Humidity Sensors Based on $LaFeO_3$ Ceramics Prepared by Sol-Gel Method

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Submitted by:

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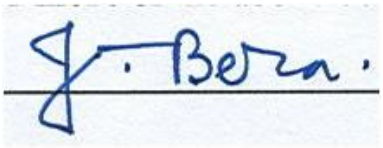
MAY 2014

CERTIFICATE

This is certified that the work contained in the project entitled "**Humidity sensors based on $LaFeO_3$ ceramic Prepared by sol-gel method"** by Jan Verma (Roll 110CR0478) in partial fulfilment of the requirements of the award of Bachelor of Technology Degree in Ceramic Engineering at the National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university / institute for the award of any Degree or Diploma.



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I am heartily thankful to Prof. japesh bera, department of ceramic engineering, national institute of technology, rourkela for his valuable advice, time and guidance in the completion of this project work. I will always remain thankful for his thorough guidance as my instructor and trailblazer.

I am thankful to Mrs. Geeta for her ineffable help and cooperation.

Jan Verma

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Abstract

$LaFeO_3$ material is fabricated by the standard sol-gel technique using lanthanum oxide and iron nitrate as starting raw material. The material synthesized by sol-gel technique is found highly porous. The sol-gel route synthesized material is further characterized by XRD, SEM, and apparent porosity. The synthesized material is found microporous that provide more number of active sites on the surface for water absorption. So $LaFeO_3$ material is found very excellent material for the application of humidity sensors. $LaFeO_3$ material is shaped to pallets followed by electroding and then an impedance characteristic is tested. All the analysis performed on $LaFeO_3$ material is found highly susceptible for the application as humidity sensing material.

CONTENTS

1. INTRODUCTION

Humidity sensors are basically used for measuring purpose of relative humidity present in the air. Measuring relative humidity means measurement of both temperature in the air and present moisture. Relative humidity is defined as the ratio of actual moisture present in the air to the highest amount of moisture present in the air at that temperature, so relative humidity is measured in percentage which is ratio of actual moisture to the maximum amount of moisture present at that particular temperature in the air. The warmer the air is the more moisture it can keep, so relative humidity changes with change in temperature [1]. Humidity is the amount of water vapor present in the air. It may be in the form of precipitation, fog or dew. Higher amount of humidity decreases the effectiveness of sweating in cooling the body by reducing the rate of evaporation of moisture from the skin [2]. This effect is also called heat index. There are mainly three type of humidity measurement: absolute relative and specific.

1.1 TYPES OF HUMIDITY

Absolute humidity

Absolute humidity is defined as the mass of water vapor, Mw that is per unit volume of the total air present and the water vapor mixture P_{net}, which can be expressed by the equation:

$$A\,H = M_W/P_{net}$$

Absolute humidity present in the atmosphere ranges from approximately value of zero to approximately 30 grams per cubic meter when air saturation is at 30 °C.

Without a doubt the mugginess changes as air temperature or weight changes. This makes it unsatisfactory for synthetic designing counts, e.g. for dress dryers, where temperature can fluctuate impressively. Subsequently, outright mugginess in compound building may allude to mass of water vapor for every unit mass of dry air, otherwise called the mass blending proportion which is more qualified for hotness and mass parity figuring. Mass of water for every unit volume as in the comparison above is additionally characterized as volumetric stickiness. In short, total mugginess is the aggregate sum of water vapor introduce in a given volume of air. It doesn't contemplate temperature [1, 3-5].

Relative humidity:

Relative humidity is defined as the ratio of actual moisture present in the air to the highest amount of moisture present in the air at that temperature, so relative humidity is measured in percentage which is ratio of actual moisture to the maximum amount of moisture present at that particular temperature in the air.

The relative moistness of an air-water mixture is characterized as the degree of the halfway weight of water vapor (H_2O) in the mixture to the immersed vapor weight of water at a given temperature. Hence the relative moistness of air is a capacity of both water substance and temperature [1-4].

Relative moistness is ordinarily communicated as a rate and is computed by utilizing the accompanying mathematical statement:

$$\phi = \frac{e_w}{e^*_w} \times 100\%$$

Relative dampness is a paramount metric utilized as a part of climate estimates and reports, as it is a marker of the probability of precipitation, dew, or mist. In hot summer climate, an ascent in relative mugginess builds the clear temperature to people (and different creatures) by ruining the vanishing of sweat from the skin. For instance, as per the Heat Index, a relative mugginess of 75% at 80.0°f (26.7°c) might feel like 83.6°f ±1.3 °f (28.7°c ±0.7 °c) at ~44% relative moisture [1, 6, 7].

Specific humidity:

Particular mugginess is the proportion of water vapor to unit mass of dry air in any given volume of the mixture, and is off and on again alluded to as the stickiness degree. Particular moistness is roughly equivalent to the “blending proportion”, which is characterized as the degree of the mass of water vapor in an air bundle to the mass of dry air for the same package [1].

Specific Humidity is characterized as:

$S.H = M_v / (M_v + M_a)$

1.2 TYPES OF HUMIDITY SENSORS:

The sensor can be classified into two categories:

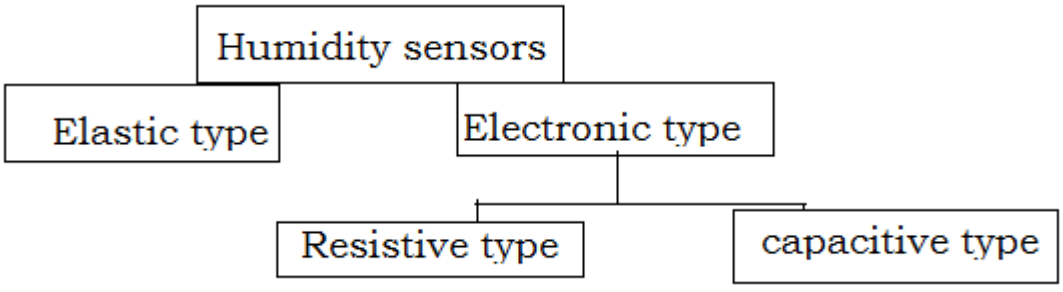


Figure 1.1 types of humidity sensors

Resistive type:-

This type of sensor mainly contains materials like alumina and thermo plastics. In this type of sensor sensing mechanism is based on the resistance that means the resistance of the sensors changes with humidity. The main disadvantage of this type of sensors is poor sensing time, response time and accuracy [8, 9].

Capacitive type:-

They use materials like polymers, polyesters etc. in this type of sensors the capacitance change is noted down against the change in the surrounding humidity. The response time, accuracy and linearity is better than that of resistive type of sensors. There are many types of measuring methods of output of capacitive types of sensors [10]. To understand the basic sensing measurement principle behind the humidity sensors based on capacitive effect, we need to know some basic facts.

Basics of Capacitive Measurements:-

The capacitance for parallel plate capacitor is defined as:

$C = €_0€_rA/D$

Where $€_0$ represents permittivity of free space

$€_r$ represents relative permittivity of dielectric sndwitched between the plates.

A represents area of plates

D represents the distance between the plates

C represents the capacitance.

In this equation if all right hand side parametes change then the capacitance value will change. So in the capacitive type sensors if any amount of moisture is absorbed then it will change thae value of capacitance.

Measurement of humidity plays a very crucial role in controlling and monitoring the human comfort and industrial processes. The measurement of presence of water vapor are very essential for the industries because it may affect the economical, physical, chemical and biological processes, monitoring of humidity also affect the processing and production cost. It is also important for control the health issues, safety issues and human comfort. Humidity control is also important for various domestic applications. In semiconductor industry moisture level should be controlled during water processing. In medical industry there are many processes where measurement and controlling is necessary factor like production of products. Humidity control is also important in agriculture and chemical industries. In agriculture, plant protection is highly dependent of moisture level. In chemical industry various types of purification processes run that required controlling of moisture level. In domestic application such as buildings, cooking, microwave ovens etc. are required control of humidity. The unit of humidity measurement is relative humidity (RH). RH is a function of temperature so it is a relative measurement [1-3].

