Selectivity Studies on Tantalum and Tantalum Nitride Barrier Layer in Copper CMP

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Copper metallization in sub-0.18 μm semiconductor devices is achieved by combining the dual damascene techniques followed by chemical mechanical planarization (CMP) [1,2]. Tantalum and its nitride have been identified as the diffusion barrier layer for copper metallization. However, the wide differences in properties between copper and tantalum layers result in selectivity problems during CMP process [3]. Differences in chemical and physical properties between copper and tantalum lead to variations in removal rates, which may result in dishing during CMP. Therefore, it is essential to understand all the aspects of barrier metal removal for proper implementation of copper interconnect into industrial process. The aim of this work is to understand the interaction between chemical and mechanical parameters that control the polishing rates of Ta and TaN. The final goal is to obtain a better understanding on the slurry selectivity between copper and tantalum or tantalum nitride and to develop slurries with best selectivity performance.

In this work, the effect of several chemical parameters (abrasive type, oxidizer type, concentration, pH etc.) was studied through static and dynamic tests using advanced electrochemical techniques and surface analysis techniques. Polishing experiments are carried out on metal disks and blanket films on wafers. Electrochemical measurements were performed using in-situ open circuit potential, potentiodynamic polarization and electro-chemical impedance spectroscopy (EIS) methods. The surface layers of the statically etched tantalum and tantalum nitride discs were investigated using X-ray photoelectron spectroscopy (XPS) and the surface defects such as scratches and dishing effects are studied using thin film surface analytical tools such as atomic force microscopy (AFM) and optical interferometer.

Ta and TaN were observed to oxidize in aqueous solutions at pH 2, 4 and 10 without and with the presence of H_2O_2. The static etching results indicate the dissolution was more pronounced at pH 10 because of enhanced dissociation of H_2O_2 in alkaline region. AFM study confirmed the formation of a thin impervious oxide layer at pH 2 in 5% H_2O_2 solution and a porous layer at pH 10. Electrochemical study indicates electrochemical dissolution plays a more pronounced role in CMP removal for TaN than Ta. Polishing rate results show that tantalum and tantalum nitride performs well in silica-based slurry but poor in alumina-based slurry. It was also observed that silica produced lesser scratches and much better surface planarity. XPS results indicate that a strong interaction between silica and tantalum oxide may cause the higher CMP removal rate in silica-based slurry.

References:

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