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A study of interface in Cu and TiN by x-ray photoelectron spectroscopy

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1. INTRODUCTION

The interconnect metallization become more and more important in development of ultra-large-scale integrated(USLI) circuits with deep submicron dimensions of interconnect linewidths since size and junction depth of electrical contacts shrink. Up to now, aluminum or its alloys have been widely used as metallization materials for silicon integrated circuits. However, Al based alloys may become inadequate since the electrical resistivities of these alloys is higher than desired for reducing interconnect propagation delay.

Copper has attracted attention as a possible substitute for Al because of its lower electrical resistivity and superior resistance to electromigration. Therefore, a development of a good diffusion barrier and/or adhesion promoters for Cu is of extreme importance for silicon integrated circuit applications. Many studies of TiN as diffusion barrier for Cu metallization have been carried out.

The requirements for diffusion barrier to prevent interdiffusion at current process are low contact resistance and good adhesion to both the metalliztion and the underlying contact configuration. Chemical reactions between materials at an interface are important in adhesion. In order to estimate adhesion between Cu metallization and the underlying contact configuration, the study of interface of Cu with TiN is necessary.

The purpose of this study is to clarify the chemical reaction of interface between Cu film and TiN substrates by XPS.

2. EXPERIMENTAL PROCEDURES

Titanium nitrides were prepared by reactively sputtering Ti metal onto the boron-doped *p*-type Si(100) wafers in a mixture of Ar and N_2 gas. The TiN samples were oxidized by exposure to air at room temperature in order to study the nature of the oxide layer between Cu and TiN.

XPS measurements were made on the TiN films and after deposition of Cu to various levels. Cu *in situ* deposition were made by Ar^+ ion sputtered deposition. The deposition rates for Cu were ~1 Å/min. as determined by RBS. The base pressure in this system was in low 10^{-10} Torr range and the pressure during the sputter deposition was in low 10^{-8} Torr range. Core level and valence band XPS spectra of the sample surfaces were taken in a PHI model 5700 spectrometer with a hemispherical electron energy analyser using monochromatic Al $K\alpha$ (1486.6 eV) irradiation. The pass energy was 23.5 eV, giving an energy resolution of 0.7 eV to the Ag $3d_{5/2}$ line.

3. RESULTS AND DISCUSSION

We obtained the Ti(2p), N(1s), O(1s), Cu(2p), and Cu(LMM) Auger spectra by XPS. With varying deposition rate of Cu, these spectra show no changes in line shape as well as in peak position. In addition, valence band spectra by XPS show also no changes. That is, it is indicated that Cu is unreactive with Ti, N, and O. The reactions in the barrier mechanism are very important.

From these results, we can conclude that the incorporation of impurities in the TiN layer does not give a good diffusion barrier property in Cu metallization since Cu is relatively unreactive with most of impurities such as oxygen and nitrogen.

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