1.3 SENSING MECHANISM:

There are two types of humidity sensing, capacitive ad resistive based:-

Humidity sensors depend on this principle according to which a hygroscopic dielectric material is placed between the pair of electrodes that forms a small capacitor. Plastic, polymer or ceramic are used as dielectric material having

dielectric constant 2 to 15. In absence of moisture the dielectric constant of the hygroscopic dielectric material that is placed between the electrodes and the sensor geometrical shape decide the value of existing capacitance. Water vapor shows a dielectric value of 80 at normal room temperature, which is very much larger than the value of constant of sensor dielectric material this is the main reason by which sensor shows increase in sensor capacitance by absorption of water or moisture.

The water absorption on the surface of capacitive type ceramic sensors results change in electrical properties. Water molecule get absorb on the active sites of the oxide surface chemically and that forms a hydroxyl ions by the dissociative mechanism. On the other side if this water absorption happens on metal surface layers of grains then it changes the local found density and a strong found electrostatic field and the proton react with a nearby oxygen anion to form an OH^- group. The water molecule which is absorbed physically are prone to dissociate easily due to the presence of high electrostatic created fields in the chemisorbed layers from single layer to multilayer. The main reason behind it is the increase in the water vapor pressure, so water molecules create dipole under applied field that results in the increase in dielectric constant.

Humidity sensors are widely used in many environments to maintain the required humid condition such as in medical industry, semiconductor industry, research lab, or food processing industry.

To measure, control and maintain humidity various types of humidity sensors are used that contains ceramic sensors, mechanical hygrometer, optical fiber sensors and polymer sensors.

Among all these sensors ceramic sensors are cheap and easy to fabricate so they are mostly used. Ceramic sensor also shows good stability in different type of environment. Ceramic sensors have simple structure that makes them easy during processing. But Research is going on for the further development and establishment of properties of ceramic sensors because sensitivity time, response time and longtime stability are required to be development in ceramic sensors. The sensing mechanism of ceramic sensors are based on the change of dielectric constant of ceramic material which is placed between the interdigital electrode, this type of setup forms a capacitor when water or moisture is absorbed on the surface of this ceramic material the dielectric constant changes. This change in dielectric constant result in change in the value of capacitance of capacitor and this change corresponds to the sensing of humidity. The sensing time depends on the geometry of the sensors so high surface area and porosity are required. The higher amount porosity and surface area leads to the more number of active sites for the humidity absorption [4, 10-14].

The ceramic materials are divided into three major parts on the basis of porosity : macro porous materials having porosity of greater than 50 nm, mesoporous materials having porosity in the range between 2 to 50 nm pore diameter and micro porous materials having porosity less than 2 nm. The mesoporous materials show good sensing characteristics so they are widely used as humidity sensors. Meso porous material is very popular Due to their high internal and external and internal surface area with high porosity. There are many metal oxides that are used as humidity sensing material [14].

1.4 CRYSTALLOGRAPHY OF $LAFEO_3$

In this paper $LaFeO_3$ mesoporous material is prepared successfully. The material $LaFeO_3$ has perovskite structure that exhibit many interesting properties from both application and theoretical point of view. The general chemical formula for perovskite crystal structure is ABO_3 in which A can be rare earth metals, alkali or alkaline earth metal, and B can be transition metals [1, 11].

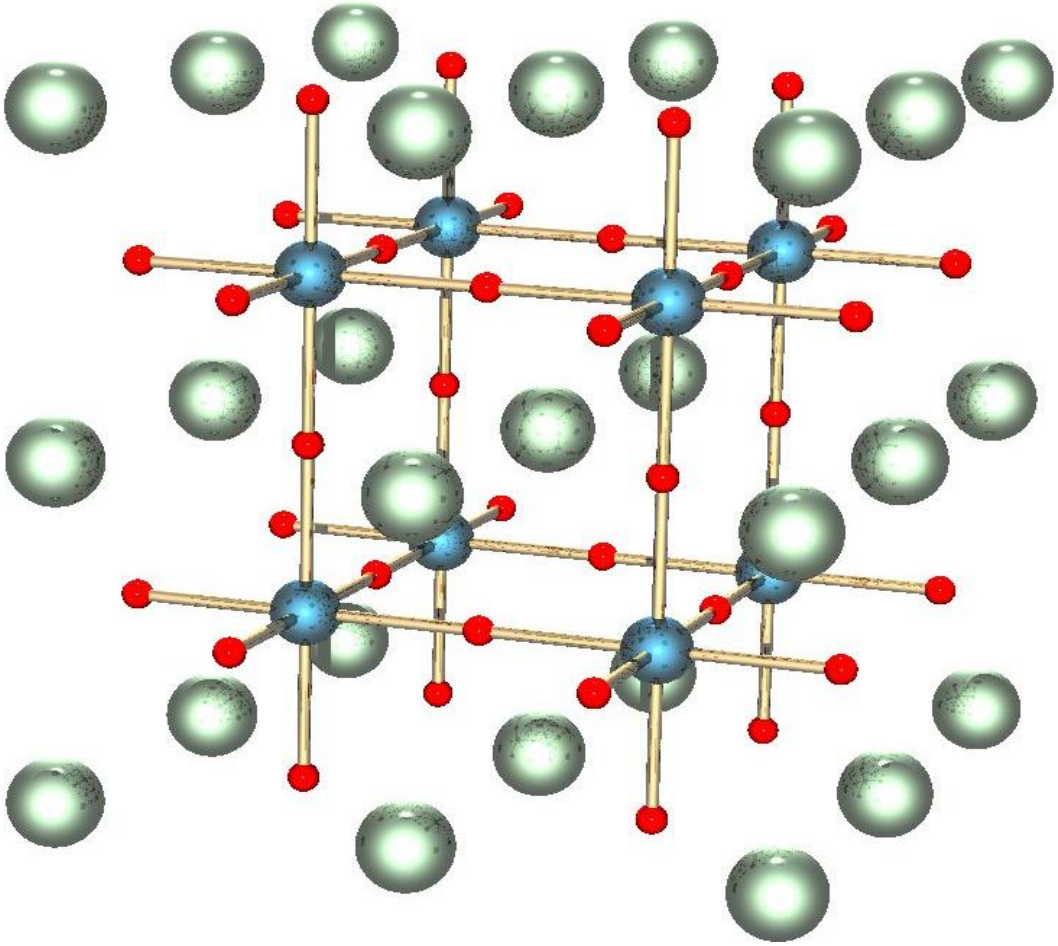


Figure 1.2: perovskite crystal structure [1, 12]

Perovskite structure show good thermal and catalytic activity stability. Another advantage is that the fabrication and processing cot is very low. In perovskite crystal structure atom on site A are very prone to susceptibility towards humidity

sensing, and this properties can also be enhanced by partial substitution of A site atom with other rare earth cations like Sc, Y, La, and all lanthanides [1-4]. The perovskite crystal structure is shown in the figure 1.2.

The 'A' atoms have bigger size than the 'B' atoms. The cubic-symmetry structure that is considered to be ideal has the B cation in 6-fold coordination, surrounded by an octahedron of anions, and the A cation in 12 fold cub octahedral coordination. Perovsktie crystal structure are well known for the application in the field of dielectric, high temperature ionic conductors, ferroelectrics and semiconductors [1, 12].

1.5 PROPERTIES OF LAFEO_3

In this present work $LaFeO_3$ is fabricated successfully, $LaFeO_3$ is taken due to its excellent properties. It is chemically stable in both oxidizing and reducing atmosphere. The properties $LaFeO_3$ can be enhanced by doping it with some other materials to get high electrical conductivity, low dielectric loss, and high dielectric constant, average type of permittivity, susceptibility and polarisibility. It also shows good piezoelectricity, good Ferro electricity. It is a very popular in the application in solid oxide fuel cells. Its application in solid electrolyte and microwave dielectric make is very useful [13].

2. EXPERIMENTAL

2.1 MATERIAL SYNTHESIS AND PROCESSING.

2.1.1 Raw materials used:

There are mainly two types of raw materials used in the synthesis:- La_2O_3 and Fe $(NO_3)_3$. PVA polymer solutions are also used.

2.1.2 Batch calculation

Batch calculation is done on the basis of purity of raw materials and amount of water content.

For the preparation of batch of 10gm of $LaFeO_3$, 6.710gm La_2O_3 and 16.64gm Fe $(NO_3)_3.9H_2O$ have been taken.

