Ellipsometry Characterization of Copper Complex for Abrasive-free CMP Process

T. Saitoh, H. Nishizawa, J. Amanokura*
and M. Hanazono*
Tokyo A&T University, Koganei, Tokyo 184-8588, Japan
*Hitachi Chemical Co., Hitachi, Ibaraki 317-8555, Japan

Recently, CMP has become a prerequisite process for copper Damascene interconnection (1). In a conventional CMP with abrasives, there existed some drawbacks including scratches and over polishing of interlayer dielectrics. To solve the issues, abrasive-free CMP process was developed by forming a soft copper complex on copper layers using an organic acid and removing the copper complex with a rotating plastic pad as shown in Fig. 1.(2).

In this study, the structure of the copper complex was investigated using spectroscopic ellipsometry. Ellipsometry was carried out with a rotating analyzer system, VASE, of J. A. Woollam Co. which measures the complex ratio, ρ , according to the following equation.

$$\rho = \tan\psi \exp i\Delta$$

where ψ and Δ are the amplitude ratio and the phase difference. The ψ and Δ were measured as a function of wavelength in a spectral range of 250 to 1100 nm. Mean-square errors between measured and calculated data were minimized to investigate the optical structures of the copper complex. The copper complex layer was chemically formed by a reaction in an organic acid and hydrogen peroxide solution.

In Fig. 2, an example of measured and fitted Δ is indicated as a function of wavelength at three incident angles. Fitting of the curves are fairly good indicating that the thickness of the copper complex is 11.3 nm after a dipping time of 5 min. And, the extinction coefficient, *k*, of the copper complex is almost zero indicating the complex layer is transparent as shown in Fig. 3. Also shown in the figure is the spectroscopic refractive index, *n* , which tends to increase an a shorter wavelength region. The refractive index values are relatively lower than relevant oxide films of Cu_2O, CuO and organic films. It might suggest that the copper complex includes void and/or water which affects softening and polishing of the copper,

To investigate the reaction mechanism at the copper surface, the thickness of the copper complex was examined as a function of dipping time in the mixture solutions and different solutions. As indicated in Fig. 4, the growth of the copper complex consists of two reaction processes, i.e. first parabolic and subsequent linear processes. The parabolic process in the short time depends on the chemical combination of the organic acid and hydrogen peroxide. The subsequent linear process might be a kind of chemical deposition of a copper complex from the solution.

(References)
1. U. Landau, Proc. of CMP-IV, p.231 (2000)
2. S. Kondo, et. al., J. Electrochem. Soc. 147(10)3907-3913 (2000)

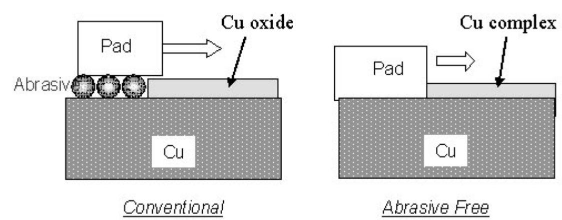

Fig.1 A polishing model of abrasive-free CMP process.

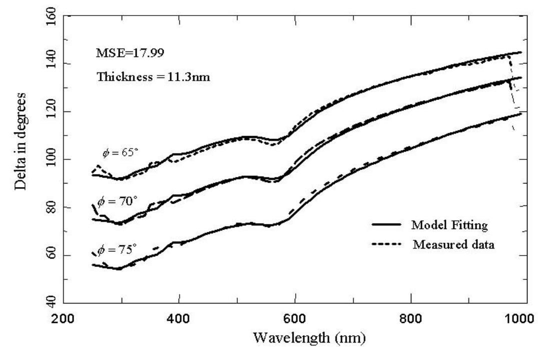

Fig.2 Measured and calculated Δ using for a copper complex during the abrasive-free CMP process.

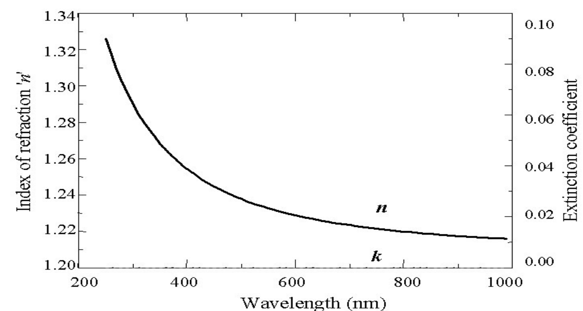

Fig.3 Index of refraction of copper complex analyzed using spectroscopic ellipsometry.

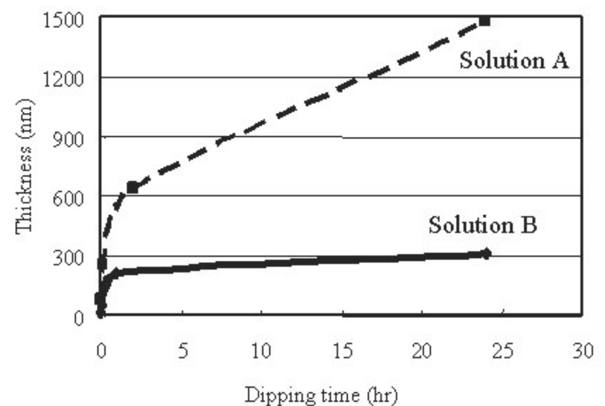

Fig.4 Growth of copper complex during abrasive-free CMP process.