SEEDLESS ELECTROCHEMICAL DEPOSITION OF COPPER ON AIR-EXPOSED TANTALUM NITRIDE BARRIERS WITH ULTRA-THIN ADHESION LAYERS

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ABSTRACT

Copper has replaced aluminum for microelectronic applications bringing the challenges of adapting to a new material with new processing systems. One impetus of changing from aluminum to copper for electronic applications is the lower resistivity which results in higher device speed. It is of the utmost importance to produce electrochemical deposition (ECD) copper with a resistivity as near to the bulk value of 1.7 $\mu\Omega$cm as possible to assure maximum device performance [1]. Current technology requires ever decreasing feature geometries and increasing aspect ratios to improve device speed. The challenge in designing smaller devices is in achieving a uniformly continuous, adherent seed layer. As geometry size is reduced and aspect ratios increase, the ability to achieve coverage with physical vapor deposition (PVD) for a copper seed layer becomes impossible. It is projected that PVD seed layers will no longer be viable below the 90 nm node [2]. The development of plating baths for direct electrodeposition of copper onto metal and metal nitride barrier layers for interconnect technology is a primary concern. Basic electrochemical principles as well as specific reasons for the choice of copper bath base and additives are discussed.

This work presented here includes electrochemical data consisting of potentiodynamic experiments, cyclic polarization data, and current density analysis for potentiostatic experiments as well as galvanostatic deposition. Samples were analyzed with electrochemical techniques, field emission scanning electron microscopy (FESEM), Scotch tape adhesion tests, and mass transport experiments utilizing a rotating disk electrode. Atomic Force Microscopy (AFM) has been employed to determine surface roughness changes indicative of the grain structure and surface condition of samples. An initial examination of copper plate has been conducted using transmission electron microscopy. Other experimental work includes a four point probe resistivity study with annealing to optimize copper conditions, XPS to quantify the impurity concentration of copper plate as well as possibility of impurity concentration in Cu deposits. The parameters of bath additive concentration and deposition potentials, that promote good adhesion of copper on barrier layers are one of the most important aspects of this study. This is quantified using four point bend testing to determine adhesion values. Superfilling using ultra thin adhesion promoting layers both an electrochemically deposited, ECD, copper seed and atomic layer deposition (ALD) deposited palladium and ruthenium will be quantified. A determination will be made as to what conditions result in the best adherent, lowest resistivity in copper plate.

Substrates studied include TaN barrier layers consisting of 30 nm blanket and patterned wafers obtained from Intel Corporation as well as 25 nm TaN blanket wafers obtained commercially from Silicon Quest International. Prof. Toh-Ming Lu's research group at RPI provided 15 nm physical vapor deposition, PVD, Ru barriers for analysis. In addition, his research group provided ultra-thin Ru and

Pd deposited via a chemical vapor deposition (CVD) ALD process onto TaN barrier layers.

There is a complicated interplay of the plating bath and parameters, annealing process, and adhesion that must be balanced to achieve superfilling behavior in features while obtaining the best adhesion and lowest resistivity possible. Overall, this proposed work represents a comprehensive study of Cu deposition on TaN and Ru barrier layers as well as Pd and Ru ALD adhesion promoters. The goal is to design a plating bath and procedure to effectively produce continuous, adherent copper films with low resistivity on blanket and patterned TaN and Ru barrier layers as well as Pd and Ru adhesion layers.