ELECTRICAL PROPERTIES OF TIN FILMS PREPARED BY PLASMA ASSISTED ATOMIC LAYER DEPOSITION USING TETRAKIS(DIMETHYLAMIDO)TITANIUM

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In microelectronic devices with deep submicron features, it is essential to use conformal processes for the deposition of diffusion barrier materials. TiN is at present the most widely used diffusion barrier material and adhesion layer in IC devices, due to its excellent barrier properties, high physical and chemical stability, and good electrical conductivity. Atomic layer deposition (ALD) for the formation of TiN films is of great attention, due to the self-limited nature which allow to control the film thickness very accurately and also achieve excellent conformality along with lowering the deposition temperatures compared to that in CVD. ALD of TiN films has been intensively studied recently using inorganic precursors, particularly titanium tetrachloride ($TiCl_4$). However, in the case of $TiCl_4$-based TiN ALD, the deposition temperature is considered still too high to be used in all the levels of IC metallization. [1-2] While, in the case of MO TiN ALD, although the issues of deposition temperature and chlorine contamination are resolved, high resistivity of the films remains a great drawback.[3] Therefore, in this work, we studied plasma assisted ALD (PAALD) processes using a metalorganic precusor, tetrakis (dimethylamido) titanium (TDMAT), to investigate the effect of plasma pulse time and power on the resistivity and stability of the TiN films in air. Also, the barrier effectiveness of the TiN films was evalusted.

The TiN films were prepared on Si substrates covered by SiO_2 (300 nm) in a vertical-flow reactor at the deposition temperature of 175 °C and 1 torr total pressure. Figure 1 shows a schematic diagram of the deposition sysytem. One deposition cycle consisted of exposure to the precursor, argon (Ar) purge, plasma pulse, and Ar purge. For all experiments, the pulse length of TDMAT and the Ar purge (300 sccm) time were 3 s and 35 s. The plams pulse time and the power were varied from 5 to 90 s and 50 to 250 W, respectively. Barrier performance of the TiN films to copper diffusion in the Cu/TiN/Si structure was evaluated by Secco etch test after annealing the test structure at 550, 650, and 750 °C.

As can be seen in table 1, the use of a longer plasma pulse and higher power improved the electrical properties, lowered resistivity and led to higher stability in air. The film growth rate (thickness/cycle) was in the range of 0.07 – 0.09 nm/cycle and the resistivity of the films varied from ~ 250 to 30000 μΩcm, depending on the plasma conditions. The step coverage of the PAALD TiN films deposited on contact holes of ~ 0.3 μm with an aspect ratio of 3:1 show excellent step coverage. (Fig. 2) The results of the etch-pit test show no evidence of copper diffusion after annealing at 550 °C. This is an improvement over the better barrier effectiveness of the films prepared by thermal ALD.

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Table 1. Stability of the PAALD TiN_x (~ 7.5 nm) films.

Plasma variables		Rs (ohm/sq) as-deposited	Rs (ohm/sq) air exposed- for 24 hr	△ Rs (%)
Power	pulse time			
Thermal ALD*		3810	93500	2350
125 W	5	15820	30800	95
125 W	20	1254	1504	20
125 W	60	366	396	8
50 W	20	4827	8320	72
250 W	20	445	491	10

* Thickness of the thermal ALD TiNx: ~ 30 nm

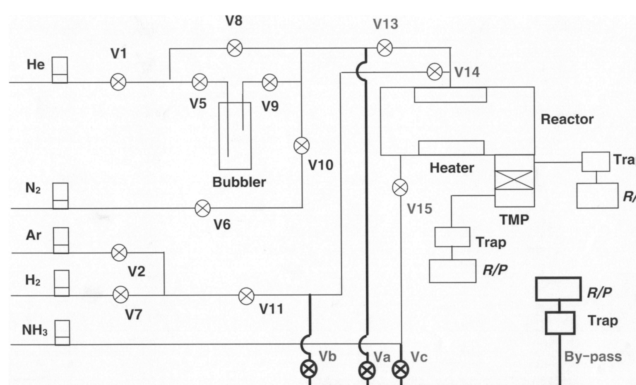

Figure 1. Schematic diagram of the PAALD TiN deposition system.

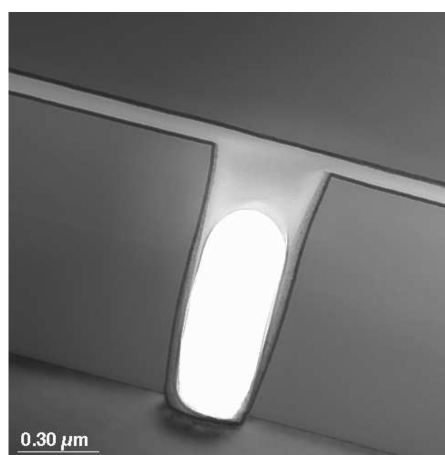

Figure 2. Conformality of the PAALD TiN film deposited using H_2 plasma of 250 W for 20 s exposure at 175°C.