A NEW ATOMIC LAYER DEPOSITION OF TUNGSTEN NITRIDE DIFFUSION BARRIER WITH NH_3 PULSE PLASMA AND WF_6 GAS

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Although W-N thin film has very excellent properties as a diffusion barrier for Cu interconnect technology, the W-N film has not been popularly used so much as the TiN since the W-N film has been deposited with plasma enhanced chemical vapor deposition (PECVD) [1-2] and then, this PECVD might provokes particle problem. In order to eliminate the particle problem, low pressure CVD (LPCVD) is necessary for depositing the W-N. However, it is very hard to deposit the W-N film with LPCVD method since vapor pressure of W-precursor is very low and W does not well react with N [3]. Furthermore, metallurgical and electrical properties of LPCVD W-N are very poor compared to those of the PECVD grown W-N [3]. Therefore, it is necessary to prepare very thin and thermally stable W-N diffusion barrier with an alternative method for Cu interconnect. In this work, we have suggested a new atomic layer deposition (ALD) method to prepare the W-N diffusion barrier with NH_3 plasma and WF_6 gas. In the conventional ALD process where WF_6 and NH_3 gases are sequentially exposed during the ALD cycles, WF_6 gas reacts with silicon very fast, causing a thicker W film till the diffusion of Si stops, and the adsorption of NH_3 gas might be blocked due to the fast reaction between the Si surface and WF_6 gas. As a result, the N concentration is not uniformly distributed but accumulated at the top of W-N film as shown in Fig. 1. In this new ALD method, we have applied a pulse RF power to the NH_3 gas during every cycle where the NH_3 gas is being introduced. This NH_3 pulse plasma modifies Si and SiO_2 surfaces to Si-N and Si-O-N surfaces, preventing the fast catalytic reaction of Si with WF_6 gas. Finally, the NH_3 pulse plasma leads to the adsorption of NH_3 on the Si and non Si surfaces. Therefore, the W-N prepared with NH_3 plasma and WF_6 gas has a uniform distribution of N concentration as shown in Fig. 2. The deposition rate is ~2.2 Å/cycle at 350 °C. High resolution transmission electron microscopy shows that 22 nm thick W-N thin film successfully prevents Cu diffusion during the annealing process at 600°C for 30 min. To use this W-N film as a gate electrode diffusion barrier to prevent the interdiffusion between gate electrodes (such as Poly-Si and Al) and high-k dielectrics (ZrO_2 and HfO_2), we have deposited the W-N on high-k dielectrics with the new ALD method and investigated the electrical characteristics of gate capacitors.

References

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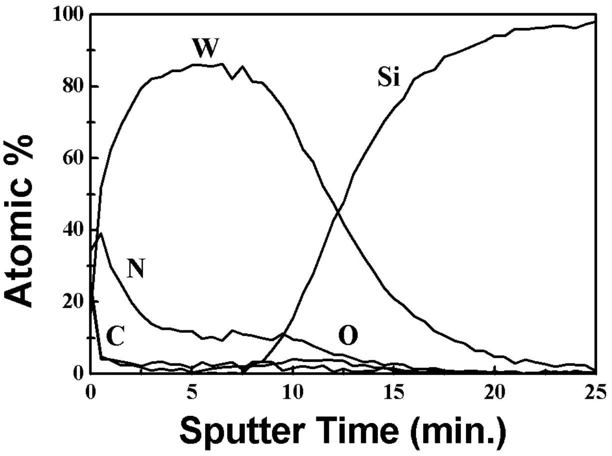

Fig 1. AES depth profile of W-N film deposited at 350 °C after 100 cycles by conventional ALD process.

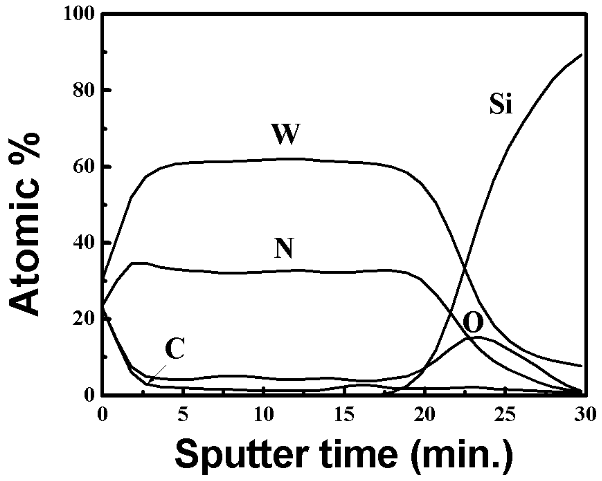

Fig 2. AES depth profile of W-N film deposited at 350 °C after 100 cycles using pulse plasma atomic layer deposition. The Si surface was treated by NH_3 pulse plasma.