The main reaction involved in this fabrication is:

La_2O_3 + Fe $(NO_3)_3$ = $LaFeO_3$

2.1.3 Batch preparation via sol- gel route:

Lanthanum oxide powder is weighted into a pan. Nitric acid is taken into a beaker; this beaker is placed onto a heater. Lanthanum oxide is dissolved into nitric acid. In this solution Fe $(NO_3)_3.9H_2O$ is added drop wise slowly to dissolve it. The temperature of heater is maintained at 80^0C. Then 5 volume % PVA solution was added manually to get gelation. This whole setup is put onto a magnetic stirrer and magnetic bar is put into the solution for stirring. After several hours when

viscosity of solution become high the magnetic stirrer is put out. This whole process is performed for the gelation of the solution.

2.1.4 Drying and grinding.

This gel is put into the oven for the purpose of drying, the temperature is maintained at 110^0C. The soaking time was 24 hours. Then dried gel is then grinded to make fine powder. The powder is formed to ease the shaping processes.

2.1.5 Shaping and firing.

Prepared batches is mixed with 5 volume % PVA solution and mixed properly to get uniformity. Then the powder is put into the die for pressing. The 4.2 ton load is given with a soaking time of 60 seconds, so powder is shaped to the pallets. These pressed samples are kept into the drier at 110^0C for 24 hours.

Now dried samples are fired at three different temperature i.e. 800^0C, 850^0C and 900^0Crespectively with 6 hours soaking time.

2.2 CHARACTERIZATION:

Inspection and testing of ceramic or refractory is important to ensure the use of end of the product but in this case we need to know the porosity of the material because the sensing property depends on water absorption and absorption depends on porosity of the material. XRD and SEM analysis is done to obtain the phases present and the microstructure.

2.2.1 Determination of A.P and B.D

The green sample, 8000 ^{o}C, 850 ^{o}C, 900 ^{o}C, fired samples (pallets) is weighed with accuracy of 0.01 gram. This is called dry weight (D).the dry specimen is placed in an beaker and is filled with water. This beaker is kept on heater to boil for 4 hour and is evacuated to a pressure of less than 25 mm of Hg. The specimen is allowed to remain in under reduced pressure for 5-6 hours after which Test specimen is suspended with the help of pan in water and suspended weight of sample in water is taken this is called suspended weight (S). Now liquid drops appearing on the surface of sample are wiped & weight is taken in air. This is called soaked weight (W).

The apparent porosity (P) and bulk density (B) is calculated as:-

$$P=\frac{W-D}{W-S}\times 100\ (\%)$$

$$B=\frac{D}{W-S}\times density\ of\ the\ media\ in\ which\ experiment\ is\ performed$$

Here water is used as media.

2.2.2 XRD ANALYSIS

When X-rays passes through or in the matter, the radiation interacts with the electrons present in the atoms that results the scattering of the radiation. For materials that are crystalline, the distances between the planes is same and if the atoms are of the same magnitude as the wavelength of the X-rays, constructive and destructive interference will occur. This diffraction where X-rays are emitted at characteristic angles based on the spaces between the atoms organized in crystalline structures called planes.

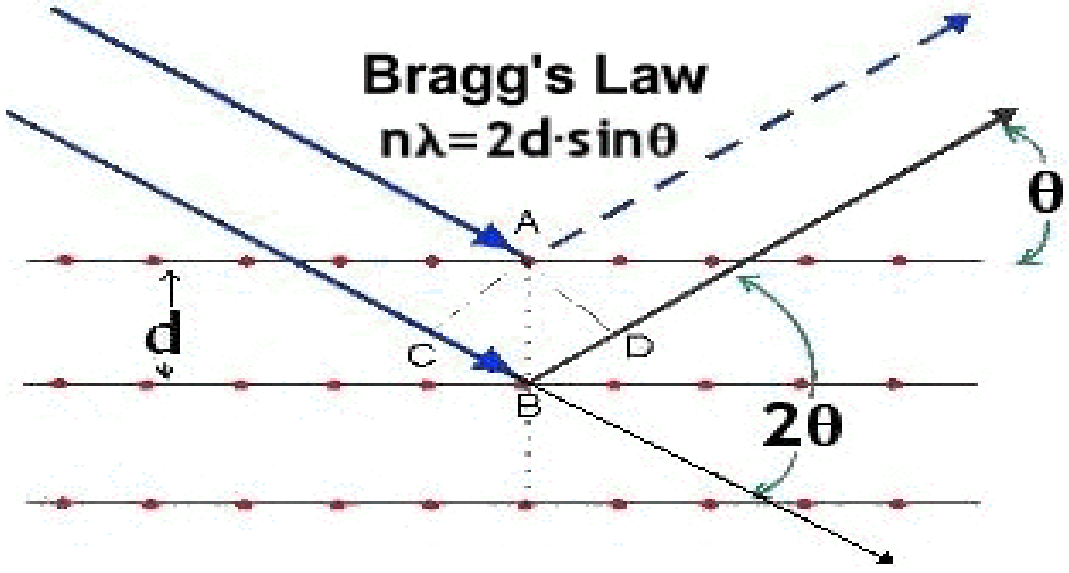


Figure-2.1 XRD Diffraction

2.2.3 SEM ANALYSIS

Scanning electron magnifying instrument (SEM) is a sort of electron magnifying instrument that transforms pictures of a specimen by checking it with a centered light emission. The electrons collaborate with molecules in the example, preparing different signs that could be caught and that hold data about the specimen's surface geography and organization. The electron pillar is for the most part filtered in a raster output example, and the bar's position is joined with the identified sign to prepare a picture. SEM can attain determination superior to 1 nanometer. Examples could be seen in high vacuum, in low vacuum, and in wet conditions.

2.3 FABRICATION AND MEASUREMENT OF HUMIDITY SENSORS:

The fired samples i.e. pallets are taken and silver paste is applied on the surface of the pallets. The silver coating was applied at the Centre of the pallets to form concentric with sample. The coating is applied approximately half of the diameter of the pallets. Then pallets are kept in driers at 110^0C for 2 hrs. The dried samples are fired at 600^0C for 2 hours soaking time. The fine copper wires are attached on the silver coating by the soldering method. Wires are soldered both side of the sample to form a capacitor. The characteristics of humidity responses curves were got carry out by a impedance analyzing device (model hioki 3532-50 LCR Hi TESTER) using specific software. The operating voltage was maintained at AC 1 V and the operating frequency was changed according to the situation of measurements. All the humidity sensitivity measurement was performed at room temperature. The sensor response can be defined as the ratio of the impedance in

11 percent of RH to that of the 98 percent of RH. The controlled humidity environment was created by creating supersaturated aqueous solutions of the different salts. The table shows supersaturated salts with relative humidity yielded accordingly [12-14].

