thermal energy. A similar behavior was reported by Acharya et al. [40] for LaFeO_3 prepared via a solid-state reaction. The relaxation in the polarization that appeared at a high temperature for the perovskite synthesized via the egg white method agreed well with the change obtained in the conductivity vs. temperature measurement and could be attributed to the existence of inertia to the electron exchange [28]. The obtained dielectric values (Figs. 8 and 9) are relatively higher than those reported in the literature [38].

4. Conclusions

Nanosized orthorhombic LaFeO_3 perovskites have been successfully synthesized via auto-combustion techniques using different fuels, including egg whites, gelatin, citric acid, urea, chitosan and sucrose. The XRD measurements detected the formation of a single phase, except for the egg white, gelatin and urea methods, which indicated a small amount of a $\text{La}_2\text{O}_3\text{CO}_3$ secondary phase. The phase formation was also confirmed using FT-IR spectra and TEM measurements. DTA-TG measurements were used to characterize the auto-combustion processes and the subsequent ferrite formation. The VSM results indicated mainly an anti-ferromagnetic ordering in addition to a weak ferromagnetic ordering. Electrical property measurements as a function of temperature and frequency indicated semiconducting properties and suggested the predominance of a hopping conduction mechanism at low temperatures, which changed to a polaron conduction at higher temperatures. The LaFeO_3 prepared via the egg white method exhibited a Neel transition from anti-ferromagnetic to paramagnetic when the temperature increased. The dielectric values presented herein were found to be relatively higher than those reported in the literature.

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