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DIELECTRIC PROPERTIES OF STRONTIUM TITANATE IN THE 1 MHZ TO 1.5 GHZ FREQUENCY REGIONS

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ABSTRACT

Strontium Titanate, $SrTiO_3$ samples were prepared using the conventional solid state reaction method. $SrTiO_3$ samples were sintered at 1100˚C, 1200˚C, and 1300˚C. XRD was used to determine the crystalline structure of the samples. The AFM showed the grain size was significantly increased with an increase in sintering temperatures. The dielectric properties of the sample were measured using Agilent 4291B Impedance/material Analyzer in the sub-microwave region in the frequency range 1 MHz to 1.5 GHz at room temperature. The dielectric constant and the average grain size were found to be the highest for the $SrTiO_3$ sample sintered at 1200˚C. Hence, greatest dielectric polarization occurred in the sample with the largest grain size.

INTRODUCTION

Strontium Titanate ($SrTiO_3$) is one of the popular materials because of its incipient ferroelectricity, superconductivity, photocatalysis and thermoelectric property. $SrTiO_3$ are generally applied as multilayer capacitors (MLCs) and dynamic random access memories (DRAM) in the industrial [1]. $SrTiO_3$ may apply in microwave application due to its high dielectric permittivity and low microwave losses [2, 3]. Researches on $SrTiO_3$ thin films had been discussed recently but there were several effects which cause on the thin film are still not clearly defined. The dielectric properties of $SrTiO_3$ are mainly influenced by its purification and microstructures [1].

Earlier literature reports showed that $SrTiO_3$ has no appreciable dielectric dispersion present from liquid He temperatures to microwave range. The permittivity values of $SrTiO_3$ ceramic are much smaller if compared with a good single crystal which reaches 25,000 [2]. Many types of fabrication of $SrTiO_3$ had been investigated. However, most of the researches more relied on the conventional solid-state reaction technique.

METHODOLOGY

$SrTiO_3$ samples were prepared using the conventional solid-state reaction method. $SrCO_3$ (99.95% purity) and TiO_3 (99.95% purity) were the starting materials. Stoichiometric amounts of materials were weighed. These samples were dry milling and calcined in air at 900˚C for 10 hours. The powders were grinded and sieved to ensure the particles size of the powders were homogenous. After that, the powders were pressed to mould the pellet shape. Those pellets were sintered in air at three different

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sintering temperatures which were 1100˚C, 1200˚C, and 1300˚C then cooled to room temperature in furnace.

All the samples were examined by XRD to determine the crystalline structure of the sample. The morphologies of the samples were examined using AFM. The dielectric properties of the samples were determined by using the Agilent 4291B Impedance/material Analyzer in the microwave region in the frequency range 1 MHz to 1.5 GHz at room temperature.

RESULTS AND DISCUSSION

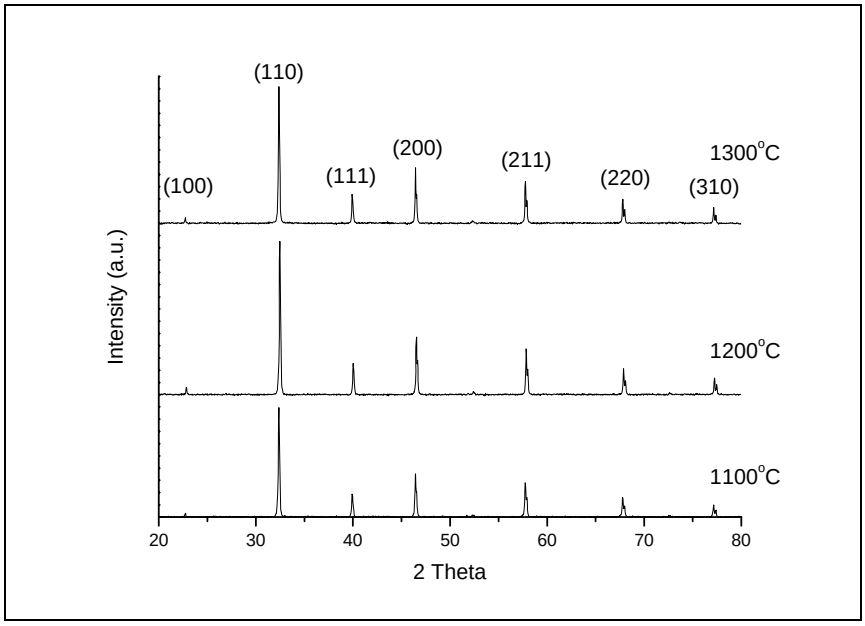

Figure 1: XRD patterns for $SrTiO_3$ samples at different sintering temperatures

Figure 1 showed the XRD patterns of $SrTiO_3$ samples after sintered at 1100˚C, 1200˚C, and 1300˚C. It showed that $SrTiO_3$ samples were in crystalline structures. The $SrTiO_3$ samples had high peaks in $2\theta = 32°$, 47° and 57°. This series corresponded to 01-079-0175 of the ICDD database that is $SrTiO_3$. No impurities were found. $SrTiO_3$ sample sintered at 1200˚C showed the highest intensity if compared with others.