Table 2.1 supersaturated aqueous solution and equivalent relative humidity

SUPERSTAURATED SOLUTION	RH (%)
LiCl	11
MgCl2	33
KCl	59
NaBr	75
NaCl	85
K2SO4	98

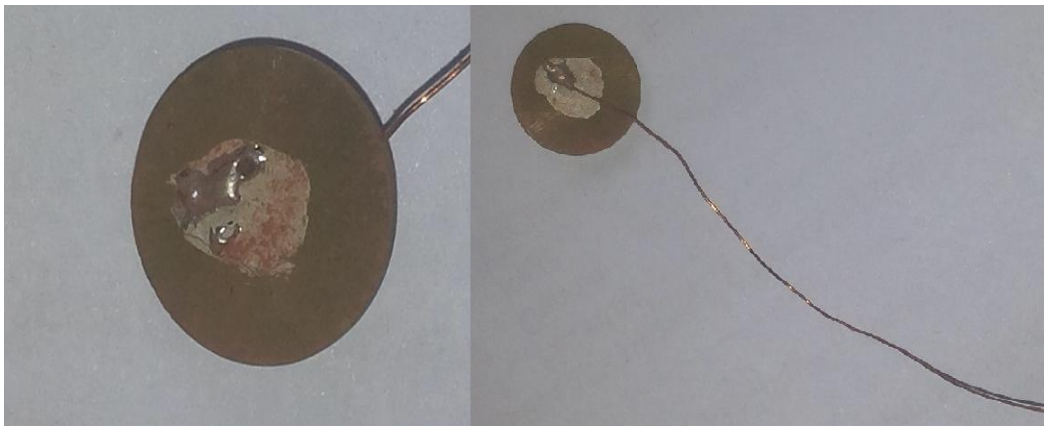
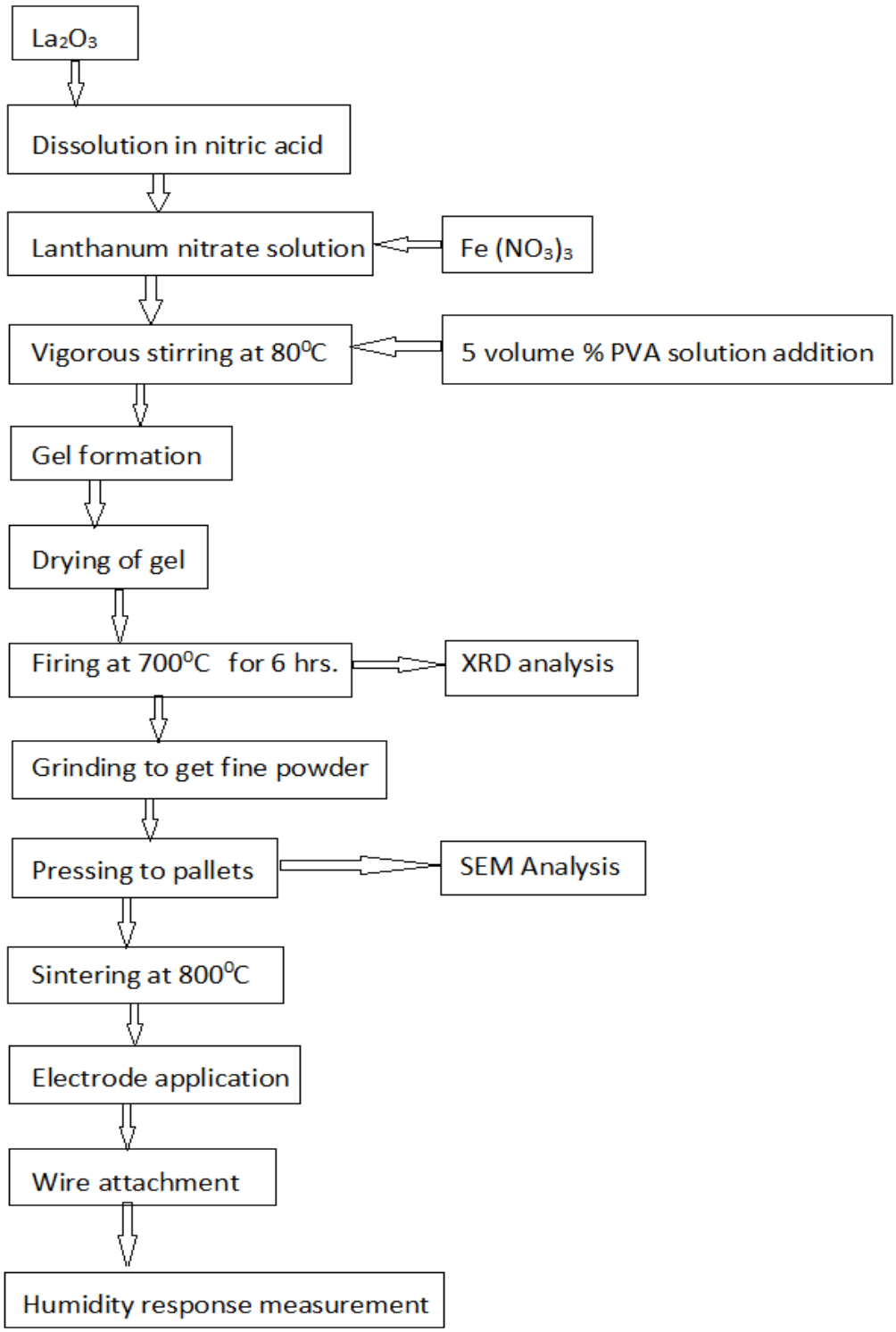


Figure 2.2 prepared sample

2.4 FLOW CHART



3. RESULT AND DISSCUSSION:

3.1 APPARENT POROSITY AND BULK DENSITY.

The apparent porosity and bulk density of four sintered samples are calculated. The result is shown in the table below.

Table 3.1 apparent porosity and bulk density

sample	Soaked wt. (W)	Suspended wt.(S)	Dry wt. (D)	B.D (D/W-S)	A.P (%) (W-D/W-S)
M1	0.5096	0.3489	0.4147	2.58	51.05
M2	0.5326	0.3600	0.4262	2.46	61.64
M3	0.5915	0.4153	0.4921	2.79	56.41
M4	0.3412	0.2333	0.2788	2.58	57.83

The apparent porosity values of four different sintered samples are found as 51%, 61%, 56% and 57%. This result shows that samples are highly porous. High porosity values of sample are very helpful in humidity sensing because it consists more active sites for moisture absorption. The characteristics of percentage

porosity with sintering temperature are shown below. This graph shows the Porosity for all the samples sintered at temperature 800°C, 850°C and 900°C are found to be very high. Porosity decreases with increase in temperature.

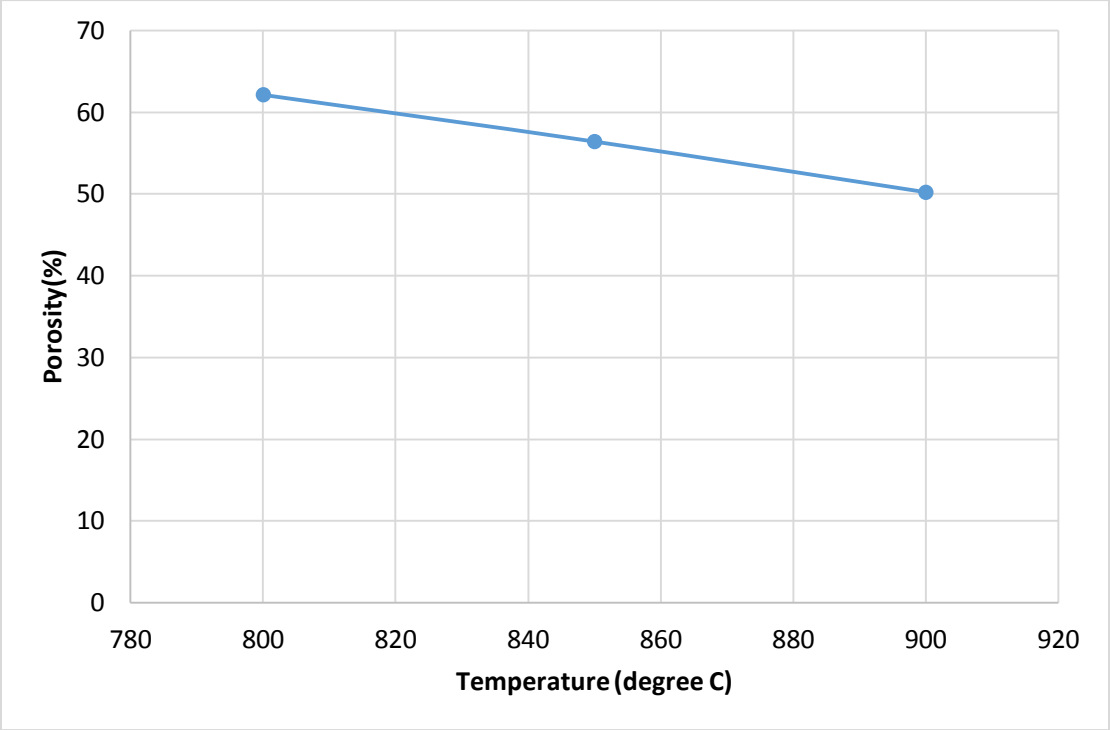


Figure 3.1 apparent porosity vs sintering temperature.

3.2 XRD ANAYSIS

XRD analysis is performed for samples sintered at temperature 800°C, 850°C and 900°C. The XRD patterns for all samples sintered between 800°C to 900°C is found same and shown in figure 3.2.

