

## Chapter 2. Modified Metalorganic Solution Deposition technique

This chapter provides a simple room temperature chemical precursor solution preparation techniques for the fabrication of pyrochlore-free crystalline films and some of the representative properties of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin film are exhibited as an example. The detailed fabrication procedure of  $\text{SrBi}_2\text{Ta}_2\text{O}_9\text{-Bi}_3\text{TaTiO}_9$  thin films will be presented in next chapter. However, for the fabrication procedure of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  and  $\text{SrBi}_2\text{Ta}_2\text{O}_9\text{-Bi}_3\text{TaTiO}_9$  thin films are quite similar, most of detailed procedure is discussed in this chapter. A chemical precursor solution technique using carboxylate-alkoxide combination has been developed which provides pyrochlore free crystalline phase even at low annealing temperatures. The main features of the process are room temperature preparation, short preparation time, easy availability of precursors, stability, and compatibility with semiconductor-fabrication technology. A rapid fabrication process is desirable, since long processes are more expensive in terms of the use of the facilities and personnel. This process can be used for the fabrication of perovskites, layered perovskite, or tungsten bronze materials and their solid solutions. The same approach can also be used for doping these materials.

### 2.1. INTRODUCTION

The process is simple and compatible with conventional integrated circuit materials and processes. The process starts with preparing a precursor solution containing each of the metals in the desired thin film compound. There are three general methods for the preparation of precursor solution for the fabrication of oxide thin films: (1) All alkoxide method, (2) Alkoxide-salt method. (3) other methods. An oxide network is formed in these techniques via hydrolysis and condensation of molecular precursors. This chemistry is controlled by parameters such as the hydrolysis ratio, catalysis or molecular structure of precursors. This latter can be simply modified by oligomerization, solvation or addition of nucleophilic chemical additives such as organic acids,  $\beta$ -diketones or allied derivatives which lead to the tailoring of the coordination shell of the metal. The selection of precursor compounds and the solvents is the most important step in the precursor solution approach for the fabrication of thin films. The most important points to be taken into consideration are: nature of initial species, formation of mixed metal

species or not?, the stoichiometry of the various elements in the solution with respect to the formulation required, influence of the solvent, the temperature of the reaction and its effect on the homogeneity at a molecular level elimination of organics from the deposited film, and temperature of crystallization.

## 2.2 SELECTION OF PRECURSORS AND SYNTHESIS METHOD

The first step in the all-alkoxide method is the selection of alkoxide for each element of the desired composition and then the synthesis of a solution containing the requisite metal cations. Commonly, the solution is comprised of metal alkoxides  $[M(OR)_n]$  in an alcohol solvent. Addition of water to an alkoxide solution results in hydrolysis followed by condensation reactions, network formation, and the eventual development of a continuous polymeric gel. While many alkoxides have been synthesized and used successfully in thin film processing, some metal alkoxides have low solubility are difficult to prepare and are not stable over time. Most metal alkoxides are very reactive towards hydrolysis and condensation. Consequently, the exclusive use of alkoxides for multicomponent solutions is sometimes not possible, and often alternative precursors are necessary. Most advanced ceramics are multicomponent materials having two or more types of cations in the lattice. Since alkoxide precursors are mixed at the molecular level in the solution a high degree of homogeneity is expected. However, a major problem in forming homogeneous multicomponent solution is the unequal hydrolysis and condensation rates of the metal alkoxides. This may result in phase separation, during hydrolysis or thermal treatment, leading to higher crystallization temperatures or even undesired crystalline phases. It is therefore necessary to prepare solutions of high homogeneity in which cations of different types are uniformly distributed at an atomic scale through M-O-M bridges. The initial solution should therefore be treated such that bonds are first formed between the various alkoxide precursors prior to gelation. A difficulty of the all-alkoxide approach, especially of soluble alkoxides are concerned, is to apprehend the formation or not of the mixed-metal species and the stoichiometry between the metals. Solubilization of one metal alkoxide in the presence of another is a criterium to be handled with care since it does not necessarily imply the formation of a mixed-metal species and thus homogeneity at a molecular level. There is for instance no reaction between bismuth and titanium methoxyethoxides (IR and  $^1H$  NMR evidence) despite the

formation of a homogeneous solution. For compounds containing bismuth as an element, the selection of precursor is a problem because of the lack of reactivity of bismuth alkoxides. The bismuth alkoxide,  $\text{Bi}(\text{OR})_3$  R=Et, iPr, has been found to show lack of reactivity towards a variety of metal alkoxides including niobium, tantalum, titanium, and lead.

