Comprehensive Studies of Atomic Layer Deposited InGaO Thin Films using InCA-1, TMGa and H_2O_2 for Oxide Semiconductor Thin Film Transistor Applications

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IGO thin films were deposited by ALD with using [1,1,1-trimethyl-N-(trimethylsilyl)silanaminato]indium (InCA-1) as the indium precursor, Trimethylgallium (TMGa) as the gallium precursor, and hydrogen peroxide (H_2O_2 30%) as the reactant. The auger electron spectroscopy (AES) and spectroscopic ellipsometry (SE) analysis was carried out for the thin film growth by ALD with 5 different sequences (shown in figure 1) that reactant pulse was launched before and after sequential metal precursor pulse, as table (in abstract) shows. The gallium oxide shows successful deposition at 200°C when accompany with InCA-1-H_2O_2 sequence (Ga-In and InO-GaO), while no growth appeared without indium oxide deposition (GaO), that is accordant to the previous report where TMGa with H_2O_2 or H_2O were not able to grow GaO by ALD even at 350°C. Besides, TMGa straightly pulsed after InCA-1 exhibited almost no growth of GaO--only 3.8% of Ga% (In-Ga).

The DFT-calculated potential energy diagram of InCA-1 and TMGa precursors on the hydroxylated Si(100) surface and hydroxylated trivalent indium on Si(100) surface were shown in figure 2, suggested the adsorption behavior. In terms of metal precursor dosed on hydroxylated Si(100) surface, molecular adsorption through O-metal dative bonding is spontaneous for both precursors. The process of CH_4 removal cannot be proceed due to higher active energy comparing to the desorption energy. While for the TMGa dose after H_2O_2 dose (hydroxylated trivalent indium on Si(100) surface), as *$In(CH_3)_2$ is oxidized to *InOH and the TMGa spontaneously dissociates into [*$Ga(CH_3)_2$ + *CH_3] without activation energy and significant stabilization, the process of CH_4 removal can be successfully proceed due to higher desorption energy than active energy and was irreversible due to gas desorption.

The ability of composition adjustment for IGO thin film by ALD was applied to the active layer of TFT. The performance of IGO TFT exhibited dependence on the In% and Ga% by controlling the number of InO cycle and GaO cycle in InO-GaO sequence. When the InO cycle increased from 1 to 3, the mobility was increased from 0.17 to 9.45cm^2/Vs, with threshold voltage negative shift due to raising composition of In.

Figure 1. ALD sequence for various sequences of indium gallium oxide thin film.

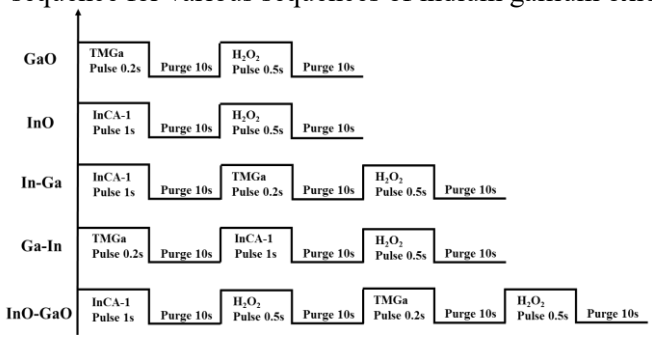

Figure 1. Calculated potential energy diagram of InCA-1 and TMGa precursors on the hydroxylated Si(100) surface and hydroxylated trivalent indium on Si(100) surface