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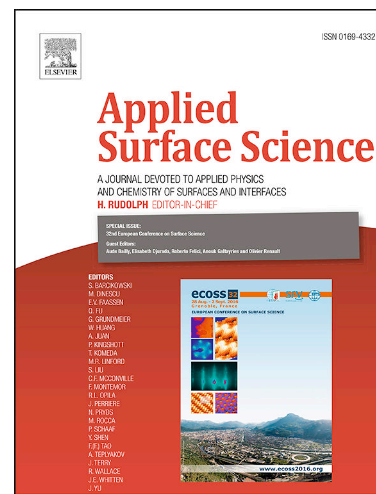

Full Length Article

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Nucleation and Adhesion of ultra-thin Copper films on amino-terminated Self-assembled Monolayers

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Abstract

In this work, we report on the effect of amino-terminated self-assembled monolayers (SAMs) on the growth and adhesion of copper on a dielectric surface in ultra-high vacuum. The nucleation and adhesion of copper is studied for a range of self-assembled monolayers both with and without nitrogen containing terminal groups, and as a function chain length using x-ray photoelectron spectroscopy, dynamic water contact angle, sheet resistance, and adhesion testing measurements.
In-situ x-ray photoelectron spectroscopy studies of ultra-thin copper films show that the presence of nitrogen significantly improves the nucleation of copper to the surface, particularly those coated with long chain SAMs. However, upon thermal annealing short chain amino-terminated SAMs retain much of the deposited copper while significant desorption occurs for longer chains.
Results consistent with these observations are obtained during conventional tape test measurements to determine adhesion. As such, for CMOS interconnect applications which require copper trenches with a nano-scale cross section, short chain SAMs offer excellent nucleation and adhesion, as well as the potential to act as a pore-sealant for low-k materials, without impacting significantly on the cross-sectional area of the copper lines.

1. Introduction

As device scaling continues towards critical dimensions of just a few nanometers, significant issues arise in back end of line (BEOL) processing. One of the most crucial is ensuring that the diffusion barrier layer which is employed to halt the migration of copper into the interlayer dielectric (ILD) maintains its integrity when scaled aggressively [1]. In order to keep line resistivity to a minimum it is important that as much of the interconnect line cross section as possible is taken up with copper rather than the barrier material. As trench widths shrink below 10 nm the barrier layer will need to be constrained to a thickness of 1 nm or less in order to meet performance criteria [2]. Furthermore, the behavior of electron transport through copper lines with such small dimensions begin to diverge significantly from bulk properties putting further pressure on the barrier layer to deliver low resistivity [3].Ta/TaN bilayers have been employed as copper diffusion barriers since the replacement of aluminum interconnects with copper in the late 1990s. However, with the advancement in technology nodes, Ta/TaN is no longer an effective barrier to copper diffusion due to difficulties with

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