The alkoxide-salt approach can overcome many of these problems with all-alkoxide method. The term salt for the described process basically refers to carboxylates but also includes the use of nitrates, sulfates, carbonates, chlorides, and hydroxides. The alkoxides and the carboxylates fall in the group of organic derivatives of metals with metal-oxygen-carbon bonds. The alkoxide-salt approach overcomes many problems with the all-alkoxide approach as for some elements of the desired composition, a salt can be selected as precursor instead of alkoxide. For most metals, a metal carboxylate with medium length ligands is the preferred precursor compound. The carboxylate anions (general formula  $-\text{RCOO}^-$ ) are versatile ligands capable of (1) existing simply as counter anions, or (2) binding the metals in (a) unidentate, (b) chelating, or (c) bridging modes. The wide variety of available groups (e.g. R may be H, alkyl, aryl, perfluoroalkyl, etc.) greatly enhance the versatility of carboxylate ligands. The metal carboxylates have the important feature of forming metal-metal bond. A metal acetate or 2 ethylhexanoate precursor works for most metals. They behave as active metal oxide sources and are involved in reactions with metal alkoxides. Acetates based on di and trivalent metals show high reactivity towards metal alkoxides and are easily incorporated in mixed metal species often in quiet mild conditions. For example, acetates based on magnesium, cadmium, barium, strontium and lead undergo dissolution and incorporation in mixed-metal-species under room temperature conditions. The choice of solvent is also important in alkoxide-salt approach. The influence of the solvent can be multiple: it can generate and/or stabilize intermediates and thus allow, preclude or modify reactions. The presence of alcohol helps in the formation of reactive species. The main advantage of the alkoxide-carboxylate approach is that the side product in the reaction is comparatively non reactive compared to  $\text{H}_2\text{O}$  in the all-alkoxide approach. In all acetatoalkoxides, the carboxylate ligand is in bridging position and holds the different metals together. The acetatoalkoxides appear generally more soluble than simple alkoxides especially in the parent alcohol. Most metal alkoxides are very reactive towards hydrolysis and condensation. They must be stabilized to avoid precipitation. These reactions are controlled by adding complexing agents that react with metal alkoxides at a molecular level, giving rise to new

molecular precursors of different structure, reactivity, and functionality. The carboxylic acids, such as acetic acid, and  $\beta$ -diketones, mainly acetylacetone, which act as hydroxylated nucleophilic ligands, help in controlling the hydrolysis rates by decreasing the functionality of the precursor. The reaction between alkoxide and carboxylate in the presence of alcohols and carboxylic acids proceeds with the formation of smallest possible aggregate which allows the metals to achieve their most usual coordination number. and thus hydrolysis becomes more difficult. Carboxylates act as assembling and oxo donor ligands, and thus have a tendency to increase the nuclearity of the aggregates; diketones are chelating ligands and thus decrease the oligomerization.

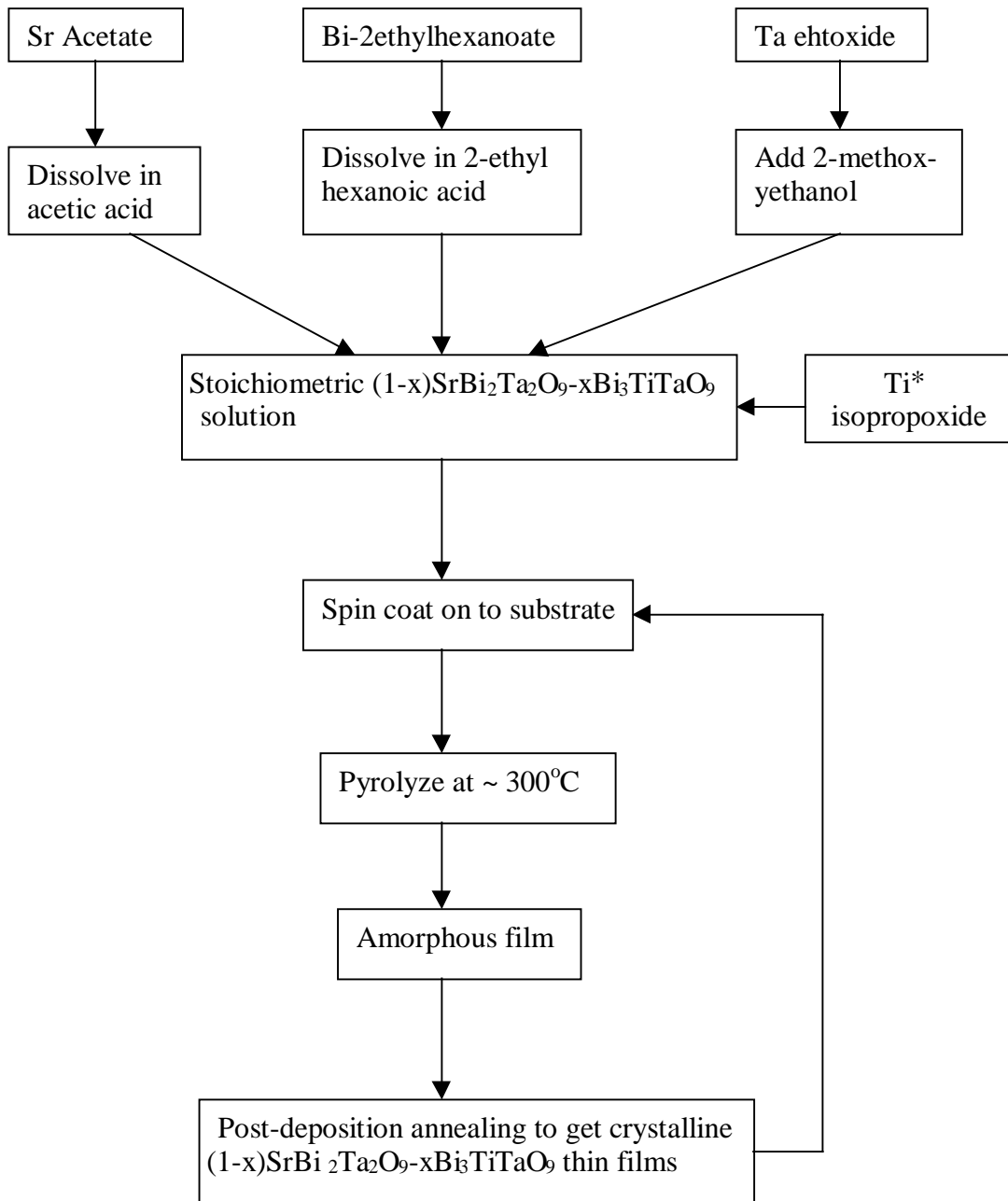
Figure 2-1 shows the general steps in the fabrication of films by the technique described in this chapter. The selection of precursor compounds and the solvents is an important step in the preparation of thin films by chemical technique using precursor solution. The precursors for individual metal should have a long shelf life. The selected precursors should have high solubility in the selected solvents and the various solvents should be compatible when mixed. The final precursor solution should have a relatively long self life so that it can be made ahead of time in volume and used as needed. The various steps in the alkoxide-salt approach are:

