HOTWIRE ASSISTED ALD OF TUNGSTEN FILMS: IN-SITU STUDY OF THE INTERPLAY BETWEEN ALD, CVD AND ETCHING MODES

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ABSTRACT

There is huge interest in atomic layer deposition (ALD) of metals for ultra-large-scale integrated circuit manufacturing. Radical-enhanced ALD (REALD) utilizing plasma (PEALD) has been proposed to grow a number of metals [1]. In this work, we investigate an alternative approach to REALD without plasma, replacing it by a hot (up to 2000 °C) tungsten (W) wire. In this so-called hot-wire ALD (HWALD), W is deposited using alternating pulses of WF₆ and atomic hydrogen (at-H). The latter is generated by catalytic dissociation of molecular hydrogen (H₂) upon the hot wire [2].

Earlier research carried out in our group focussed on in-situ monitoring of at-H delivery to the substrate by etching of tellurium films [3]. In the current work, we applied this knowledge to the use of at-H as a reducing agent for WF₆, thereby enabling ALD of W films. W films were grown on a 100-nm thick thermal SiO₂ (note, a proper W seed layer was previously grown on the oxide). The growth process was monitored in real time by an in-situ spectroscopic ellipsometer (SE) Woollam M2000. The inlets of WF₆ and at-H were separated at a distance of 70 cm, to prevent mixing the precursors in gas line.

The real-time SE monitoring of the film formation however revealed the co-existence of three processes: etching, CVD and ALD of the W film. Within a certain pressure range and at a relatively high dose, WF₆ could back-stream diffuse to the hot wire, resulting in WF₆ decomposition and generation of a large flux of atomic fluorine (F) towards the substrate. The latter caused etching of the grown W film and provided extra WF₆ supply, which may later cause CVD. On the other hand, when the dose of WF₆ was sufficiently low and the purge time between the WF₆ and at-H pulses was not long enough, the at-H reacted with the remaining WF₆ thereby enhancing CVD. Higher pressure and higher carrier gas flow rate were found to largely suppress the back-stream diffusion of WF₆, which efficiently limited CVD. By controlling the dose of WF₆ and process pressure, the etching has also been minimized. Composition of the films is thus obtained, analysed by X-ray photoelectron spectroscopy, revealed 98% of W; concentrations of oxygen and fluorine were lower than 1%. The resistivity measured by four-point probe was in the range of 20 to 100 µΩ.cm. In our full paper, we will give an extended overview of the interplay between the three co-existing processes as well as the film characteristics.