High-Quality Tungsten Films by Hotwire-Assisted CVD/ALD at Low Temperature

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There is a growing interest in atomic layer deposition (ALD) of metals for ultra-large-scale integrated circuit (ULSIC) manufacturing. Radical-enhanced ALD (REALD) utilizing plasma (PEALD) has been proposed to grow a number of metals [1]. In our work, we investigate an alternative approach to REALD without plasma, i.e. replacing plasma by a hot (up to 2000 ^{o}C) tungsten (W) wire. In this so-called hot-wire ALD (HWALD) approach, tungsten is deposited by using alternating pulses of WF_6 gas and atomic hydrogen (at-H). The latter is generated by catalytic dissociation of molecular hydrogen (H_2) upon the hot wire. Apart from HWALD, W films have additionally been deposited by hot-wire chemical vapor deposition (HWCVD), for a comparison of their properties.

Earlier research carried out in our group was focused on the effectiveness of at-H delivery to the substrate, examined by etching of tellurium films [2]. Further, we applied this knowledge to the use of at-H as a reducing agent for WF_6, thereby enabling either ALD or CVD of W films. The films were grown on a 100-nm thick thermal SiO_2 with a proper seed layer. The growth process was monitored in real time by an *in-situ* spectroscopic ellipsometer (SE) Woollam M2000. Two different reactor configurations were employed: a *large-volume cold-wall* reactor (70 cm distance between the HW and the substrate) and a *small-volume hot-wall* reactor (3-5 cm distance between the HW and the substrate).

In the cold-wall reactor, real-time SE monitoring revealed a co-existence of three process modes: etching, CVD and ALD [3]. By tuning the process conditions, each of these modes could be made dominant. X-ray photoelectron spectroscopy (XPS) analysis revealed 98% W. X-ray diffraction (XRD) scans showed the formation of β-phase W with a resistivity of 100 μΩ.cm in case of HWALD and of α-phase W with a resistivity of 20 μΩ.cm for HWCVD [4]. These results will further be compared with properties of HWALD W obtained in the hot-wall reactor.

In my presentation, I will demonstrate the mentioned interplay between etching, CVD and ALD modes, and characterize deposition and properties of HWCVD and HWALD W films in details.

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