ELECTROMIGRATION CHARACTERISTICS OF Al/W-N/LOW-k/Si SUBMICRON INTERCONNECT STRUCTURE

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Throughout the continuous evolution of very large scale integrated (VLSI) circuits, the limitations of VLSI in the circuit speed and the reliability become to more depends on the characteristics of interconnect than the scaled active device. Especially, thin film multilevel interconnects are sensitive to increasingly high current densities which give rise to electromigration due to microstructure at discontinuities of grain structure and metal penetration driven by electron flow at the interface of the scaled down multilevel interconnects[1]. In this work, we have investigated several basic aspects of the electromigration behavior and damage formation in Al/diffusion barrier/interlevel dielectric(ILD)/Si submicron interconnect structure. The diffusion barriers chosen for our study are TiN and W-N and ILD material is hydrogen silsesquoxane (HSQ).

The electromigration test were carried out with TiN/Al (600 nm)/TiN(30 nm)/HSQ/Si and TiN/Al(600 nm)/W-N(30nm)/HSQ/Si structures. These multilayer films were patterned with reactive ion etching and the length was 2000 µm and the line width was 0.6 µm. All the samples were annealed in argon at 450 °C for 30 min to stabilize the microstructure before testing. The wafers were tested on a vacuum hot chuck where the temperature was measured with a calibrated thermocouple buried in a hole etched in the Si. The current density used for testing 9 MA/cm^2 and the temperature ranged from 150 to 300 °C. The average temperature increase in the multilevel interconnect lines under the test due to Joule heating was estimated from the measured resistance changes as a function of temperature and current. The edge displacement were investigated using a scanning electron microscope.

Fig. 1 shows that the mean time to failure of TiN/Al/TiN/HSQ/Si is 21 hrs, whereas that of TiN/Al/W-N/HSQ/Si is 42 hrs. The activation energies of TiN/Al/TiN/HSQ/Si and TiN/Al/W-N/HSQ/Si are 0.12 and 0.14 eV, respectively. This means that the W-N is more reliable than TiN as a diffusion barrier. Fig. 2 shows that severe edge displacement due to the electromigration in Al deposited on TiN diffusion barrier. However, in the case of TiN/Al/W-N/HSQ/Si the edge displacement is not so serious as the case of TiN/Al/TiN/HSQ/Si. High resolution transmission electron micrograms for both cases reveal that the Al metal lines are changed to bamboo structure on TiN diffusion barrier under the high current density of 9 MA/cm^2 and Al hillocks are produced at the bamboo grain boundary. However, in the TiN/Al/W-N/HSQ/Si interconnect line, the bamboo structured Al metal lines are not observed. To explain the reason, we will discuss the correlation between the film stress of diffusion barrier and electromigration.

Reference

1. H. A. Le, N. C. Tso, and T. A. Rost, and C.-U. Kim, Appl. Phys. Lett. **72**, 2814(1998).

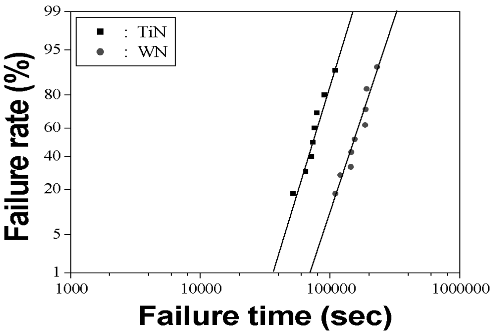
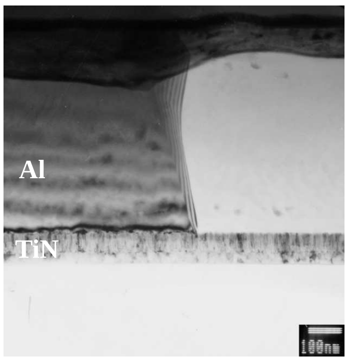
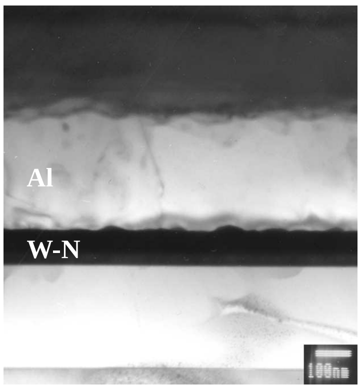


Fig 1. MTTF(mean time to failure) characteristics of TiN/Al/TiN/HSQ/Si and TiN/Al/W-N//HSQ/Si.



(a) Al/TiN/Si



(b) Al/WN/Si

Fig 2. Transmission electron microscopy of (a) Al/TiN/Si and (b) Al/WN/Si structures.