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논 문
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$BaTiO_3$ 박막 커패시터의 유전특성

The Dielectric Characteristics of $BaTiO_3$ Thin Capacitor

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요 약

최근 커패시터의 전극은 Pt, Au등으로 이용되고 있다. 이러한 전극의 전기적 특성은 우수하나 고가이다. 본 연구에서는 전극의 저가격화 측면에서 알루미늄 전극 위에 $BaTiO_3$를 증착하고 기판의 온도를 실온에서 600[℃]까지 변화시켜 RF 스퍼터링법으로 제작하였다.

$BaTiO_3$ 세라믹의 유전특성은 구성하고 있는 입자의 강유전 분역 밀도와 입자의 크기에 의존하므로 입자가 성장되는 온도영역에서 입자의 크기와 유전율간의 관계를 연구하였다. 또한 $BaTiO_3$ 박막 커패시터의 유전상수는 $BaTiO_3$ 세라믹과 알루미늄기판의 계면에서 산화특성이 일어나기 때문에 기판온도의 변화에 의해 조사되었다.

기판의 온도를 증가시킴에 따라 결정면의 피크와 강도는 증가하였으며, 유전특성은 결정입자의 크기가 0.8[μm]일 때 가장 양호하였다. 유전율값은 기판 온도가 400[℃]일 때 가장 크게 나타났다.

결과적으로, 알루미늄 전극에 $BaTiO_3$ 세라믹을 증착하여 저가의 적층용 세라믹 콘덴서를 제조할 수 있음을 알았다.

Key Word(중요용어) : $BaTiO_3$ thin capacitor ($BaTiO_3$ 박막 커패시터), Ferroelectric domain density (강유전체 분역밀도), Substrate temperature (기판온도), Dielectric factor(유전율)

1. Introduction

Recently the inorganic material has been widely used like electronic elements, sensors, coatings, etc. Many of the several applications of this material have been reported, including radiation insulation, capacitor condenser, and pyroelectric element.

Among various methods for the preparation of the thin capacitor, RF sputtering is one of the simple and convenient methods. The thin capacitor, for improved properties such as increased domain density, enhanced crystallization, and controlled morphology has been produced.[1-4]

Also it is well known that the thin capacitor is strongly influenced by the properties of substrate temperature. Barium titanate is a very promising material for optical coating and dielectric capacitor because of its high refractive index, low absorption, high adhesion to glass surface, chemical stability, high dielectric characteristics, and high hardness which make it resistant to mechanical demage.[5-8]

At this time, the capacitor electrode is being used by Pt, Au, and so on. These material have a good conductivity, but it is very high cost.

The study of $BaTiO_3$ ceramics has shown that dielectric properties of $BaTiO_3$ thin capacitor strongly depend on the size and ferroelectric domain density of the constituting grains.

The dielectric constant, ε_r, reaches a maximum value of 5000-6000 at the grain size 0.7~1[μm] at which the domain density is also the highest.[9,12,13]

The purpose of the present study is the dielectric properties analysis of $BaTiO_3$ thin capacitor because the grain size and dielectric

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characteristics is very important on the growing temperature of grain.

In this study, the $BaTiO_3$ thin capacitor for the low cost was prepared on the Aluminum electrode by RF sputtering. The dielectric characteristics was measured by grain size and the substrate temperature changing, from room temperature to 600 [℃]. And, we tried to investigate the oxidation between the substrate and the $BaTiO_3$ ceramic.

2. Experimental methods.

The thin capacitor using a target of $BaTiO_3$ ceramics was prepared on Al plate to change the substrate temperature from room temperature to 600[℃].

The sputtering conditions are listed in Table Ⅰ.

Table Ⅰ. Sputtering condition of $BaTiO_3$ by RF sputtering

Target	$BaTiO_3$ Ceramic
Substrate	Aluminum
Target substrate distance	30[mm]
Substrate Temperature	from 25 to 600 [℃]
RF power	150[W]
Sputtering gas	Ar
Sputtering gas pressure	1[Pa]
Deposition rate	3.2[Å/S]

The residual gas pressure before sputtering was about 3×10^{-3}[Pa]. The thickness of the sputtered capacitor was fixed at 1[μm] by the thickness monitor(model TM-200R) which was calibrated by a Dektak 3030(Auto Ⅱ Programmable Stage Profiler) from measuring the height of a step produced by masking a region of the substrate during deposition. The microstructure and crystallographic properties of the thin capacitors deposited on Al electrode were analyzed by X-ray diffraction (XRD) and scanning electron microscopy(SEM).

