



CHAPTER III

LITERATURE REVIEWS

This chapter contains literature reviews of representative reports involving RIE-generated redeposit removal. Several researchers have reported the cleaning process improvements to increase the cleaning efficiency. The driving force behind these investigations have been the reduction of feature sizes; thus making the removal of the post-etch residue at sidewall and the bottom layer a critical issue in the fabrication of electronic device. There is also a rising trend in which to significant increase the etching time in order to create a deeper trenches accompanied by a more complex pattern design. This increase in etching time and complicated etch pattern also leads to an increase in post-etch residue formation along with an increase in cleaning difficulty, respectively.

Jonkook Song, Jong-Soo Kim, Hyungtak Seo, Yangdo Kim and Hyeongtag Jeon [2002] studied the removal of the polymer formed via hole with via etching stopped on an Al (VESA) layer structure. Double metal-organic polymer layers, with and without F, were found at the bottom of the via hole; while only a homogeneous single metal-organic polymer layer with F was observed at the sidewall. The layer at the sidewall cannot be removed by oxygen-based plasma ashing. An additional wet stripping process was required to completely remove the sidewall polymer and to realize uniform metal gap filling.

This study has shown the result of sidewall polymer removal by using different cleaning approaches. Wet stripping efficiency increased as the ashing temperature was lowered. A non-hydroxylamine (non-HA) based stripper removed the RIE-induced polymer more effectively than a HA based stripper regardless of the photoresist used. This study revealed that it is necessary to reduce the hardening of the polymer layer by lowering the ashing temperatures and to use a non-HA based stripper.

John J. Rosato [2000] demonstrated the effectiveness of wet immersion cleans employing advanced semi-aqueous solvent chemistries for use with Cu/low-k interconnects to remove the post etch residue for the hole and sidewall of device. A wide range of semi-aqueous solvent cleaning chemistries were evaluated for both cleaning efficacy and compatibility with the organic low-k dielectrics. A two-tank immersion cleaning platform was used for these experiments. The wafers were immersed in a filtered and re-circulated solvent bath for a recommended time and temperature. It is then transferred into a DI rinse tank and finally dried in an IPA vapor dryer. After processing, the wafers were stored under nitrogen, and subsequently processed through electrical test. For this dielectric, it was found both the ACSI ST-220 and EKC JFX139 solvents were the most effective cleaning processes.

Hong Young-tack, Yong Il Kim, Moon-chul Lee, Park Suhee, Shim Dongha, C.M. Park, Byungyou Hong, Yonghan Roh, Sung Hae Jung, Insang Song [2003] evaluated the post-etch residue removal after descumming BCB (Benzocyclobutene). The descumming process is necessary to remove the residue that remains after the developing process. O_2/CF_4 , in which the ratio of O_2 to CF_4 is 80:20, has been used as etching gas. There is noticeable post-etch residue after reactive ion etching (RIE) where the main composition was a mixture of Al, Cu, photoresist, and BCB as identified by the X-Ray Photoemission Spectroscopy (XPS) analysis. In other words, these could not be removed by O_2 ashing which is a general method to remove the residue.

This study tried a few chemicals to make the surface cleaning for the low contact resistance and found that the EKC chemical is very effective to cleaning via the surface. Best cleaning process is 10%Acetic acid + ultrasonic and EKC chemicals. EKC691B showed a better performance for residue removal than any other series because it contains higher concentration of NH_4F . In addition when operated at pH 8, the parts were found to be cleaner than at pH 6 – which showed a similar level of effectiveness at pH 7.

Denis Shamirayan, Mikhail Baklanov and Serge Vanhaelemeersch [2001]

investigated the surface cleaning after high-density plasma (HDP) dry etching. The following cleaning procedure was developed to clean the silicon surface after spacer etching. It included O₂-plasma ashing, HF dip and ammonia-peroxide mixture (APM) treatment. It was concluded that the oxygen plasma was responsible for removing the polymeric layer; HF removed the silicon dioxide which formed during previous step; and, finally, APM removed the damaged silicon layer from the substrate.

The insufficient cleanliness after moving etch process to HDP reactor can manifest itself, for example, in the slow re-oxidation rate after spacer etching and cleaning. This could lead to a bad device performance. It has also been found that a critical step in cleaning procedure was the plasma ashing. In this step, the best result has been obtained by adding an Ar beam to O₂ plasma. The subsequent wet steps has and less influence on the cleaning.

Nattaporn Khamnualthong [2007] evaluated the removal of post reactive ion etching (RIE) residue (redeposition) by using the NH₄OH solution from the magnetic recording (MR) head compared to the existing removal process of using the NaOH. The AlTiC substrate was etched by CF₄ gas to perform the patterning of the air bearing surface (ABS) on MR head. The residue has accumulated at the etched sidewall and need to be removed by using the proper solution without any impact to the electrical performance. The following cleaning procedure was developed to clean the MR head after RIE etching. The MR heads were immerse in

NH₄OH and scrubbing 4 min then transferred to DI rinsing and N₂ blow dry. The SEM images after removal process were taken and use for cleanliness comparisons.

This study has shown the removal of redeposition from RIE process by using the NH₄OH is lower than using of NaOH.

Nattaporn Khamnualthong and Chupong Pakpum [2007] evaluated EKC series solution for removing post-RIE residue in a joint collaboration with the EKC UK. In this study tried, several EKC chemicals were evaluated to clean the surface that has been etched by CF₄. The result has shown that the EKC06-255 was the best solution to remove the redeposition from RIE process from etched sidewall of MR head. EKC06-255 at 65 C were applied with agitation only, ultrasonic only, and combining both the agitation and ultrasonic. The result has shown that the redeposit were almost completely removed. However, the EKC solution has also severely corroded the read-write device. Further analysis has shown that the EKC solution will preferentially attack nickel – which is one of the major composition of the read-write element. Based on the result, EKC solution was deemed not suitable as a redeposit removal agent in the slider processing.

Berntand Lo, ChuChun Tai, Jia Yaw Chang, ChienHui Wu, BoJong Chen, Tzu-Chen Kuo, Pei-Jung Lian and YongChien Ling [2006] studied the green cleaning method involving oxidative degradation in supercritical carbon dioxide (scCO₂) to remove the polymer residue from the chlorine-based RIE. The ashing of the photoresist by Benzoyl Peroxide dissolved in pentane-2,4-dione was used as an oxidizing reagent to degrade the polymer residue. Random chain scission products from oxidative degradation was removed by scCO₂.

The results indicated that oxidative degradation by Benzoyl Peroxide in scCO₂ provided an effective alternative route to remove post-RIE polymer residue in semiconductor devices.

Satyanarayana Mynei, Dennis E.Hess [2005] studied the post plasma etch residue removal by using CO₂-based mixtures. High-pressure CO₂-based fluids have recently been proposed for post-plasma etch residue removal as an environmentally benign alternative to current liquid-based methods. Specifically, CO₂-tetramethylammonium bicarbonate (TMAHCO₃) methanol mixtures have been used to remove the photoresist residues from a CORAL low-dielectric constant film.

The primary cleaning mechanism appears to be attack of the interface between the residue and the capping layer by OH⁻ ions generated by dissociation of TMAHCO₃. Methanol promotes dissociation of the bicarbonate, while the role of CO₂ is promote diffusion of the additives to the interface.