

KINETIC MODELING FOR MULTI-COMPONENT THIN FILM GROWTH IN PLASMA ENHANCED ATOMIC LAYER DEPOSITION

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Atomic layer deposition (ALD) has received significant attention to be the promising technique for ultra-thin film deposition due to its unique feature of layer-by-layer growth. This layer-by-layer growth provides exact control of film thickness, even in conformal deposition for a large area of thin film.^{1,2} Some studies have examined the film growth kinetics in ALD.^{3,4} Lim *et al.* used a kinetic model of a film to explain film growth of one monolayer (ML)/cycle and described characteristics of ALD more accurately, such as the existence of a transient region in the initial stage.⁴ However, they focused on binary systems, so expansion of their model to a multi-component thin film system is very difficult. The anticipated dynamic random access memory (DRAM) technology will use perovskite structure materials with high k values. This will necessitate the deposition of films using multiple reactants to deposit each element. The reactants will be adsorbed onto various surfaces during deposition. Since throughout the process of multi-component thin film deposition, ALD occurs only in the transient region, control of film thickness by controlling the number of deposition cycles in ALD is lost.

In this study, the growth kinetics of films grown by plasma-enhanced atomic layer deposition (PEALD) was modeled in order to control the composition of multi-component thin films. Reactants corresponding to the elements to be deposited were used individually rather than in a cocktail. A new cycle design for multi-component thin-film PEALD was considered. First, the precursor was injected and adsorbed onto the surface. Then, the adsorbed precursor was reacted with plasma radicals. This is defined as a sub-cycle. After several repetitions of this sub-cycle, the second precursor was deposited in the same manner as the first. These steps are defined as one cycle. The film thickness per cycle and the composition ratio of elements can be evaluated from the total coverage of precursors adsorbed onto the surface during one cycle.

The proposed model was applied to the deposition of SrTiO₃ thin films. Deposition of SrO and TiO₂ films was carried out on Si-wafers at growth temperatures 275 °C with a total pressure of 3 Torr using Sr(dpm)₂ and titanium-isopropoxide (TTIP, Ti(OC₃H₇)₄) as precursors. Ar and O₂ gas mixture was used as the reactant to generate plasma. Fig. 1 depicts the deposition thickness of SrO and TiO₂ films per cycle as a function of precursor injection number. The saturated thickness per cycle was achieved with one injection and the saturated thickness per cycle of SrO and TiO₂ was 0.55 and 0.35 Å/cycle, respectively. Using our model, we can predict the thickness per cycle and the composition for various combinations of sequences. Fig. 2 and 3 shows the variation in composition and thickness per cycle with the ratio of Ti sub-cycles to Sr sub-cycles, respectively. Both the experimental thickness per cycle and the composition

were in good agreement with the simulations.

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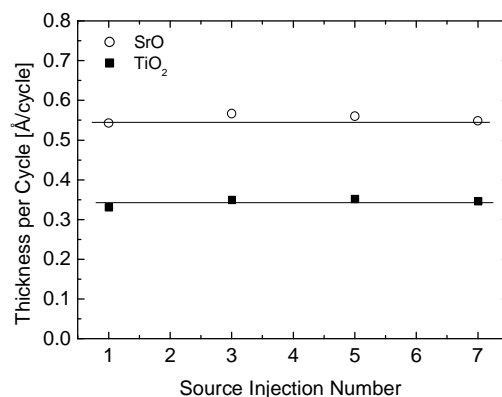


Fig. 1. The dependence of film growth thickness per cycle on source injection number

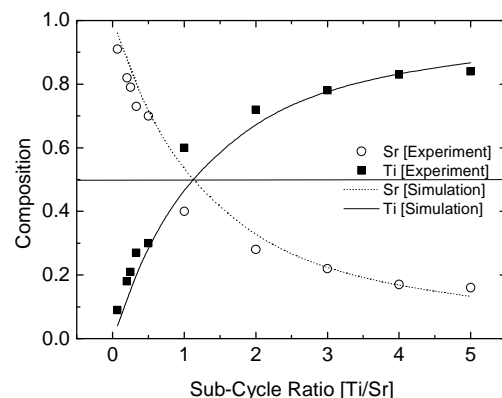


Fig. 2. The variation of composition versus the sub-cycle ratio of Ti to Sr

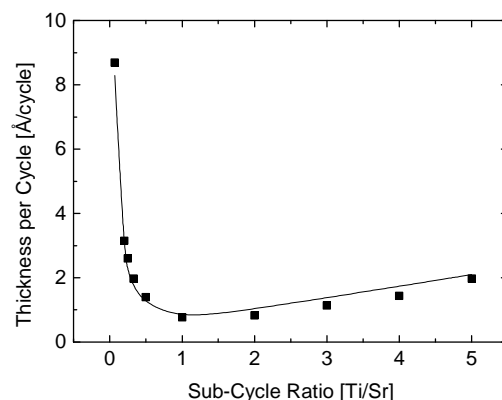


Fig. 3. Thickness per cycle with the variation of sub-cycle ratio