Plasma-assisted ALD of $SrTiO_3$ for Pt/$SrTiO_3$/Pt MIM structures: Growth and Crystallization study

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$SrTiO_3$ (STO) is a perovskite material that exhibits many interesting properties (ferro-electricity, para-electricity, ultrahigh-k value, resistive switching properties, etc.). To exploit such properties, thin STO films can be deposited as the insulating layer in metal-insulator-metal (MIM) structures, for example for DRAM or ReRAM applications. When prepared by atomic layer deposition (ALD), the as-deposited STO films require an annealing step to obtain the crystalline phase with the required dielectric properties. For these reasons, a detailed study of the growth and crystallization of the STO films on a functional bottom electrode material is of significant interest.

In this work, thin STO films (~ 15 nm) were deposited by plasma-assisted ALD on Pt-coated substrates. The Pt layers were prepared by both plasma-assisted ALD using cyclopentadienyl-based precursors [1] and by PVD. To investigate the influence of the film composition on the growth and on the crystallization behavior, films with two different stoichiometries were deposited ([Sr]/([Sr]+[Ti]) = 0.54 and 0.63). The composition and thickness of the films were determined by spectroscopic ellipsometry (SE) [1]. The STO films were crystallized by rapid thermal annealing (RTA) at 550 °C and 600 °C. Pt was also deposited by ALD on crystallized STO to manufacture Pt/STO/Pt MIM structures.

Fig. 1a shows the evolution of STO film thickness as measured by in-situ SE of the STO films on the Pt substrates. For both stoichiometries the STO layers showed the same growth behavior. The growth-per-supercycle and stoichiometries obtained were comparable to the results reported in our previous work for STO on Si_3N_4 and Al_2O_3 [2]. Fig. 1b shows the thickness evolution of Pt films deposited by plasma-assisted ALD on STO showing a similar nucleation delay and growth behaviour as on a SiO_2 substrate.

Fig. 2 shows grazing-incidence X-ray diffraction (GI-XRD) patterns of the STO films with [Sr]/([Sr]+[Ti]) = 0.54 and 0.63 deposited on Pt and on Al_2O_3 and after RTA for 1 minute at 600 °C. STO films were fully crystalline after the RTA step and were randomly oriented on both substrates. A shift to lower angles of the peaks was recorded for the Sr-rich films and was imputed to an increased lattice parameter [2].

Fig. 3a shows a Bright-field transmission electron microscopy (TEM) image of a Si_3N_4 TEM membrane on which a 15 nm Pt film was deposited by plasma-assisted ALD. The Pt grains show an average size of ~ 10 nm. Fig. 3b shows a High Angle Annular Dark-Field Scanning TEM (HAADF STEM) image of a crystallized STO layer ([Sr]/([Sr]+[Ti]) = 0.54) deposited on a Pt-coated TEM membrane. The STO grains can be identified and have a large size (~ 100 nm) compared to the Pt ones which can still be recognized.

With these and other results, we will address that STO thin films deposited on Pt show a growth and crystallization behavior similar to those grown on Al_2O_3 and Si_3N_4 with comparable grain size, morphology and crystallization temperature. We will also demonstrate and discuss that Pt can be deposited by plasma-assisted ALD on crystallized STO to obtain MIM structures.

We acknowledge the funding from the European Community's 7th Framework Programme (FP7/2007-2013) under grant agreement number ENHANCE-238409.

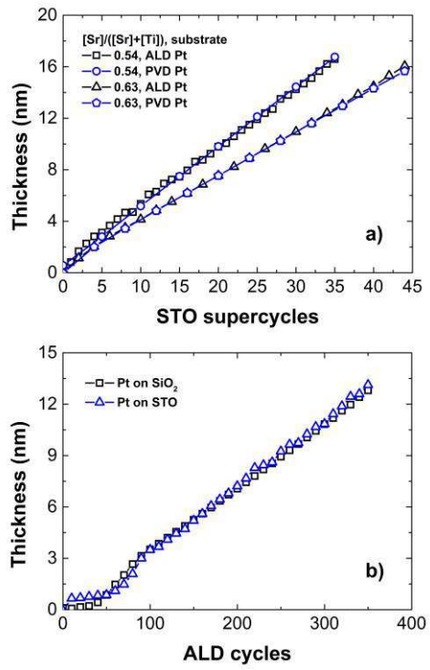

Fig. 1 STO film thickness evolution of STO on Pt (deposited by ALD and PVD) as measured by in-situ SE (a) and Pt film thickness evolution on STO and SiO_2 (b).

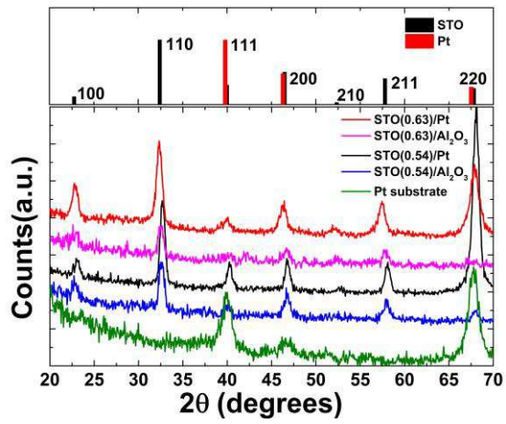

Fig. 2 GI-XRD patterns of STO films with [Sr]/([Sr]+[Ti]) = 0.54 and 0.63 grown on Pt and on Al_2O_3 after RTA at 600 °C for 1 min. The GI-XRD of the Pt substrate is included as a reference.

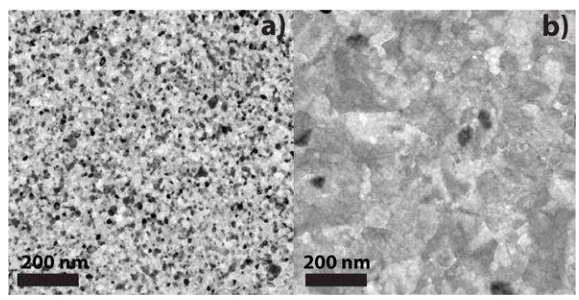

Fig. 3 Bright-field TEM image of a 15 nm Pt film deposited by plasma-assisted ALD (a). HAADF STEM image of an STO ([Sr]/([Sr]+[Ti]) = 0.54)/Pt stack after RTA at 600 °C for 1 min.

References:

[1] V. Longo, et al., ECS J. Solid State Sci. Technol., 2(1), N15 (2013).
[2] V. Longo, et al., ECS J. Solid State Sci. Technol., 2(5), N120 (2013).