1. The selection of metal alkoxides or carboxylates as the starting precursors. The precursor should be one in which the organic groups forming the ligands which held the metals of the future film were relatively small so as to minimize the amount of organic material that had to be vaporized, and thus minimize the size of the pores and other microscopic defects in the film. Short chain metal carboxylates are also usually very polar and are therefore very water soluble. thus they do not separate when hydrolysis water is added to the solution. However, the high polarity also tends to make them insoluble in high boiling point solvents such as xylenes and 2-methoxyethanol. On the other hand, the longer-chain metal carboxylates, such as neodeconates, and 2-ethylhexanoates are generally all soluble in either 2-methoxyethanol or xylenes. However, they are not soluble in water. Thus the presence of any substantial amount of a metal neodeconate or a metal 2-ethylhexanoate usually will cause separation of the hydrolysis water and gelation of the alkoxide around the water droplets formed if hydrolysis is attempted. Furthermore, longer chain materials contain too much organic material to produce good films. So the metal carboxylates with intermediate length ligands will be more suitable for the preparation of a precursor solution with longer shelf life and

also for fabricating high quality thin films. Preferably the metal carboxylate is a metal carboxylate having medium chain ligand, such as metal acetates and metal 2-ethylhexanoates. These are available for most of the metals. Alternatively, nitrates, sulfates, carbonates, chlorides, and hydroxides can also be selected as precursors.

2. A carboxylic acid can be selected as solvent for metal carboxylates. Preferably the boiling point of the solvent should be greater than 100 °C and in the range 100-250 °C. The preferred solvents for the alkoxide-salt precursors are alcohols, aromatic hydrocarbons, ketones, esters, ethers, and alkanolamines. A single solvent or a combination of solvents can be used to optimize the solubility and viscosity to obtain high quality coatings.

The films can be prepared from the precursor solution using spin, dip, or spray technique. Alcoholic solutions are generally capable of wetting all metal substrates, oxide substrates or metal-semiconductor substrates with a thin oxide layer on the surface. Almost any substrate that will support a thin film and is compatible with the materials and processes may be used. In the present case the thin films were prepared by using spin coating technique, which is a well known form of deposition in which the precursor is placed on a wafer and the wafer is spun to evenly distribute the precursor over the wafer. The spinning speed and the viscosity of the solutions need to be optimized to control the thickness of the films. Preferably, the wafer is spun at a spin rate of between 1000 rpm and 7000 rpm for a period of 5 seconds to 120 seconds. After the coating process, the wafer is transferred to a hot plate in which it is baked. Alternatively, an oven may be used in baking if it is desirable to control ambients. Preferably, the baking is at a temperature in the range 150-350 °C for a time period between 1-15 minutes. Optionally, a drying step may be performed between the coating and the bake steps. Preferably, the drying is performed between the temperature range 150-200 °C. If the desired thickness is not obtained in single coating, then the spin, dry, and bake steps are repeated till the desired thickness is achieved. After the last layer is coated and baked, the film is annealed in a diffusion furnace or in a rapid thermal annealing system. The annealing is preferably done at different temperatures for different times in an oxygen atmosphere at different flow rates. Depending on the type of substrate and the processing procedure, crystalline films with different morphologies can be obtained. The most common product is polycrystalline film with no apparent preferred crystallographic orientations. Polycrystalline films are usually obtained when any one of the following substrate type is used: polycrystalline substrates, amorphous substrates, and single-