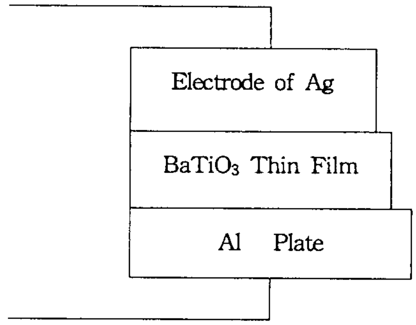


Fig. 1 Capacitor model of $BaTiO_3$ thin film.

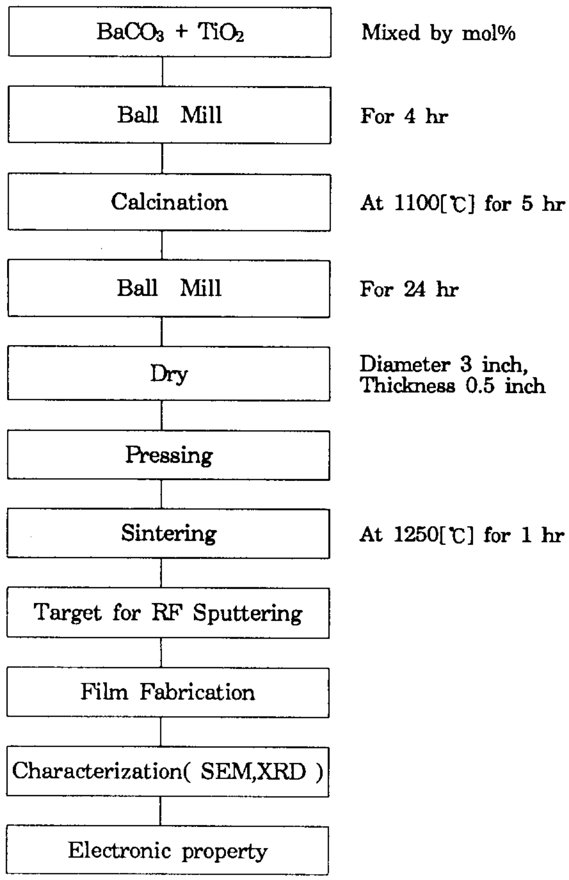


Fig. 2. The flow chart of experiment.

The dielectric characteristics of $BaTiO_3$ thin capacitor were measured by the impedance analyzer(model HP 4192A, JAPAN).

The thin capacitor was fabricated by the Al electrode. Aluminum is used as bottom electrode and silver is painted as upper electrode.

Fig. 1 shows the capacitor structure and Fig. 2 represents the flow chart of experiment.

3. Result and discussion

The microstructure changing were investigated by the X ray diffraction. Fig.3(d) shows the X ray diffraction patterns of the deposited film at 600[℃].

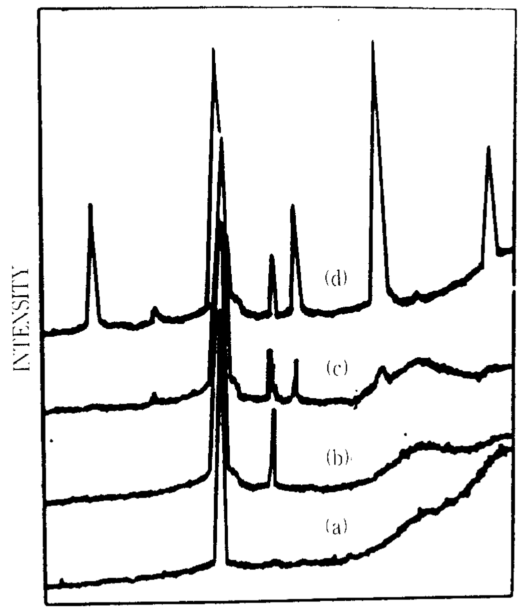


Fig. 3. The result of X-ray diffraction pattern.
(a) at substrate temperature 25[℃].
(b) at substrate temperature 300[℃].
(c) at substrate temperature 400[℃].
(d) at substrate temperature 600[℃].

