Kinetics of chemical etching in nano-confined volumes

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With the continuous downscaling of transistors in microelectronic devices, the semiconductor industry has entered the nano-age. The fundamental limitations encountered in planar devices have motivated the introduction of new 3-dimensional architectures [1]. Consequently wet chemical processes used to etch and clean materials are facing new issues related to nano-confinement. A recent study showed that the chemical etching of nanochannels was affected by the decrease in concentration of active ions with charge opposite to that of the created surface, caused by the overlap of the electrostatic double-layers [2,3]. In this work etching of transistor TiN gate films was studied in 1-D and 2-D confined nano-volumes. Kinetics were correlated with surface potentials measured on planar films.

Test structures consisted in trenches etched in Si (1-D) and nanoholes made by a sacrificial Si-nanopillar process (2-D), that were covered with 1.5nm HfO2 and 5nm TiN by ALD (Fig.1). The TiN film was etched in solutions of ammonia and hydrogen peroxide at various temperatures. Planar films were characterized by ellipsometry and streaming potential, for etch rate and surface potential, respectively. The etch rate in nanostructures was characterized by FIB-TEM. Fig.1 shows an 18nm nanohole (initial opening of 5nm) with TiN mostly etched (c), while TiN was not etched in a 15nm nanohole with 2nm opening (d). Chemical and dimensional conditions have been determined where etching no longer occurred with solution penetration and etching from top to bottom had to be pursued instead. Kinetics were correlated with concentration profiles calculated from surface potentials measured on planar films.

Figure 1 Electron microscopy images of nanoholes: (a) top down SEM of nanoholes before HfO2/TiN deposition; (b)(c)(d) cross-section TEM of nanoholes before (b) and after etching (c)(d), with (c) and without (d) TiN etching.