\* is not required for the fabrication of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  precursors

Figure 2-1. Fabrication of bismuth layered structure thin films

crystal substrates with large lattice mismatch. Texture-oriented films may be obtained under several special conditions. First, when single-crystal substrates with fairly large lattice mismatch are used, the film grown over the surface may be highly preferentially oriented. Alternatively, the films can be grown with a preferred orientation if a small dc bias field is applied along the substrate surface during the post-deposition annealing treatment. The films annealed using rapid thermal annealing process also show preferred orientation for some cases. When single-crystal substrates with a small lattice mismatch are used, epitaxial films can be formed for some ferroelectric systems.

### 2.3. PROPERTIES OF SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> FERROELECTRIC THIN FILMS PREPARED BY A MODIFIED METALORGANIC SOLUTION DEPOSITION TECHNIQUE

#### 2.3.1. Abstract

Polycrystalline SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films having layered-perovskite structure were fabricated by a modified metalorganic solution deposition technique using room temperature processed alkoxide-carboxylate precursor solution. It was possible to obtain a complete perovskite phase at an annealing temperature of 650 °C and no pyrochlore phase was observed even up to 600 °C. In addition, the SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films annealed at 750 °C exhibited better structural, dielectric, and ferroelectric properties than those reported by previous techniques. The effects of post-deposition annealing on the structural, dielectric, and ferroelectric properties were analyzed. The electrical measurements were conducted on Pt/SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub>/Pt capacitors. The typical measured small signal dielectric constant and dissipation factor at 100 kHz were 330 and 0.023 and the remanent polarization and the coercive field were 8.6 μC/cm<sup>2</sup> and 23 kV/cm, respectively, for 0.25-μm-thick films annealed at 750 °C. The leakage current density was lower than 10<sup>-8</sup> A/cm<sup>2</sup> at an applied electric field of 150 kV/cm. The films showed good switching endurance under bipolar stressing at least up to 10<sup>10</sup> switching cycles.

#### 2.3.2. Introduction

Ferroelectric thin films have attracted considerable attention for their potential applications in electronic devices such as pyroelectric infrared detectors, optical switches, actuators, displays, dynamic random access memories (DRAMs) and nonvolatile random access memories (NVRAMs).<sup>1-3</sup> Ferroelectric nonvolatile memories have the potential to replace current state-of-the-art nonvolatile memories such as floating and flash erasable programmable read only memories (EEPROMs) because of their lower writing voltages, faster writing speeds, better endurance, and potentially fewer processing steps.<sup>4</sup> Recently, there has been a surge in research activity on bismuth layer-structured ferroelectric materials for NVRAM applications. In particular, strontium bismuth tantalate,  $\text{SrBi}_2\text{Ta}_2\text{O}_9$ , which is one of the bismuth layer-structured compounds, is the most promising candidate for ferroelectric random access memories (FRAMs) with high fatigue endurance and good retention.  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  has high potential for device applications because of its high dielectric constant, high Curie temperature, low leakage current, and good ferroelectric switching characteristics. In this letter, we report the fabrication of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films by a modified metalorganic solution deposition (MOSD) technique using a stable alkoxide-carboxylate precursor solution prepared under ambient room temperature conditions. It was possible to obtain a perovskite phase at an annealing temperature of 650 °C and no pyrochlore phase was observed even up to 600 °C;<sup>5</sup> however, the ferroelectricity was found to be weaker in films annealed at 650 °C due to smaller grain sizes. But there is a possibility to enhance the grain growth in the  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films prepared by the present technique at lower annealing temperatures due to absence of pyrochlore phase. The present  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films exhibited better structural, dielectric, and ferroelectric properties than those reported by other methods under similar post-deposition annealing conditions.

### 2.3.3. *Experimental Procedure*

The preparation of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films has been reported by pulsed laser deposition,<sup>6</sup> metalorganic chemical vapor deposition,<sup>7</sup> metalorganic decomposition,<sup>8-10</sup> and sol-gel techniques.<sup>5,11</sup> The electrical and optical properties of bismuth layer-structured ferroelectrics are dependent on their crystallographic orientation due to their large structural anisotropy. So the properties of these materials are strongly dependent on the nature of substrate, preparation technique, and the post-deposition annealing treatment. The selection of precursor compounds

