TT-P049

In-situ Synchrotron Radiation Photoemission Spectroscopy Study of Property Variation of Ta_2O_5 Film during the Atomic Layer Deposition

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Atomic layer deposition (ALD) can be regarded as a special variation of the chemical vapor deposition method for reducing film thickness. ALD is based on sequential self-limiting reactions from the gas phase to produce thin films and over-layers in the nanometer scale with perfect conformality and process controllability. These characteristics make ALD an important film deposition technique for nanoelectronics. Tantalum pentoxide (Ta_2O_5) has a number of applications in optics and electronics due to its superior properties, such as thermal and chemical stability, high refractive index (>2.0), low absorption in near-UV to IR regions, and high-k. In particular, the dielectric constant of amorphous Ta_2O_5 is typically close to 25. Accordingly, Ta_2O_5 has been extensively studied in various electronics such as metal oxide semiconductor field-effect transistors (FET), organic FET, dynamic random access memories (RAM), resistance RAM, etc. In this experiment, the variations of chemical and interfacial state during the growth of Ta_2O_5 films on the Si substrate by ALD was investigated using in-situ synchrotron radiation photoemission spectroscopy. A newly synthesized liquid precursor $Ta(N^tBu)(dmamp)_2$ Me was used as the metal precursor, with Ar as a purging gas and H_2O as the oxidant source. The core-level spectra of Si 2p, Ta 4f, and O 1s revealed that Ta suboxide and Si dioxide were formed at the initial stages of Ta_2O_5 growth. However, the Ta suboxide states almost disappeared as the ALD cycles progressed. Consequently, the Ta^{5+} state, which corresponds with the stoichiometric Ta_2O_5, only appeared after 4.0 cycles. Additionally, tantalum silicide was not detected at the interfacial states between Ta_2O_5 and Si. The measured valence band offset value between Ta_2O_5 and the Si substrate was 3.08 eV after 2.5 cycles.

Keywords: Atomic layer deposition, In-situ Synchrotron Radiation Photoemission Spectroscopy, Tantalum pentoxide (Ta_2O_5)