Materials such as $BaTiO_3$ having a perovskite structure seem to exhibit a similar tendency.

This tendency may be caused by the fact that the (110) crystal plane has the highest occupation density of the component atoms among crystal planes refer.[10-11]

Al plate can be easily oxidized at atmosphere. Therefore, it is proved that $BaTiO_3$ thin capacitor was occupied by oxidation at interface between Al electrode and $BaTiO_3$ ceramics.

According to rising substrate temperature from room temperature to 600[℃], the peak intensity of crystal plane are increased.

As shown in Fig.3(a), the diffraction pattern of the deposited sample at 25[℃] is basically featureless, indicating that the sample is still amorphous phase. There is no feature to show the X Ray diffraction pattern the same as substrate temperature 300[℃] in Fig.3(b). But it shows that the grain is started to crystallize at this temperature. It means that the peak is (111) plane of $BaTiO_3$. However, the deposited sample at 400[℃] shows the weak peak at 30.9° .

This peak corresponds to (110)plane of $BaTiO_3$ crystall.

The X ray diffraction revealed that the grain of amorphous $BaTiO_3$ ceramic started to crystallize from depositing temperature at 400[℃].

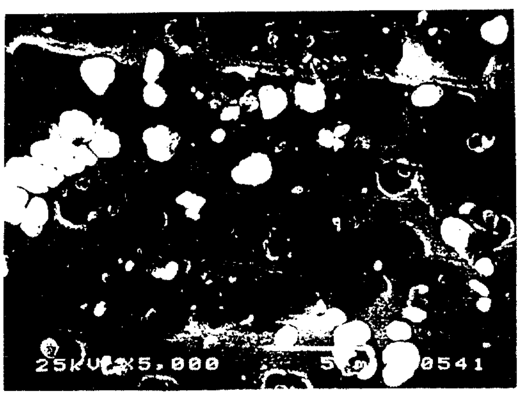
The peak intensity of substrate temperature at 500[℃] was stronger (110) plane than the observed (100) plane in Fig.3(c).

The peak of (214) in Fig.3(d) was shown by XRD analysis. It shows the same peak as 500[℃] substrate temperature. As the result of the same peak, the crystallization of grain starts at depositing temperature 400[℃] and the grain size can recognize to grow both 500[℃] and 600[℃].

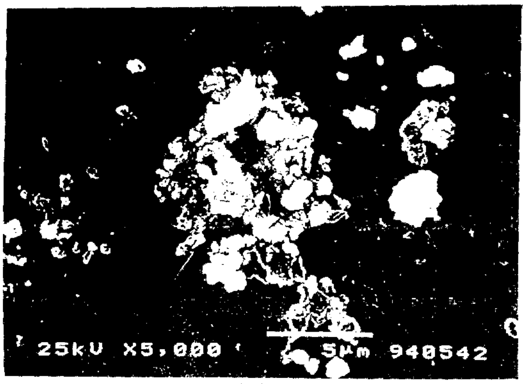
Fig. 4 shows the Scanning Electron Microscopic photo.

The random grain of $BaTiO_3$ was small size. It is thought that it relates to the dielectric factor.

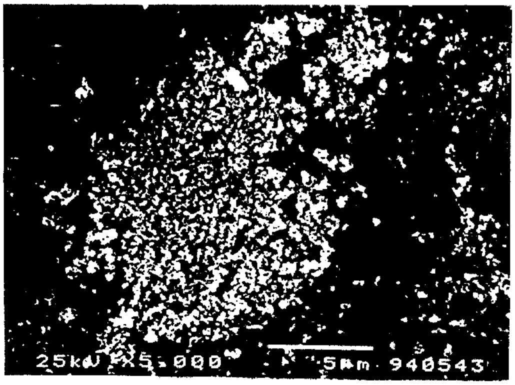
In Fig.4(a), the $BaTiO_3$ is only coated on Al electrode. According to rising the substrate