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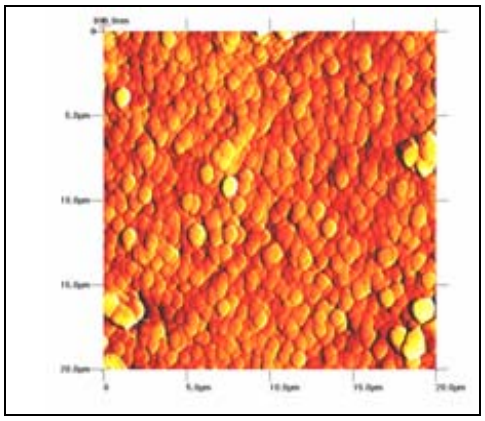

Figure 2: AFM micrograph for $SrTiO_3$ sample sintered at 1100˚C

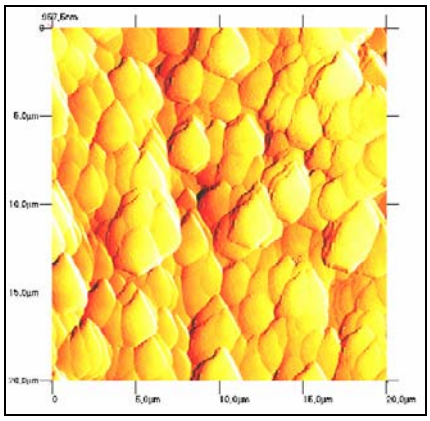

Figure 3: AFM micrograph for $SrTiO_3$ sample sintered at 1200˚C

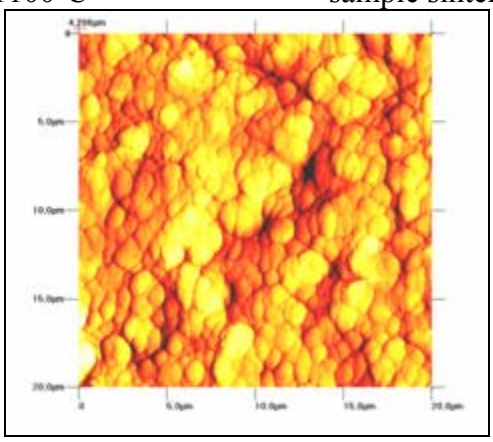

Figure 4: AFM micrograph for $SrTiO_3$ sample sintered at 1300˚C

Table 1: Average grain sizes for $SrTiO_3$ samples at different sintering temperatures

Samples	Average Grain Sizes
Sintered at 1100°C	880nm
Sintered at 1200°C	2.5µm
Sintered at 1300°C	950nm

Figures 2-4 showed the AFM micrographs for $SrTiO_3$ samples after sintered at 1100˚C, 1200˚C, and 1300˚C. From the AFM analysis, the average grain sizes for $SrTiO_3$ samples were at the range from 880nm to 2.5µm. The density of the samples will increased with the increasing of sintering temperature because of the increment of grain sizes of the samples [4]. Table 1 showed that $SrTiO_3$ sample sintered at 1200˚C had the largest grain size if compared with others.

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Table 2: Dielectric constant and dielectric loss of $SrTiO_3$ samples at different sintering temperatures at microwave region

Frequency	1100°C		1200°C		1300°C	
(Hz)	ε_r'	ε_r''	ε_r'	ε_r''	ε_r'	ε_r''
1.00E+06	3.04E+01	9.13E-02	5.02E+01	8.20E-02	4.09E+01	1.13E-01
1.00E+07	3.04E+01	5.85E-02	5.02E+01	2.22E-01	4.10E+01	2.54E-01
1.00E+08	3.02E+01	6.69E-02	5.00E+01	9.26E-03	4.09E+01	3.45E-02
1.00E+09	3.30E+01	2.39E-01	5.70E+01	1.17E+00	4.37E+01	6.65E-01

Table 2 showed the results of dielectric constant and dielectric loss of $SrTiO_3$ samples at different sintering temperatures from 1 MHz to 1.5 GHz at room temperature. The values of dielectric constant for $SrTiO_3$ samples were very constant while the values of dielectric loss for those samples were inconsistent.