and solvents is the most important step in the MOSD technique. The final film properties are strongly dependent on the selected precursor compounds and the solvents, and the preparation conditions. The  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films were prepared by alkoxide-salt method using alkoxide-carboxylate precursors. The precursor solution was prepared under ambient room temperature conditions. For the preparation of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films; strontium acetate, bismuth 2-ethylhexanoate, and tantalum ethoxide were selected as precursors, and acetic acid, 2-ethylhexanoic acid, and 2-methoxyethanol were selected as solvents. In the experiment, Bismuth 2-ethylhexanoate and strontium acetate were initially dissolved in 2-ethylhexanoic acid and acetic acid, respectively, under room temperature conditions. These solutions were then added to the solution of tantalum ethoxide in 2-methoxyethanol to prepare a stoichiometric, clear, and stable  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  precursor solution. The viscosity of the solution was controlled by varying the 2-methoxyethanol content. Dust and other suspended impurities were removed from the solution by filtering through 0.2  $\mu\text{m}$  syringe filters. The precursor films were coated on to Pt-coated Si substrates by spin coating using a photoresist spinner. The thickness of the films was controlled by adjusting the viscosity of the solution and the spin speed. After spinning on to various substrates, films were kept on a hot plate (at  $\sim 350$  °C) in air for 10 min. This step was repeated after each coating to ensure complete removal of volatile matter. In this letter, we report the structural, dielectric, and ferroelectric properties of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films. The film microstructure and properties were found to be strongly dependent on the excess bismuth content. The best results were obtained for 30 % excess bismuth content. So this letter focuses on the structural and electrical characteristics of  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films with 30 % excess bismuth. The effects of the post-deposition annealing temperature on the film microstructure and properties are also analyzed.

#### *2.3.4 Results and Discussion*

The structure of the films was analyzed by x-ray diffraction (XRD). The XRD patterns were recorded on a Scintag XDS 2000 diffractometer using  $\text{Cu } K_\alpha$  radiation at 40 kV. The as-synthesized films were found to be amorphous and post-deposition annealing was required to develop crystallinity. The post-deposition annealing of the films was carried out at various temperatures for 30 min. in an oxygen atmosphere. Figure 2-2 shows the XRD patterns of the

