ABSTRACT

This thesis presents the synthesis of $SrTiO_3$ based metal-insulator-metal capacitors and their characterizations. The capacitors assemblies are developed by using an AJA ATC ORION PVD system. It consists of five magnetron systems equipped with DC and RF power supplies. Moreover, there are *in situ* facilities of substrate heating and rapid thermal annealing. All the structures are constructed at room temperature by precisely controlling the thickness of the thin films using a thickness meter. Before the deposition of the required thin films the optimum conditions (e.g. gas flow rates, electrode spacing and rotation power) are found. Deposition of metallic thin films are conducted by using DC magnetron sputtering and thin films of oxides are deposited by RF magnetron sputtering to avoid the poisoning of the oxide target. All the films are deposited in ultra-high vacuum of about 10^{-7} mbar to elude contaminations.

To find the crystal structures, bonding and surface morphology X-ray diffraction, Raman Spectroscopy and field emission scanning electron microscopy techniques are employed. The electrical properties (capacitance and leakage current) of the capacitors are measured by using Keithley-4200 SCS system by varying the voltage from -3 V to +3V.

$SrTiO_3$ (STO) and TiO_2 are insulating materials with large dielectric constants and opposite signs of the quadratic coefficient of voltage (α). Insertion of a TiO_2 thin film between STO causes to increase the linearity of the capacitance with applied voltage to meet the increasing demand by dynamic random access memory capacitors with a large capacitance density. Both STO and TiO_2 suffer the same problem of high leakage current due to the almost equivalent and low value of bandgap energy. To cope with this issue, the thickness of the TiO_2 film sandwiched between the STO films is varied. A magnetron sputtering system equipped with radio frequency and direct current power supplies is employed to deposit the thin films. TiN is

deposited as the top and bottom metal electrodes to form the metal-insulator metal (MIM) structure which shows a very large linear capacitance density of 21 fF/um^2 that decreases by increasing the thickness of TiO_2. The leakage current decrease with increasing the thickness of TiO_2 and for 27 nm thick film, the measured leakage current decreases to 2.0×10^{-10} A. X-ray diffraction and Raman spectroscopy analysis show that TiN, STO and TiO_2 films are crystalline and TiO_2 has dominant anatese phase structure.

The role of oxygen deficiencies on the electrical performance of $SrTiO_3$ films is investigated by depositing on the stack of TiN/Ti/SiO_2/Si films using radio-frequency (RF) and direct current (DC) magnetron sputtering systems operating in oxygen-deficient plasma environment. Electrodes of silver (Ag) and titanium (Ti) are used to observe the effects of their sizes on the electrical properties of the $SrTiO_3$ films. It is found that the nonlinearity in capacitance-voltage graphs (capacitance tunability) of the varactor can be controlled by varying the electrode area. In addition, the material of the electrode plays a vital role in controlling the non-linearity in the capacitance of the oxygen-deficient $SrTiO_3$ dielectric films with varying voltage. It is found that the silver top electrode instead of titanium, delivers better performance with high capacitance tunability, low leakage current and good quality factor. Post deposition annealing at 550 °C in nitrogen ambient, creates more oxygen deficiencies in $SrTiO_3$ film thereby increasing the linearity of the capacitance-voltage graph thereby decreasing the capacitance tunability.

Al_2O_3 thin films of thicknesses varying from 5 nm to 25 nm were deposited between $SrTiO_3$ to control the capacitance linearity and minimize the leakage current of $SrTiO_3$. X-ray diffraction results show that Al_2O_3 has amorphous structure (a-Al_2O_3) before annealing. After rapid thermal annealing at 600 °C for 5 minutes it becomes γ-Al_2O_3 phase. Amorphous phase has larger value of dielectric constant than γ-Al_2O_3 phase and capacitance density of the capacitor decreases after annealing. For as deposited thin films a high capacitance density of 15.8 fF/µm^2

is achieved for 5 nm thickness which decreases by increasing the thickness. The leakage current decreases by increasing the thickness and for 25 nm thin film a leakage current of 3.4×10^{-11} A is achieved. An increase in linearity and smoothness of the capacitance with applied voltage and frequency was observed after annealing and capacitors show more stability at higher frequencies.