# The impact of the annealing temperature of the seed layer on the growth and the electrical properties of the main layer in atomic layer deposition of $SrTiO_3$ films

**S. H. Kim,[1] W. Lee,[2] C. H. An,[1] D. S. Kwon,[1] D. Kim,[1] S. H. Cha,[3] S. T. Cho, [1] and C. S. Hwang[1]**

[1] *Department of Materials Science and Engineering and Inter-University Semiconductor Research Center, Seoul National University, Seoul 08826, Republic of Korea*

[2]*Department of Materials Science and Engineering, Northwestern University, Evanston, IL 60208, United States*

[3]*Department of Engineering Practice, Seoul National University, Seoul 08826, Republic of Korea*

The atomic layer deposition of $SrTiO_3$ (STO) films was studied with $Sr(^iPr_3Cp)_2$ and $Ti(CpMe_5)(OMe)_3$ (Pr, Cp, and Me are propyl, cyclopentadienyl, and methyl groups, respectively) on Ru and Si substrates at 370 $^oC$. The second STO layer (main layer) was grown on the annealed first 3-5 nm-thick STO layer (seed layer) to induce the in-situ crystallization. The electrical properties and the growth behavior of the main layer were studied with the variations in the seed layer condition, which was varied by varying the annealing temperature of the seed layer in the range of 450-650 $^oC$. The STO films were remained in amorphous by annealing below 500 $^oC$. They were started to be crystallized at 550-575 $^oC$, and well crystallized at 600 $^oC$ or above. The growth rate of the main layer on the crystallized seed layer (0.15 nm/cycle) was 50 % higher than that on the amorphous seed layer (0.10 nm/cycle). As a result, the root-mean-square roughness of the main layer increased from 0.5 nm on the amorphous seed layer to 2.1 nm on the mixed phase (amorphous and crystalline) seed layer, where the main layer growth on the crystallized portion was higher than that on remaining amorphous portion. When the seed layer was well crystallized, the main layer roughness decreased again to 1.0 nm by the uniformly high growth rate across the entire surface. The dielectric constants of the main layers increased from 20 to 100 when the annealing temperature of the seed layer increased from 450 to 650 $^oC$ due to the improvement of the film crystallinity.

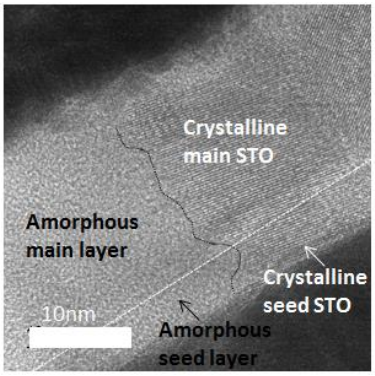


Figure 1. TEM image of the main STO layer grown on the annealed seed STO layer

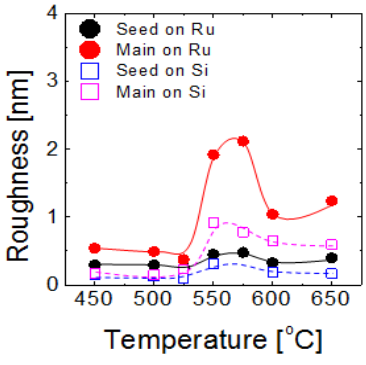


Figure 2. RMS Roughness variations of the main STO layers as a function of the seed STO annealing temperature

# Supplementary Pages (Optional)

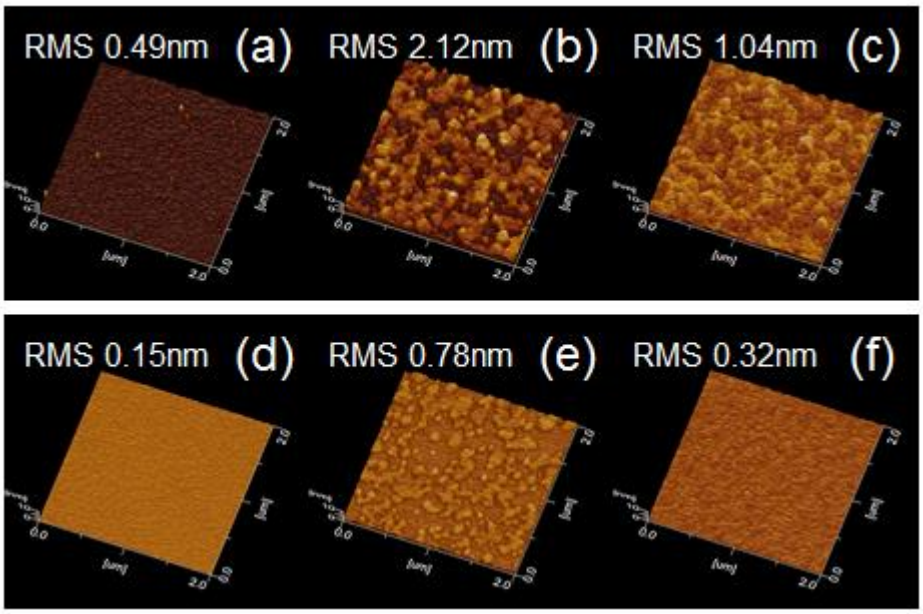


Figure 3 Atomic force microscopy images of STO main layers on (a) 500 $^{o}$C, (b) 550 $^{o}$C, and (c) 600$^{o}$C annealed STO seed layers on Ru substrate. Atomic force microscopy images of STO main layers on (a) 500 $^{o}$C, (b) 550 $^{o}$C, and (c) 600$^{o}$C annealed STO seed layers on Si substrate. The total thickness of STO films was about 20 nm.