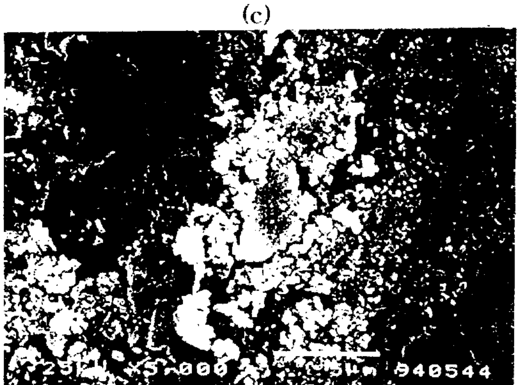
(a)



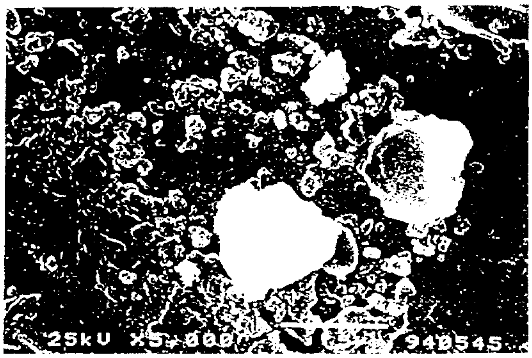
(b)



(c)



(d)



(e)

Fig. 4. SEM of $BaTiO_3$ thin film
(a) at substrate temperature 25[℃].
(b) at substrate temperature 300[℃].
(c) at substrate temperature 400[℃].
(d) at substrate temperature 500[℃].
(e) at substrate temperature 600[℃].

temperature, the grain of $BaTiO_3$ thin capacitor was more condensed and the grain size was shown 0.8[μm] at substrate temperature 400[℃].

When the film was deposited at substrate temperature 500[℃], the substrate was oxidized by chemical action and occupied by crack.

According to SEM photo, the sputtering of $BaTiO_3$ thin capacitor could be to deposit on Al electrode.

As shown in Fig.4, the average grain size of the capacitor was 0.6-1.2[μm].

To measure the dielectric characteristics of $BaTiO_3$ thin capacitor, the electrode of Ag was painted on the capacitor. The dielectric constant, ε_r, and the dissipation factor, $\tan\delta$, were measured from 1[KHz] to 10[MHz] with the Impedance Analyzer.

Not only the dielectric constant but also the dissipation factor increased when the substrate temperature increased.

The dissipation factor at room temperature shows in Fig. 5. In this figure the dielectric constant dependent on the substrate temperature

As shown in Fig.5, the dielectric factor of the deposited sample at 25[℃] is low value because the sample is still amorphous phase such as SEM analysis.

According to rising substrate temperature, the dielectric factor was high value because the grain is started to crystallize by temperature.

However, the deposited sample at 500[℃] and 600[℃] shows decreasing value because the crack was made of oxidation in grain boundary.

It was found that the substrate temperature of 400[℃] was the best condition of dielectric properties. It is thought that the grain of amorphous $BaTiO_3$ started to crystallize at depositing temperature from 400[℃].

Fig.6 is the dielectric characteristics according to grain size. The high dielectric characteristics was substrate temperature at 400[°C] and the grain size was 0.8[μm].

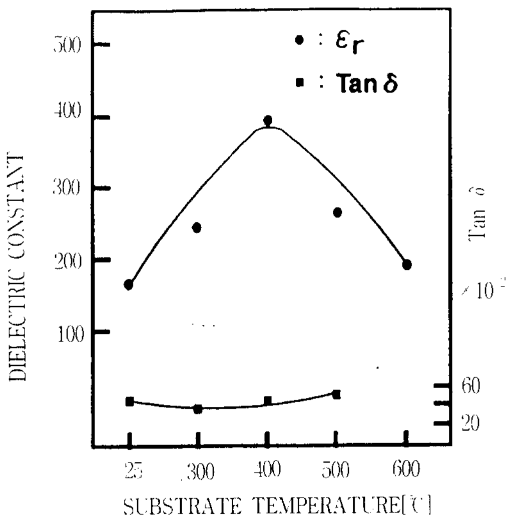


Fig. 5. Dielectric constant and tan δ according to rising substrate temperature at 1[KHz].