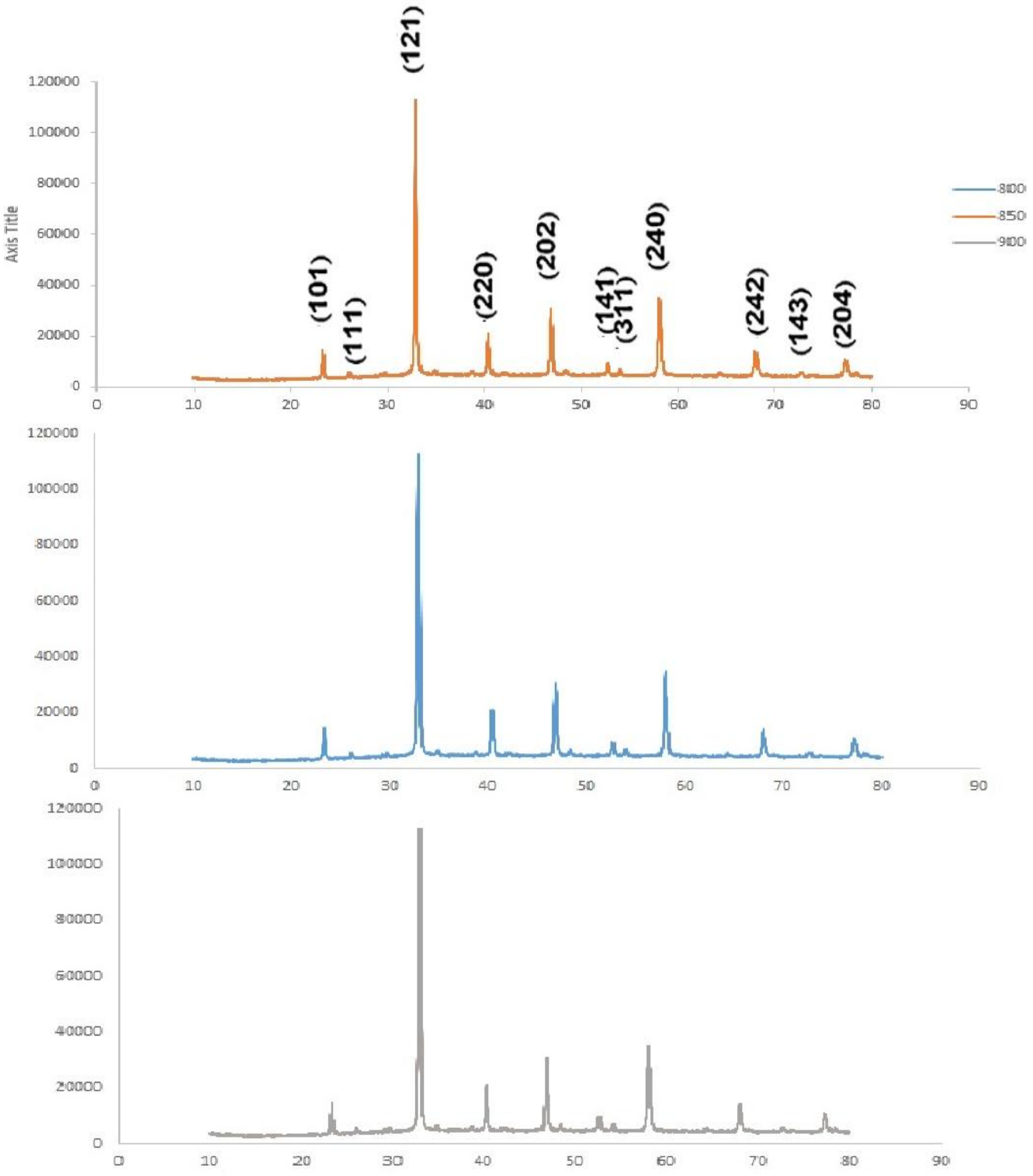


Figure 3.2 XRD pattern of sample sintered at (a) 850oC (b) 850°C and (c) 900°C

The major phase present in the sample sintered at 800°C, 850 ^{o} C and 900°C is lanthanum iron oxide as shown in figure 3.2(a), 3.2(b)and 3.2(c). No any other phase is found. The XRD patterns of LeFeO3 shown indicating that the lanthanum oxide and iron nitrate taken as raw material have been completely transformed into crystalline LaFeO3. So the major phase is lanthanum iron oxide and no other major crystalline phases are found.

3.3 SEM ANALYSIS

3.3.1 SEM of sample sintered at 800°C.

Scanning electron microscopy analysis is performed for the sample sintered at 800°C. Micrometer range morphology in Fig. 3.3 (a) shows high micropores in the sample. The micrograph in figure 3.3(b) shows that the grain size are in the range from 100-150nm. That implies that samples sintered at 800°C are highly porous.

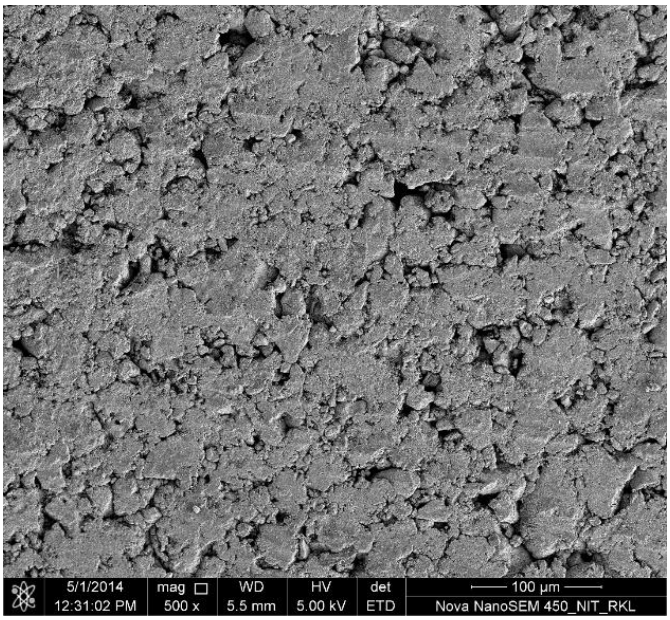


Figure 3.3(a) 800^{0}C sample SEM micrograph

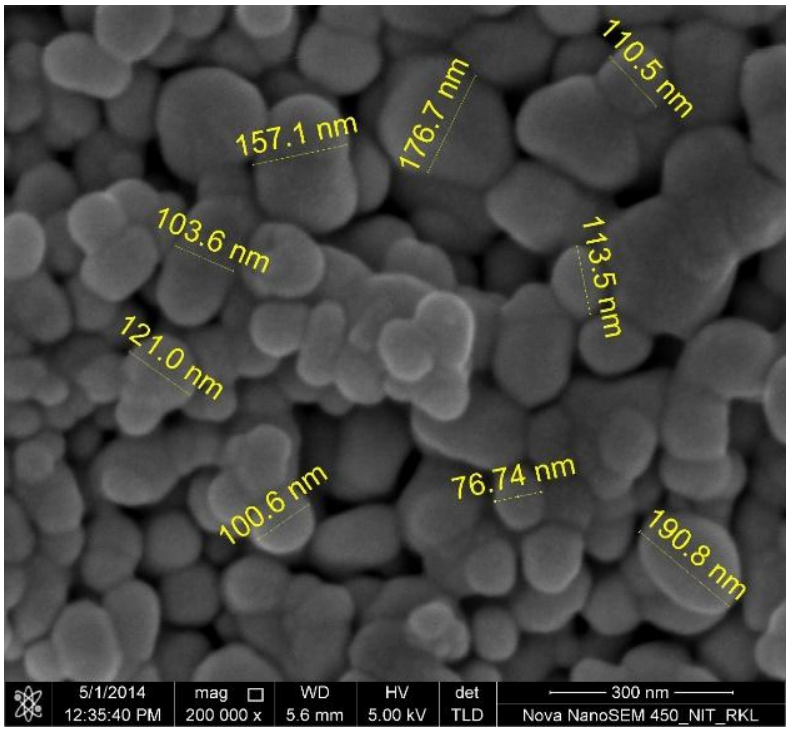


Figure 3.3 (b)800^{0}C sample SEM micrograph

3.3.2 SEM of sample sintered at 900°C.

Scanning electron microscopy analysis is performed for the sample sintered at 900°C. The micrograph shows that the grain size are in the range from 200-250nm. That implies that samples sintered at 900°C have less porosity than that of sample sintered at 800°C. The micrographs are shown in figure 3.4.

