Supercritical CO_2 Post-Etch Cleaning of a Patterned Porous Low-K Dielectric
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Supercritical CO_2 ($SCCO_2$) cleaning of dielectric patterns has been recognized as a potential enabling technology for sub-100nm integrated circuit (IC) technology nodes.[1,2] Photoresist pattern collapse, due to capillary forces during drying after a deionized water rinse, has been shown to occur for features at or below 100nm in width. Pattern collapse is also possible for high-density patterns in low-k dielectrics subjected to a water rinse. In addition, integration of porous low-k dielectrics could pose a significant challenge for wet cleans, which typically use a water rinse. Entrapment of water in the pores of the dielectric can result in outgassing during subsequent processing steps, possibly leading to incomplete trench or via filling resulting in open circuits, or an increase in the dielectric constant. $SCCO_2$ processing allows post-etch cleaning and drying of dense, high aspect ratio, sub-100nm patterns without capillary forces.

The properties of supercritical fluids can aid in post-etch cleaning of IC patterns: diffusitivity like that of a gas - allowing penetration into small, high aspect ratio patterns; density approaching a liquid - yielding reasonable solubility of organic residues; and low surface tension – resulting in excellent “wetting” of surfaces. However, the solubility characteristics of $SCCO_2$ are similar to hexane. Typical ionic, inorganic dry etch residues are not very soluble in such a non-polar solvent like hexane; consequently, polar solvents are added to $SCCO_2$. The polar solvent is usually added to a co-solvent which is highly soluble in $SCCO_2$, such as an alcohol. Typical levels of polar solvent and co-solvent are about 5wt%. In addition, other additives containing fluoride or hydroxide can be included to increase the effectiveness for etch residue removal. The cleaning process involves penetration, swelling, and dissolution of the etch residue or photoresist. The inorganic etch residue can also be modified during the cleaning process to increase its solubility in a non-polar, organic solvent, like $SCCO_2$.

Scanning electron micrographs (SEM) for typical post-etch $SCCO_2$ cleaning results will be presented for a patterned, porous low-k dielectric. The impact of the polar solvent and co-solvent on etch residue removal was studied. Process times can significantly vary depending on the solvents used. Data showing the integrity of a porous low-k film after $SCCO_2$ processing will be presented. The film thickness loss was ~10Å The dielectric constant was reduced by about 6% compared to that for the as spun film, most likely due to a reduction of entrapped water. Thermal desorption spectra for pre- and post-processed films also showed a reduction in water content and no significant out gassing. The FTIR spectra showed no change. Lastly, several different methods to control the etch rate of dielectrics during $SCCO_2$ cleaning will be presented.

References:
1. N. Kawakami, K. Suzuki, Proceedings of IITC (2000).
2. 2. Y. Kikuchi, T. Fukuda, S. Shishiguchi, K. Masuda, and N. Kawakami, Proceedings of SPIE’s Microlithography Symposium, 4688-101 (2002).

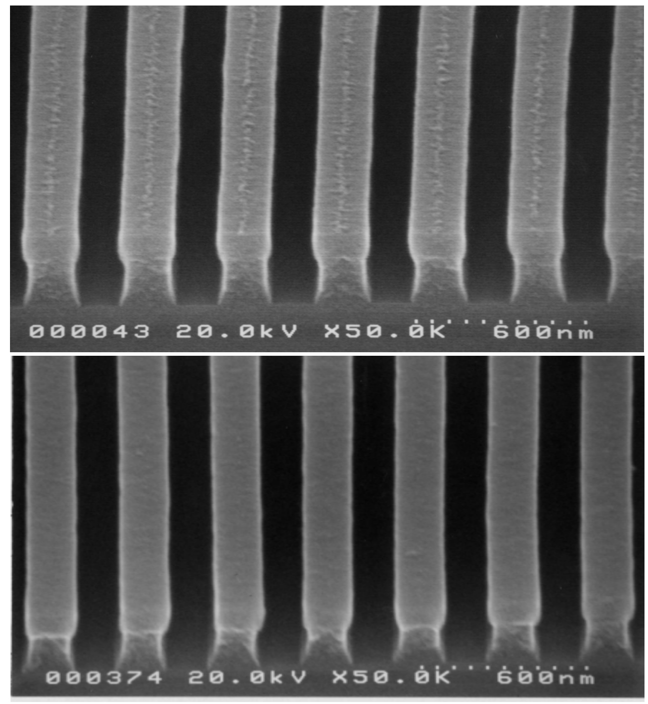

Figure 1. Before and after $SCCO_2$ cleaning SEMs of patterned, ashed porous low-k dielectric. Process included $SCCO_2$, DP6630-19A, and ethanol at 40°C and 15MPa.

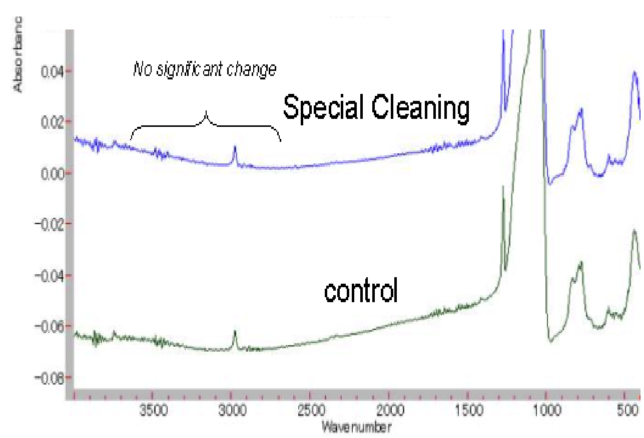

Figure 2. FTIR spectra of pre- and post-$SCCO_2$ processing for a porous low-k dielectric. No noticeable changes were observed in the spectra.

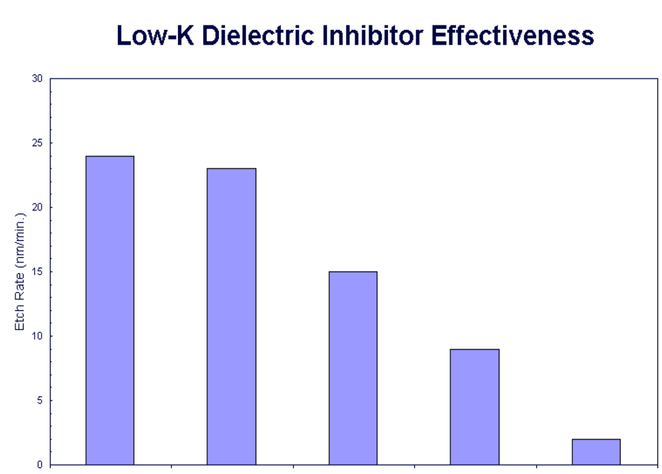

Figure 3. Effectiveness of an added “inhibitor” to minimize the etch rate of a porous low-k dielectric. An order of magnitude reduction in etch rate was achieved.