Study of Copper Electrodeposition and its Inter-diffusion Properties on Ruthenium Metal Surface

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In the sub-0.13 µm generation of integrated circuits, copper (Cu) will completely replace aluminum as the new interconnect material due to its favorable electrical conductivity and its superior resistance to electromigration.[1] Improved electromigration resistance allows integrated circuits to operate at higher current densities and possibly at higher temperatures. IC chips fabricated with more conductive Cu interconnects and low-k dielectrics operate with less power and at significantly higher speed due to decreases in the interconnect RC coupling delay. The new dual-damascene patterning process[2] coupling with chemical-mechanical planarization[3,4] significantly simplifies Cu interconnect routing and lowers manufacturing costs. The most challenging aspect of implementing Cu interconnects for near-term CMOS applications beyond the 100 nm mode is the increasing difficulty with the overall process integration.[5] Shrinking dimensions demand an increasingly high-aspect-ratio of trench/via features that make PVD barrier/seed deposition and Cu electrofill more difficult.

Ruthenium has near twice the electrical and thermal conductivities as tantalum and tantalum nitride, i.e. currently used as the diffusion barriers for Cu interconnects. In this paper, we report the electrodeposition of Cu on Ru metal PVD deposited on silicon wafer surface. The Cu nucleation was found to begin at ca. 0.04 V vs Ag/AgCl in 50 mM $CuSO_4$ /0.5 M H_2SO_4. The I-V curve showed a mass transport limiting region at ca. -175 mV and H_2-evolution onset occurred around -400 mV. The nucleation and growth process of Cu on Ru was investigated using a current-transient electrochemical method and compared to SEM and AFM results. Preliminary results showed that the nucleation mode (progressive or instantaneous) was controlled by the overpotential. In addition, XRD patterns indicated heteroepitaxial growth of Cu on Ru with strong Cu(111) texture and no new phases or formation of bimetallic compounds between the Cu deposit and Ru substrate. The interface of Cu/Ru was investigated by XPS and Auger electron spectroscopy. The inter-diffusion of Cu /Ru after thermal annealing was studied by XRD and Time-of-flight SIMS. The potential application of Ru to function as a new Cu diffusion barrier will be discussed.

References

1) Murarka, S. P.; Verner, I. V.; Gutmann, R. J. "*Copper--Fundamental Mechanisms for Microelectronic Applications*"; Chapter. 1 and references therein, Wiley Interscience: New York, 2000.
2) J. M.; Murarka, S. P.; Gutmann, R. J. "*Chemical-Mechanical Planarization of Microelectronic Materials*"; Wiley Interscience: New York, 1997.
(3) Zhao, B, *"Method of making a damascene metallization"*;: United States Patent #5,736,457, SEMATECH, Austin, TX, April 7,1998.
(4) "*Damascene:optimized etch stop structure and method,"* IBM Technical Disclosure Bulletin **1993**, 36, 649
(5) Peters, L. Semiconductor International **2000**, 23, 25-26.