Spectroscopic Ellipsometry Analysis of Nanoporous Low Dielectric Constant Films Processed via Supercritical CO_2 for Next-generation Microelectronic Devices

Maslina Tasrin Othman

Professor Shubhra Gangopadhyay, Dissertation advisor

ABSTRACT

My research will address issues at the back-end-of-line in microelectronics fabrication, specifically the need for Low-*k* extendibility. The International Roadmap for Semiconductors (2005) suggested that interconnect insulation must be replaced with a material having an ultra-low dielectric constant (*k*) of < 2.0 and can withstand rigorous current process integration for the 65 nm technology. Creating porosity in the films produces *k*-values as low (1.0) air. In this research, supercritical CO_2 ($SCCO_2$) process is utilized to create pores, remove water, repair plasma-damaged sample and seal pores. These multi-step processing does not only produce low-*k* film but also create device reliability. Spectroscopy ellipsometric (SE) analysis is used to evaluate the performance of each process on porous film. In SE analysis, Cauchy, Bruggeman Effective Medium Approximation and graded models are used to model the processed samples. The depth profile SE analysis demonstrates the individual process performance based on its changes of refractive index (*n*) throughout the film thickness. SE also provide important film properties like thickness, porosity etc. In addition to SE, Fourier Transform Infra-red (FT-IR), Scanning Electron Microscopy (SEM) and electrical characterizations are used. Results show that $SCCO_2$/co-solvents can extract porogens and remove water effectively

at a significantly shorter time (≤1 hr) and at a low temperature (≤160°C) without thickness shrinkage in contrast with thermal annealing which uses 450°C and 5 hours without significantly shrinkage. $SCCO_2$/TMCS removes water and terminates silanol group with methyl group, and hence preventing water re-adsorption which increases *k*. The dense layer on the sample surface that formed through the vapor treatment/HMDS helps to seal pores and prevent metal diffusion. This research also shows that patterning samples prior to porogen/water removal can minimize plasma damages on porous sample.