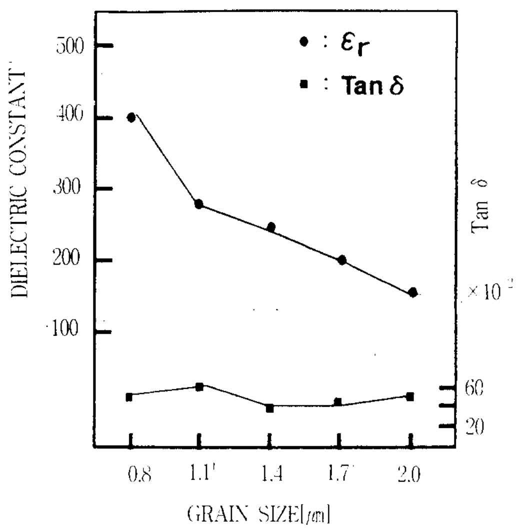


Fig. 6. Dielectric constant and tan δ according to grain size.

Arlt reported that the increasing of the dielectric factor is possibly cause by a summation of the domain size and the stress effect[9]. Higher internal stress near the grain boundary and more domain walls present in a grain may ultimately be the reason for the dielectric constant value of the $BaTiO_3$ ceramics.

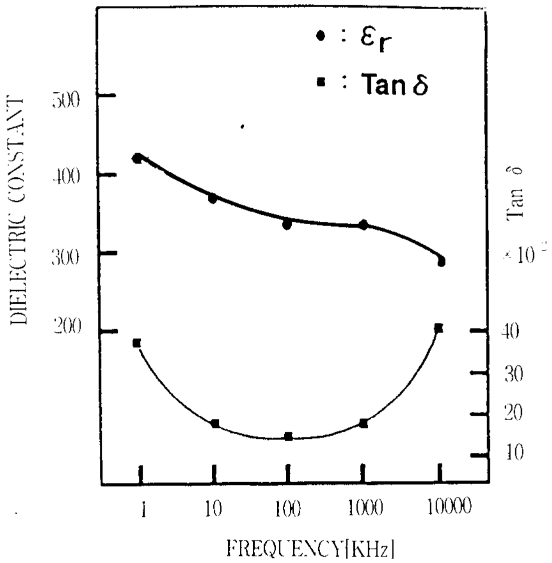


Fig. 7. Dielectric constant and tan δ according to frequency at 400[°C].

Fig.7 shows the relation between dielectric constant and frequency of the film grown at substrate temperature 400[°C].

The dielectric characteristics of $BaTiO_3$ as ferrodielectric were shown by polarization effect.

The polarization required the time when the electric field applied, the electric field banished, and the polarization completed or consumed. If the frequency is high, the polarization doesn't appear because the relaxation time is long.

The higher frequency became, the lower dielectric constant did. But the dielectric constant increased 1[MHz] over.

Therefore, it is thought that the ion polarization of $BaTiO_3$ thin capacitor according to frequency is higher than 1[MHz].

It agreed with the results from SEM and X-ray diffraction. The crystallization of grain to $BaTiO_3$ thin capacitor started at substrate temperature 400[°C], and the capacitor had the maximum value of dielectric constant at this temperature. It is better than that at substrate temperature 500[°C].

4. Conclusion

As the result of the dielectric properties on $BaTiO_3$ thin capacitor using RF sputtering, the crystallization of grain started at substrate temperature 400[℃].

The dielectric constant increased as the crystallization of grain grew. The dielectric characteristics increased over 1[MHz].

It was found that the substrate temperature of 400[℃] was the best condition of dielectric properties. This is caused by the fact that the (110) crystal plane has the highest occupation density to the component atoms among crystal planes in X ray diffraction pattern of $BaTiO_3$ thin capacitor. And at this temperature, the capacitor has the maximum value of dielectric constant.

The grain size of the $BaTiO_3$ thin capacitor was 0.6-1.2[μm].

It appeared that the dielectric constant was very high value when the grain size had 0.8[μm].

It is thought that the sputtering of $BaTiO_3$ thin capacitor could be to deposit on Al electrode according to measurement dielectric factor, SEM and XRD.

In this study, the $BaTiO_3$ thin capacitor deposited on the aluminum electrode can be used by multilayer ceramic capacitor of low cost.

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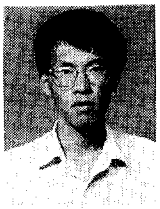
저자소개



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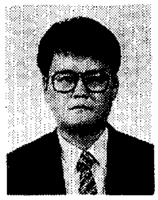

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