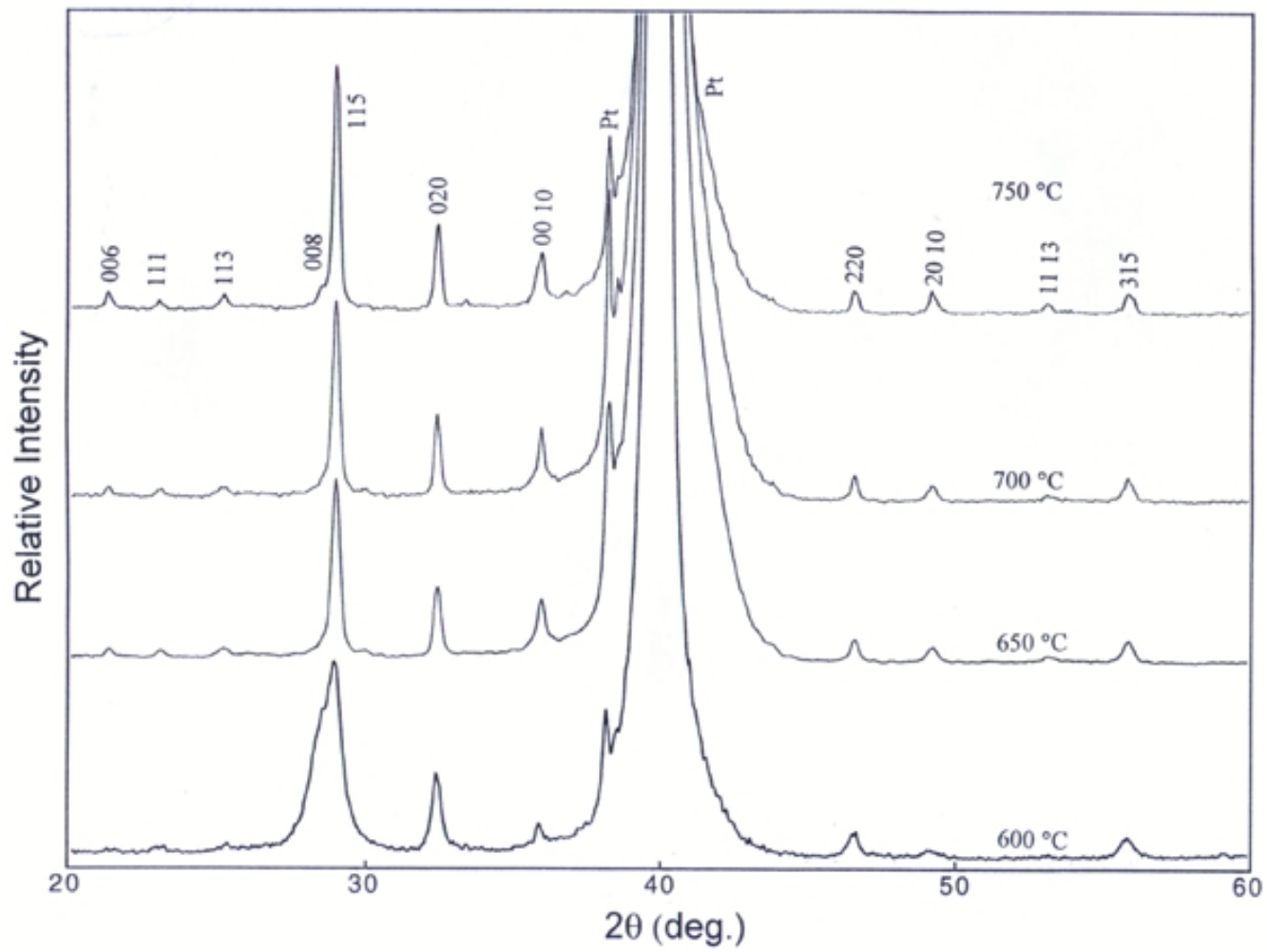


Figure 2-2. X-ray diffraction patterns of SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films annealed at various temperatures for 30 min

films, deposited on Pt-coated Si substrates, as a function of annealing temperature. It was possible to attain perovskite phase at an annealing temperature of 650 °C. The films annealed at 650 °C exhibited better crystallinity than those reported by Amanuma *et al*<sup>8</sup> and Boyle *et al*<sup>5</sup> using chemical methods. As the annealing temperature was increased, the peaks in the XRD pattern became sharper and the full width at half-maximum (FWHM) decreased indicating better crystallinity and an increase in grain size with increasing annealing temperature. The XRD patterns also revealed that films were polycrystalline in nature with no evidence of preferred orientation or secondary phases. No pyrochlore phase formation was observed in the XRD patterns of the SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films (0-30 % excess Bi) prepared by the present method as was observed in the films prepared by sol-gel method.<sup>5</sup>

The surface morphology of the SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films was analyzed by Digital Instrument's Dimension 3000 atomic force microscope (AFM) using tapping mode with amplitude modulation. The scan area was 1µm x 1µm. The surface morphology of the films was smooth with no cracks and defects, as shown in Fig. 2-3, and the average surface roughness was less than 12 nm for films annealed in the temperature range 650-750 °C. The films exhibited a dense microstructure and the grain size was found to increase with the increase in annealing temperature, as shown in Table 1, and was in the range 85-165 nm for films annealed in the temperature range 650-750 °C.

The dielectric properties of SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films were measured in terms of the dielectric constant  $\epsilon_r$  and loss factor  $\tan \delta$ . The dielectric measurements were conducted on metal-ferroelectric-metal (MFM) capacitors with an HP 4192A impedance analyzer at room temperature. Several platinum electrodes (area=3.1x10<sup>-4</sup> cm<sup>2</sup>) were sputter deposited through a mask on the top surface of the films to form MFM capacitors. Figure 2-4 shows the low field dielectric constant and dissipation factor as a function of frequency for a 0.25-µm-thick film annealed at 750 °C. The small signal dielectric constant and dissipation factor at a frequency of 100 kHz were 330 and 0.023, respectively. The dielectric constant was larger than that for bulk ceramics; however, the dielectric constant and the loss factor values for the present films were found to be smaller than those reported by others.<sup>5,8</sup> The permittivity showed no dispersion with frequency up to about 1 MHz, as shown in Fig. 2-4, indicating that the values were not masked by any surface layer effects or electrode barrier effects in the measured frequency range. The dielectric constant and the dissipation factor were found to increase, as shown in Table 2-1, with