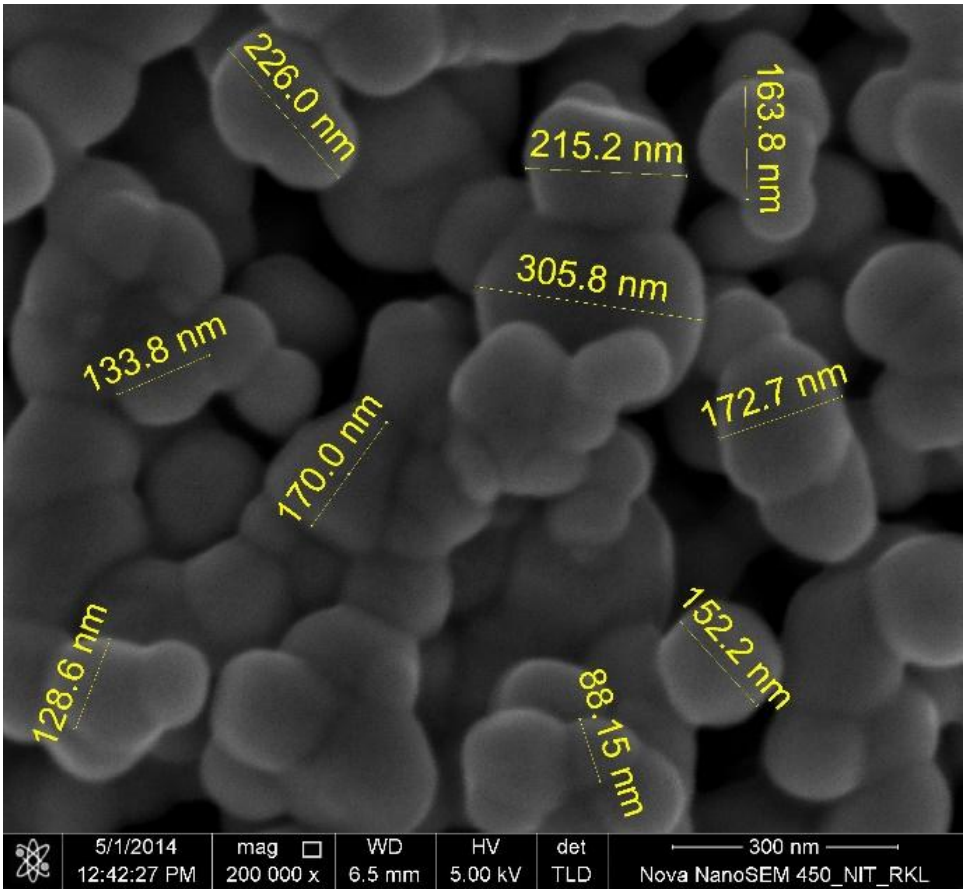


Figure 3.4 (a) 900^{0}C sample SEM micrograph

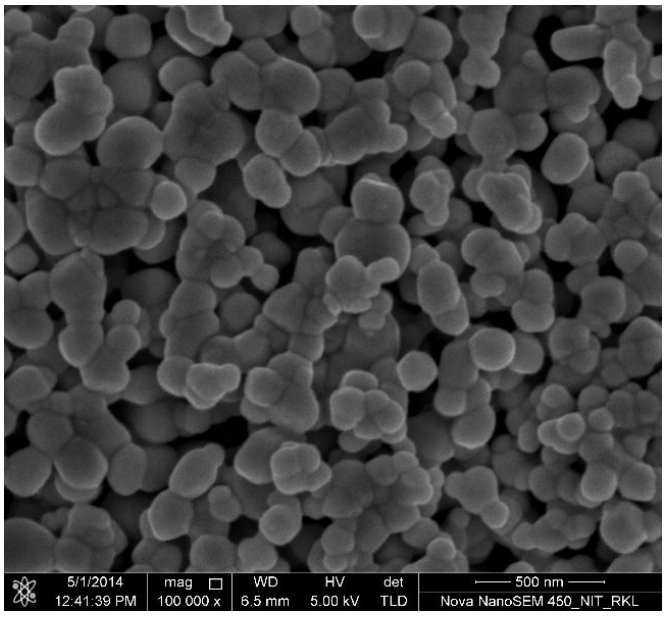


Figure 3.4 (b) 900^{0}C sample SEM micrograph

So the result indicates that the material prepared through sol-gel process is capable of giving very fine grain size, hence high porosity, which is very much suitable for humidity sensing. The high porosity means more number no active sites are present at the surface so material surface have excellent susceptibility for moisture or water absorption. This is very good for humidity sensing. SEM result is also supported by apparent porosity according to which that 800°C fired sample are much porous than that of 900°C fired sample.

3.4 HUMIDITY SENSING MECHANISM AND CHARACTERSTICS

As per Zhao, Jinig et al [14], the water absorption on the surface of capacitive type ceramic sensors results change in electrical properties. Water molecule get absorb on the active sites of the oxide surface chemically and that forms a hydroxyl ions by the dissociative mechanism. On the other side if this water absorption happens on metal surface layers of grains then it changes the local density and a strong electrostatic field and the proton react with a nearby oxygen anion to form an OH^- group. The water molecule which is absorbed physically are prone to dissociate easily due to the presence of high electrostatic fields in the chemisorb layers from single layer to multilayer. The main reason behind it is the increase in the water vapor pressure, so water molecules create dipole under applied field that results in the increase in dielectric constant. Conduction instrument about the permeable artistic dampness sensors begins from concoction and the physical absorption of water particles on their surface and also the hair like buildup of water inside the pores initially, at the low percentage of relative humidity, the water atom is predominantly chemically absorbed onto

the surface dynamic locales of the existing sensing material. A separating system prompts the structuring of a hydroxyl ion (Oh−) and a proton having positive charge (H+). The previous is chemically absorbed on the surface of metal cations exhibit in the surface layer of the existing grains and the recent cohorts with the surface O2− gathering to structure a second hydroxyl bunch. Protons starting from the separation hydroxyl aggregates as the charge bearers will jump between the hydroxyl bunches it might be comprehended that the conduction procedure of the sensor chiefly starts from the water absorption on the specimen surface. Consequently, the fabulous properties of the fabricated sensor focused around the semi porous Lafeo3 are identified with the higher surface zone and porosity which give more dynamic destinations to water adsorption, lastly offer more charge transporters for electrical conductivity. The chemically absorbed layer, once shaped, is no further influenced presentation to stickiness. Resulting water particles that are physically adsorbed on the layer having hydroxyl ions by two fold hydrogen bonds with the oxygen iotas of the water particle. In this present stage, the surface scope is not finish. Hydronium is the overwhelming charge bearer and H+ move between the contiguous water atoms in groups With the increment of the RH, when water particles are inexhaustible, the physically consumed water separates because of the existing high electric field in the chemically absorbed water: 2h2o → H3o+ + Oh− Water particles get to be slowly indistinguishable to mass fluid water, with H3o+ being hydrated and discharging a near proton, H3o+ → H2o + H+. The charge transport is legislated by proton exchange between adjoining water particles in the consistent water film. This procedure is known as the Grotthess chain reaction [14].

The impedance dependency of the fabricated samples on the measured relative humidity for the sensor by using the LaFeO3 ceramic humidity sensor having mesoporous structure was measured at various frequencies, as shown in below in figure 3.5.