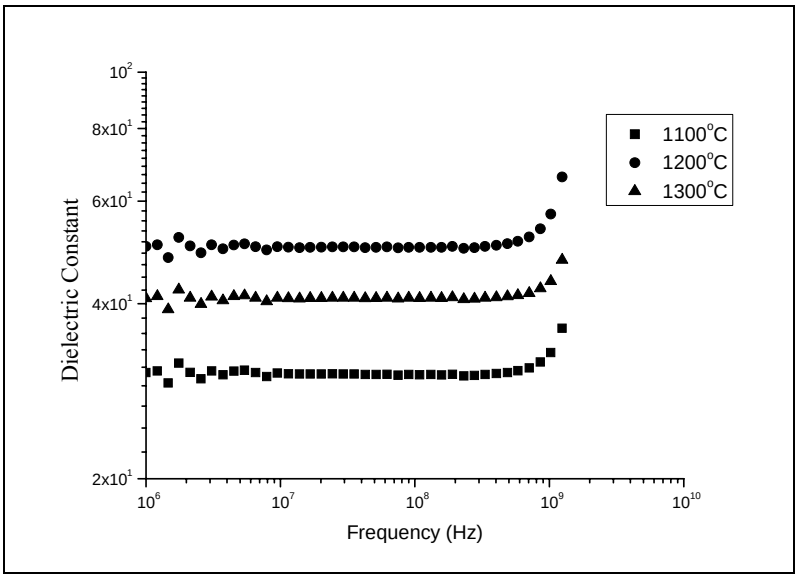

Figure 5: Dielectric constant of $SrTiO_3$ samples at different sintering temperatures

Figure 5 showed the dielectric constant of $SrTiO_3$ samples after sintered at 1100˚C, 1200˚C, and 1300˚C. The graph showed the same trend for all the samples. The microwave measurement of $SrTiO_3$ samples showed that the values of dielectric constant were constant while start increasing after 1 GHz. The $SrTiO_3$ sample sintered at 1200˚C had a better dielectric response which was around 50 followed by $SrTiO_3$ samples sintered at 1300˚C and 1100˚C. This may be due to the increment of grain sizes which helped increasing the polarization [4]. It was probable that the movement of the dipolar species due to the polarizing field occurred with greater ease in larger grains than in smaller ones. The increasing part after 1 GHz may be the arising of resonance.

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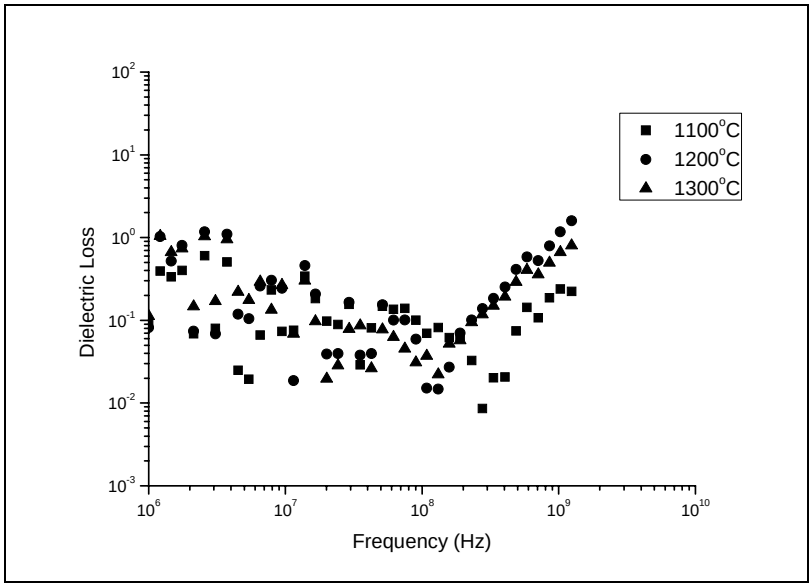

Figure 6: Dielectric loss of $SrTiO_3$ samples at different sintering temperatures

Figure 6 showed the dielectric loss of $SrTiO_3$ samples after sintered at 1100˚C, 1200˚C, and 1300˚C. The dielectric loss for both samples sintered at 1200˚C and 1300˚C showed the same trend while for sample sintered at 1100˚C had a lower loss around the GHz. The lowest dielectric loss for all the samples was at around 10^8 Hz.

CONCLUSION

According to experimental results, the $SrTiO_3$ samples were successfully prepared by conventional solid state reaction method. The dielectric properties of $SrTiO_3$ samples were measured at microwave frequency region. The dielectric constant of $SrTiO_3$ samples had constant values within the microwave frequency region while they had a lowest dielectric loss at around 10^8 Hz. $SrTiO_3$ samples sintered at 1200˚C showed the highest dielectric constant probably due to the greater ease of dielectric polarization in large grains.

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