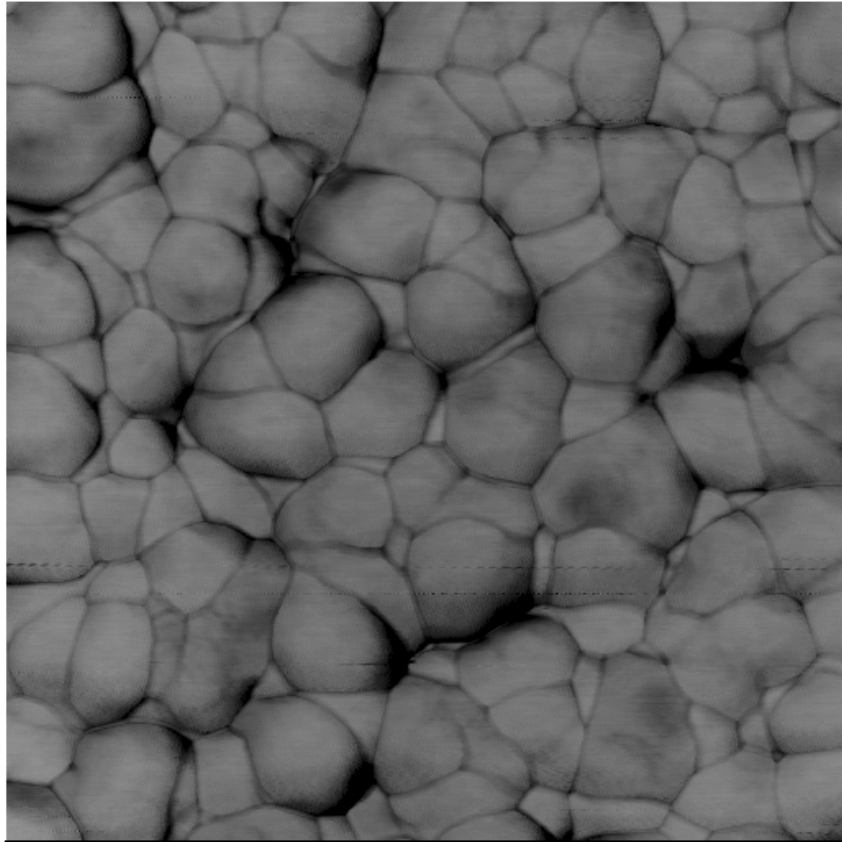


Figure 2-3. AFM photograph of SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin film annealed at 750 °C for 30 min

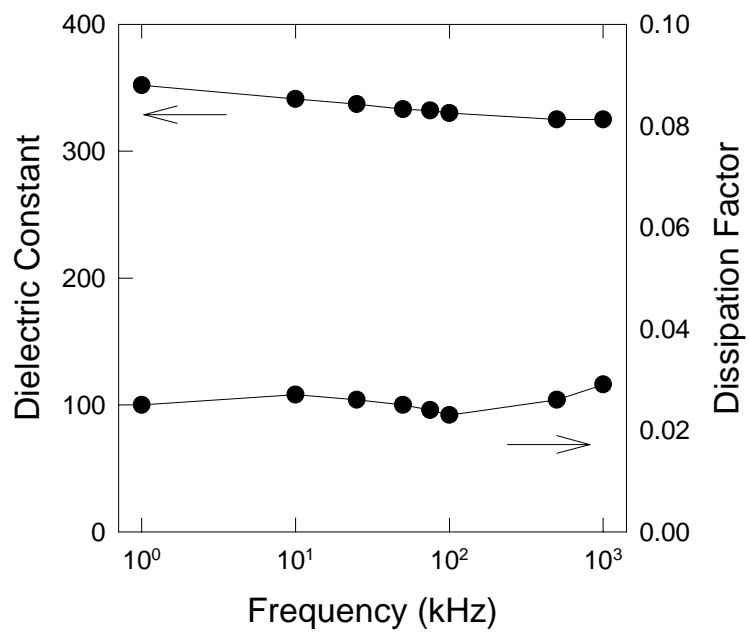


Figure 2-4. Dielectric constant and dissipation factor as a function of frequency for SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin film annealed at 750 °C for 30 min.

Table 2-1. Dependence of grain size, dielectric parameters, and ferroelectric properties on post-deposition annealing temperature.

Temperature (°C)	Grain Size (nm)	$\epsilon_r$	$\tan \delta$	$2P_r$ ( $\mu\text{C}/\text{cm}^2$ )	$E_c$ (kV/cm)
650 °C	85	240	0.007	4.4.	30
700 °C	125	310	0.020	12.8	23
750 °C	165	330	0.023	17.2	23

the increase in annealing temperatures from 650 to 750 °C. This increase in dielectric constant with annealing temperature may be attributed to an increase in grain size and density of the films as was observed in AFM studies.

Ferroelectric hysteresis measurements were conducted on 0.25- $\mu\text{m}$ -thick  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  films in MFM configuration at room temperature using standardized RT66A ferroelectric test system. Figure 2-5 shows a typical hysteresis loop of a film annealed at 750 °C. The measured remanent polarization ( $P_r$ ) and the coercive field ( $E_c$ ) values at an applied electric field of amplitude 150 kV/cm were 8.6  $\mu\text{C}/\text{cm}^2$  and 23 kV/cm, respectively. The remanent polarization value was found to be improved compared to that reported by others and the value of the coercive field was found to be smaller.<sup>5,8,9,10</sup> The  $P_r$  and  $E_c$  were also measured as a function of annealing temperature, as shown in Table 3-1. The remanent polarization ranged from 2.2 to 8.6  $\mu\text{C}/\text{cm}^2$  and the coercive field was between 23 and 30 kV/cm under an applied electric field of amplitude 150 kV/cm. This trend may be found consistent with the XRD and AFM data which indicate improvement in crystallinity with increasing annealing temperature. Low leakage current density is an important consideration for memory device applications. The leakage current density of the  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films was found to be lower than  $10^{-8}$  A/cm<sup>2</sup> at an applied electric field of 150 kV/cm for films annealed in the temperature range 650-750 °C, indicating good insulating characteristics.