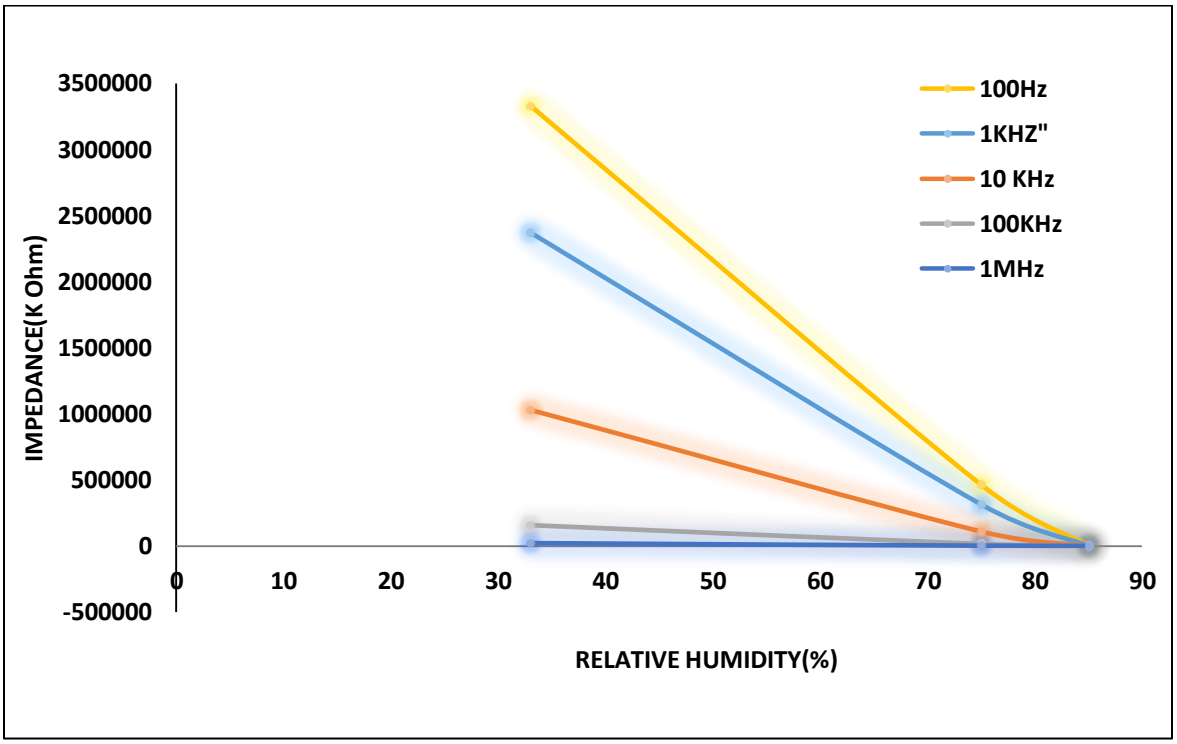


Figure 3.5 impedance vs relative humidity characteristics

From the above diagram it can be seen that the impedance value at different relative humidity is strongly influenced by the measuring frequencies. If we look at low humidity range the impedance is highly affected by frequencies. The impedance greatly changes with the variation in relative humidity from 33% to

85% at 100 Hz frequency, so it shows the highest humidity response and the best linearity over a large range of humidity. Hence 100 Hz is best frequency for the operation so it can be said that the optimum operating frequency is 100 Hz [14].

Analyzing impedance characteristics is very crucial to determine various type of sensing properties. To explain the sensing mechanism we refer to the impedance characteristics diagrams shown below.

