Amorphous Bi-Ti-O Thin Film Dielectrics

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Abstract:

Amorphous bismuth titanate (Bi-Ti-O) composition spread thin films were fabricated using off-axis reactive RF co-sputtering. Continuous compositional spreads allow for high-throughput analysis techniques. Optical reflectometry and profilometry were applied on reference single-element samples and Bi-Ti-O composition spreads to generate composition maps. Metal contacts were deposited on the samples for dielectric properties measurement. Dielectric constant, dissipation factor and current-voltage characteristics reveal the potential of amorphous Bi-Ti-O thin films as a novel dielectric for application in capacitive circuit elements.

Summary of Research:

The investigation of new candidate thin film dielectric materials has been of great importance in capacitive circuits applications for various electronic devices. A good dielectric material exhibits a high dielectric constant and a low dissipation factor that gives low leakage current. These features increase the effective capacitance of the capacitive circuit elements. Besides, amorphous thin films are preferable over polycrystalline materials, since they are generally cheaper and easier to fabricate, especially on modern circuitry that has nanoscale features. Polycrystalline dielectrics are also expected to show a lower breakdown field than that of amorphous dielectrics due to the presence of grain boundaries. [1]

Amorphous bismuth titanate (Bi-Ti-O) thin films can be considered as a potential candidate thin film dielectric material. Crystalline $Bi_4Ti_3O_{12}$ has been reported to show a high dielectric constant and low dissipation factor [2]. Furthermore, to investigate composition-dependent trends of dielectric properties, a composition-spread technique for thin film growth can be applied for high-throughput analysis of a wide range of compositions [3].

In this work, amorphous Bi-Ti-O composition spread thin films were synthesized by off-axis reactive RF magnetron sputtering to investigate the composition-dependence of dielectric properties.

Optical reflectometry was performed on Bi-Ti-O composition spread thin films by FilMetrics in the Cornell NanoScale Science and Technology Facility (CNF). Profilometry was performed on calibration Bi-O and Ti-O samples to help obtain composition maps of samples. The thickness of Bi-Ti-O thin films was measured by profilometry. An array of silver contacts was deposited on Bi-Ti-O thin films as top electrodes for the characterization of dielectric properties. Silver dot contacts were deposited by thermal evaporation in CNF. Capacitance, dissipation factor and current-voltage characteristics were measured using a high-throughput setup which consists of an LCR meter and an electric probe with an automatic stage.

Figure 1 shows the capacitance map as a function of the sample position (Bi-rich region on the left, Ti-rich region on the right) on the Bi-Ti-O thin film. The data shown was measured at 10 kHz, while values that were too high or too low to be realistic are shown in white color. High capacitance values can be observed in the central region and the Ti-rich side of the Bi-Ti-O composition spread thin film.

Figure 2 and Figure 3 illustrate the dielectric constant and the dissipation factor of Bi-Ti-O as a function of composition. It can be seen that Bi-Ti-O thin film with a Bi:Ti ratio of roughly 1:1 appears to exhibit a high dielectric constant while maintaining a low dissipation factor.

Figure 4 shows the maximum breakdown field as a function of composition. Addition of Ti in $Bi_{1-x}Ti_xO_y$ up

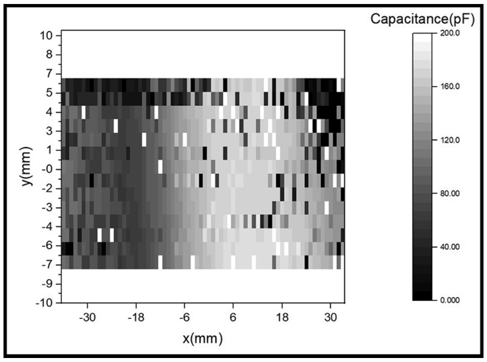

Figure 1: Capacitance map of Bi-Ti-O thin film as a function of sample position (Bi-rich region on the left, Ti-rich region on the right).

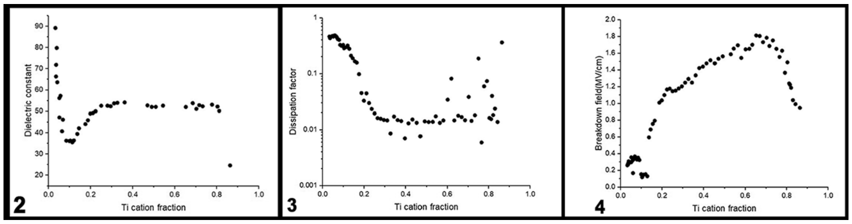

Figure 2, left: *Dielectric constant of Bi-Ti-O as a function of Ti cation composition.* ***Figure 3, middle:*** *Dissipation factor of Bi-Ti-O as a function of Ti cation composition.* ***Figure 4, right:*** *Breakdown field of Bi-Ti-O as a function of Ti cation composition.*

to x around 0.7 increases the breakdown field of the sample, which can result in a good maximum stored charge of approximately 8 $\mu C/cm_2$.

Conclusions and Future Steps:

The dielectric properties of amorphous Bi-Ti-O composition spread thin films were examined. Amorphous Bi-Ti-O was found to show good potential as a dielectric material. However, using the profilometry data to characterize the composition as a function of the sample position is a rough approximation. More accurate data can be obtained from optical reflectometry, which can be further used to characterize the refractive index of samples. Furthermore, laser spike annealing can be performed on the samples to form stable and metastable phases in addition to the as-deposited amorphous phase [4], which can be enable the investigation of the effect of different crystalline phases on dielectric properties of Bi-Ti-O thin films.

References:

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