The switching endurance of a 0.25- $\mu\text{m}$ -thick  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  capacitor as a function of switching cycles was studied. This was done by applying 8.6- $\mu\text{s}$ -wide bipolar pulses of 5 V amplitude. Figure 2-6 shows the decay of the remanent polarization as a function of polarization reversing switching cycles  $N$ . During initial cycles no rapid fall off in  $P_r$  was observed. There was an initial long period (up to about  $10^8$  cycles) over which  $P_r$  was nearly constant which was then followed by a final decay period. Even after  $10^{10}$  cycles, the decay in  $P_r$  was observed to be less than 5 % of the initial value, suggesting  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  to be an attractive material for memory devices with operating voltage levels of 3-5 V.

### 2.3.5 Conclusions

In conclusion, polycrystalline  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  thin films were successfully produced on Pt-coated Si substrates by a modified MOSD technique. The precursor solution was prepared under

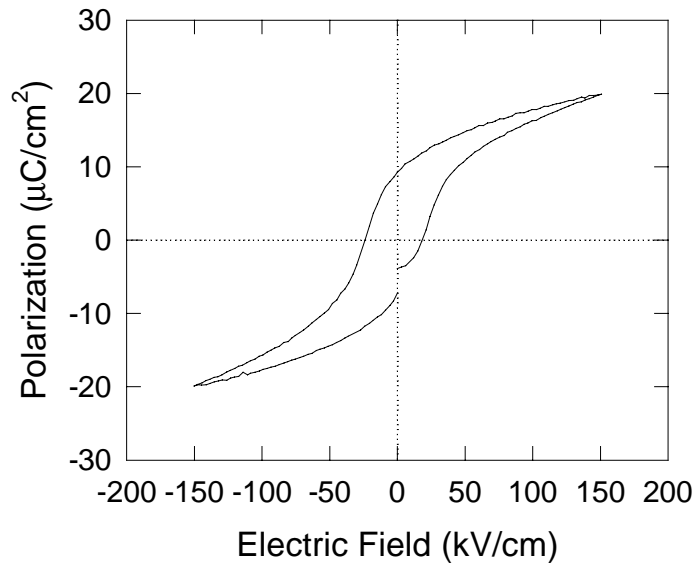


Figure 2-5. Hysteresis loop of 0.25- $\mu\text{m}$ -thick  $\text{SrBi}_2\text{Ta}_2\text{O}_9$  film annealed at 750  $^\circ\text{C}$  for 30 min

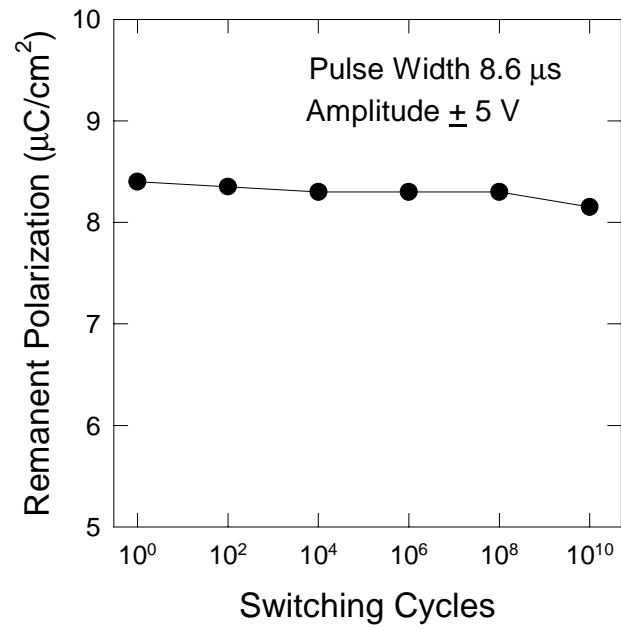


Figure 2-6. Decay in remanent polarization as a function of number of bipolar switching cycles

ambient room temperature conditions using alkoxide-carboxylate precursors. The SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films exhibited good structural and electrical characteristics. It was possible to obtain a complete perovskite phase at an annealing temperature of 650 °C. The surface morphology of the films was smooth with no cracks or defects while the grain size was found to increase with the increase in annealing temperature. For a film annealed at 750 °C, the small signal dielectric constant and dissipation factor at 100 kHz were 330 and 0.023 and the remanent polarization and the coercive field were 8.6 μC/cm<sup>2</sup> and 23 kV/cm, respectively. The dielectric and the ferroelectric properties were found to be annealing temperature dependent due to annealing temperature dependence of the grain size as verified from AFM observations. The leakage current density was lower than 10<sup>-8</sup>A/cm<sup>2</sup> at an applied electric field of 150 kV/cm for films annealed in the temperature range 650-750 °C. The decay in remanent polarization was less than 5 % up to at least 10<sup>10</sup> bipolar switching cycles. The dielectric and ferroelectric measurements on the films suggest that SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> has good potential for applications in memories. Detailed studies are being done to analyze the effects of excess bismuth content and the post-deposition annealing treatment on the structural, dielectric, and ferroelectric properties of the SrBi<sub>2</sub>Ta<sub>2</sub>O<sub>9</sub> thin films.

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