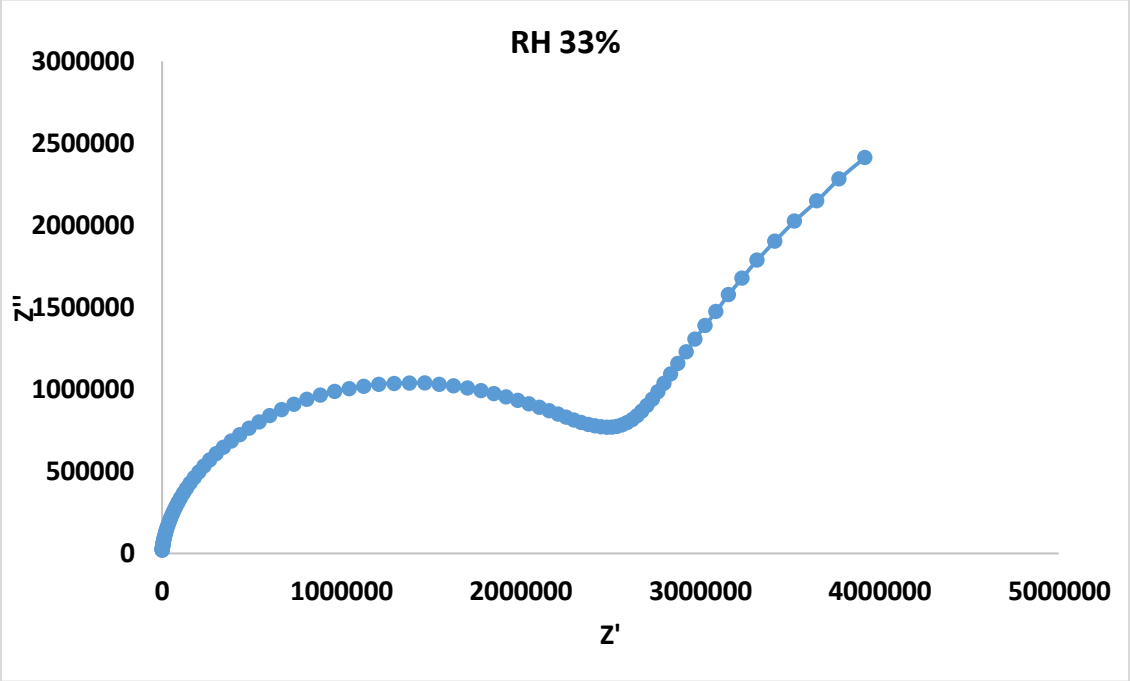


Figure 3.6 impedance spectra at 33% RH

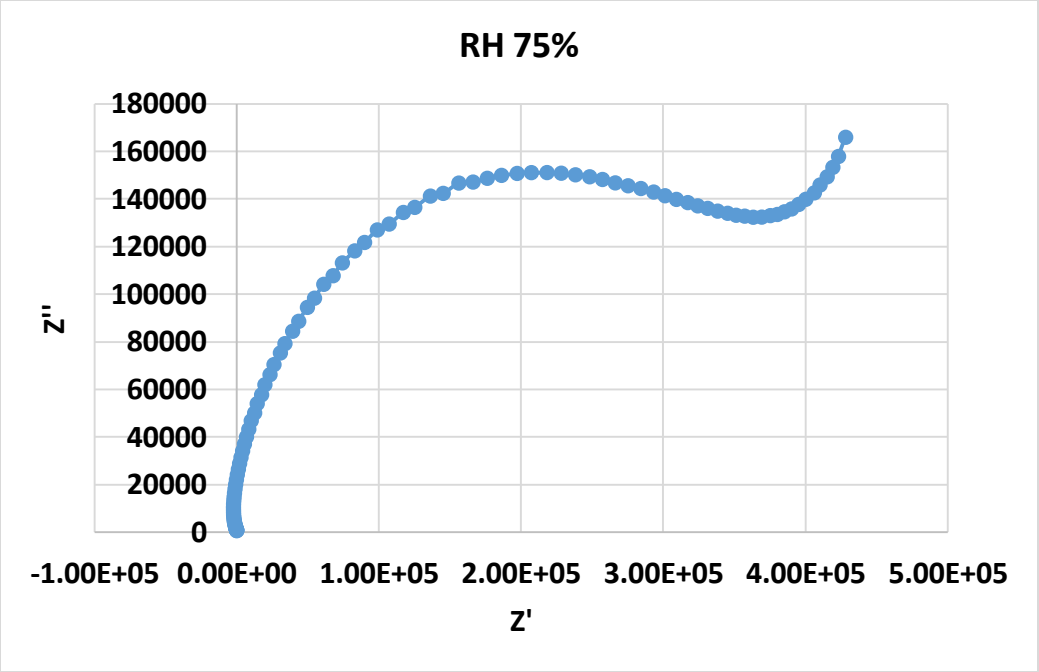


Figure 3.7 impedance spectra at 75% RH

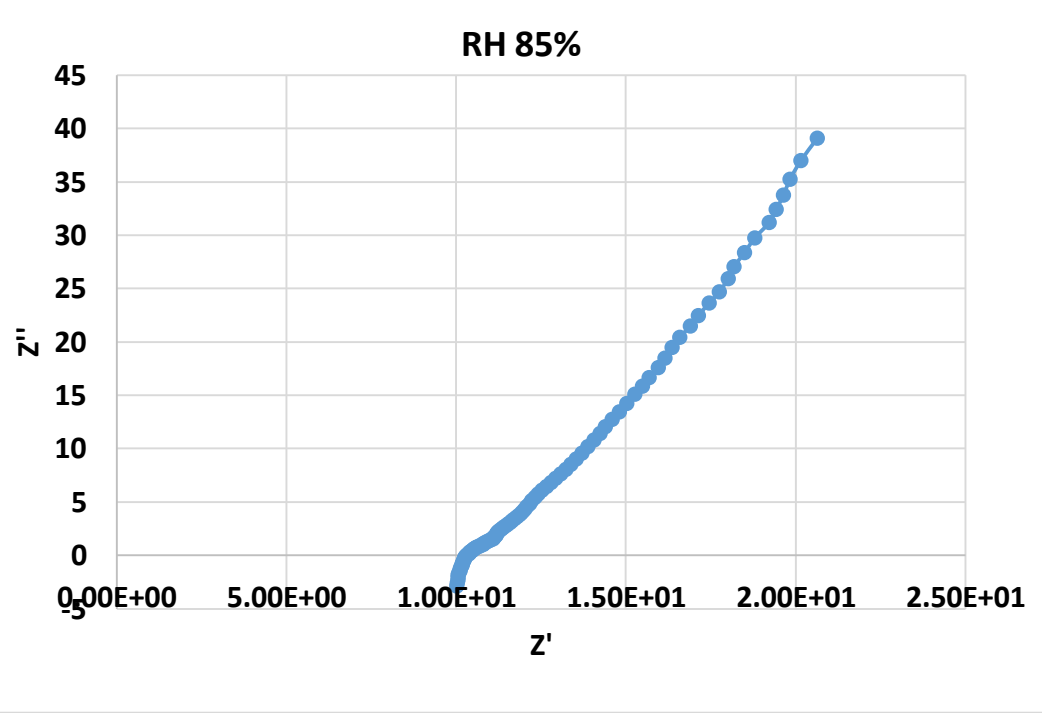


Figure 3.8 impedance spectra at 85% RH

The impedance spectra measured at different range of frequency from 33% to 85% of relative humidity. Impedance spectra at 33% of RH is shown in figure3.6,impedance spectra at 75% of RH is shown in figure 3.7 and impedance spectra at 85% of RH is shown in figure3.8. At low relative humidity the graph show a semicircular region having a large radius of curvature. This semicircle represents a capacitor that is parallel with resistor. The semicircular region is at high frequency and the straight line part is for low operating frequency. The straight line part can be explained by Warburg behavior according to which at high percentage of relative humidity the diffusion rate become fast at the electrolyte-electrode interface and also conduction become smooth in water condensed phase, this may be due to the high amount of moisture. The semicircular part diminishes at higher percentage of relative humidity, and this can be seen that at 85 % of relative humidity.

The equivalent circuit diagram for semicircular region and straight line region is shown in diagram 3.9.

The change in capacitance with relative humidity is shown in figure3.10. The increase in capacitance is low with relative humidity. The change is slow up to 75 percent of relative humidity but after that there is little increase in change rate, the slope becomes more.

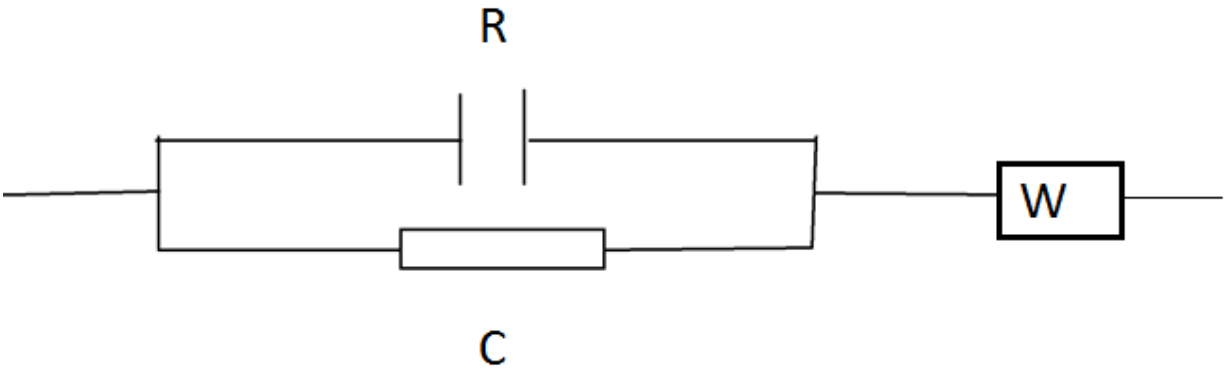


Figure 3.9 equivalent circuit diagram

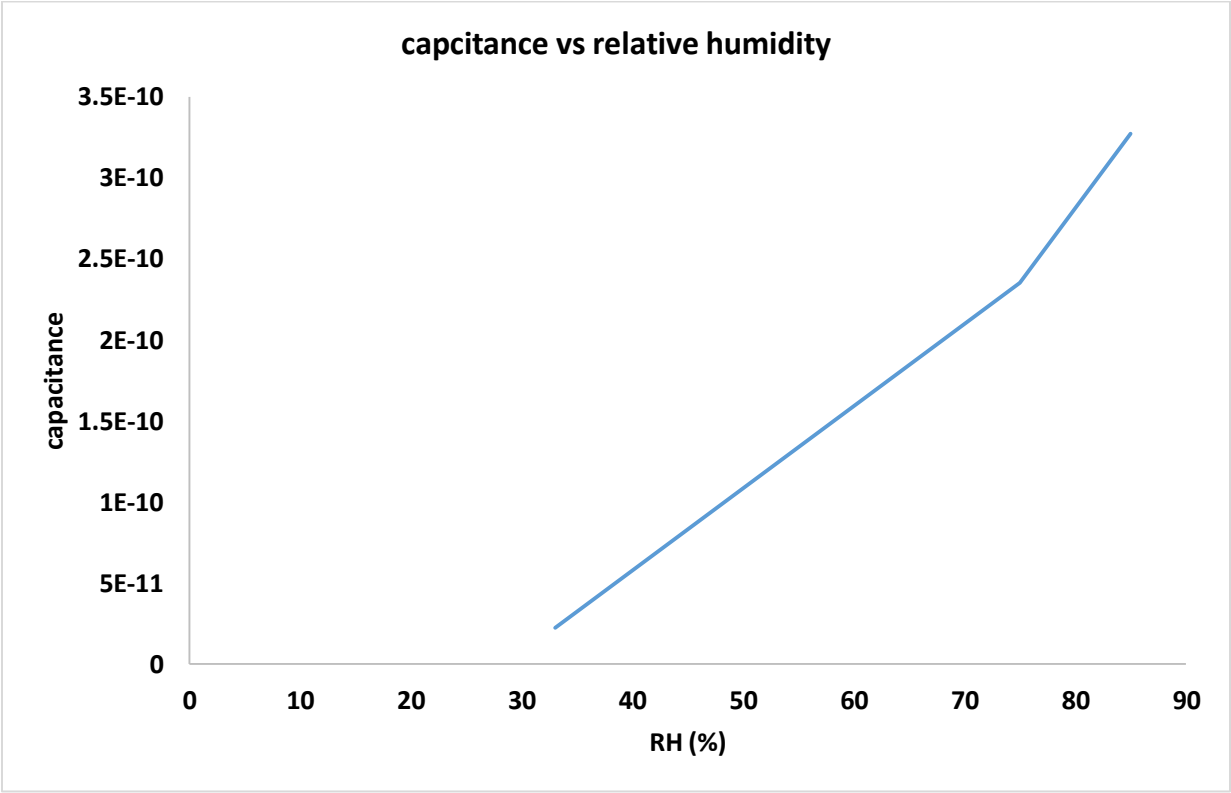


Figure 3.10 Capacitance vs relative humidity

4. CONCLUSION:

LaFeO3 was successfully synthesized via the sol-gel method. A ceramic LaFeO3 humidity sensor was fabricated, evaluated and tested. Humidity sensing testing, characterization and measurements shows that impedance changes over a large value when the relative humidity varies from 33% to 85% at different measuring frequencies. This change is approximately by more than four orders of magnitude and it also displays fast response time, high response, and long-time stability over a large range of humidity region. So conclusion can be drawn that obtained LaFeO3 is an excellent material for application as humidity sensor because of their high pore volume and highly porous structure.

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