TSV Cleaning using SAPS Megasonic Cleaning Technology

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Selected Topic: **Copper and low-k dielectric related cleaning and ashing issues for 3D and advanced interconnect**

Abstract

Through Silicon Via (TSV) process is emerging as a critical technology for scaling, packaging and continuing the drive to increase packing density and improve the performance of ICs. For a typical “via middle” TSV construction with the front-end-of-line (FEOL) transistor layer process, wafer is coated with photoresist, patterned and developed to expose via pattern on silicon. Silicon is then removed using a fluorocarbon plasma etch chemistry. Bosch etch is a typical method to yield a high aspect ratio via hole.

Formation of through silicon via interconnects using the Bosch etch process results in the deposition of a fluoropolymer etch residue on the sidewall of the vias. This residue has the potential, if not thoroughly removed from sidewalls, to inhibit sidewall passivation resulting in reduced device yield, and can be barrier layer delamination and increased thermal stress of the metal interconnect due to non-uniform sidewall profiles or copper voiding.

Typical method of fluoropolymer residue removal is to utilize dilute hydrofluoric acid (HF) and/or amine chemistries. It relies on chemical etching to remove and dissolve the sidewall residue. However, in critical dimensions, the sidewall residue removal is not high efficient and it will result in non-selective material corrosion in the completed device. In this study, the method of space alternated phase shift (SAPS) megasonic technology is applied for sidewall residue removal in post silicon etch cleaning. The SAPS technology provides uniformly sonic energy on each point of entire wafer by alternating phase of megasonic wave in the gap between a megasonic device and the wafer. The radicals for residue removal are generated in dilute solution, and the radical generation is promoted by megasonic energy. Furthermore, the mechanical force of bubble cavitations generated by megasonic also enhances the mass transfer rate and improves residue removal capability during the cleaning process is shown in Figure 1. As compared with typical method of fluoropolymer residue removal, SAPS megasonic technology advantage is high residue removal efficiency and low material loss for via with high aspect ratio. Furthermore, it is the minimal damage to structures.

Both theory simulation and experimental verification is studied. The megasonic simulations are worked by COMSOL Multiphysics. The results include megasonic energy intensity distribution inside TSV with different aspect ratio. It shows that the megasonic energy can propagate into bottom of TSV through dilute solution by this technology. For experimental verification, silicon test wafers were patterned and etched using a Bosch etch process to yield a fluoropolymer sidewall residue. Scanning electron microscopy (SEM) equipped with an energy dispersive x-ray

spectrometer (EDX) was used to detect the presence of fluoropolymer residue (i.e., C, F), pre- and post-cleaning by SAPS megasonic technology. SEM/EDX results on a TSV (aspect ratio=10:1) test wafer pre- and post-cleaning are shown in Figures 2 and 3, respectively. The results show that SAPS megasonic technology incorporating with dilute solution has a high cleaning efficiency for fluoropolymer sidewall residue removal in post silicon etch TSV cleaning process, while with the minimal damage to the structures and low material loss.

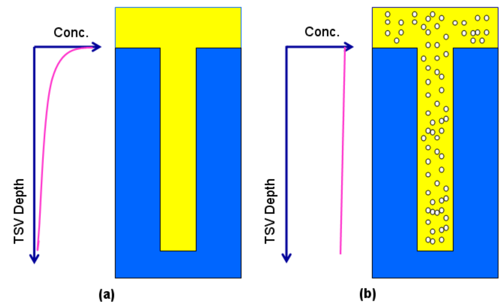

Figure 1. Bubble cavitations generated by megasonic enhance the mass transfer rate. (a) Chemical concentration in solution reduces with TSV depth at no megasonic effect. (b) Chemical concentration in solution almost doesn't change with TSV depth at megasonic effect.

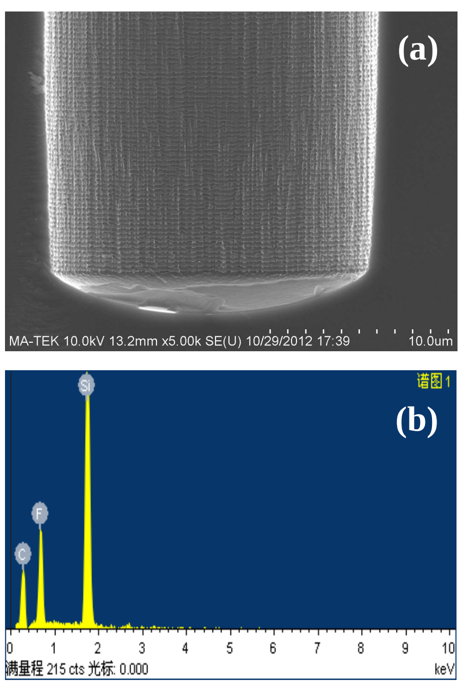

Figure 2. SEM/EDX inspection of via prior to cleaning by SAPS megasonic technology. (a) SEM of via cross-section showing fluoropolymer residue. (b) X-Ray spectra from SEM showing carbon and fluorine signature.

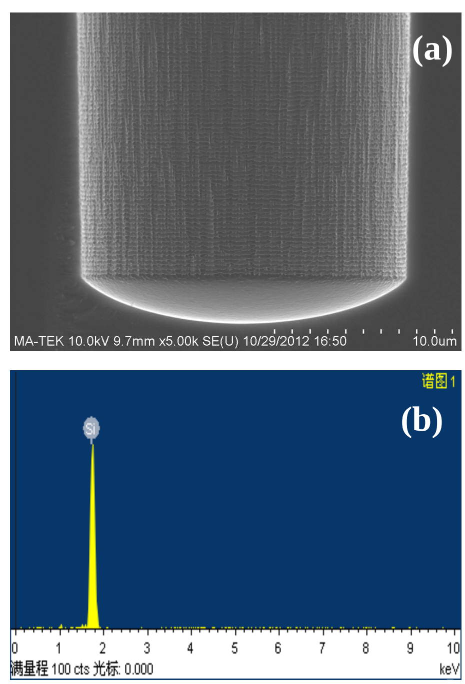

Figure 3. SEM/EDX inspection of via after cleaning by SAPS megasonic technology. (a) SEM of via cross-section showing clean bottom. (b) X-Ray spectra from SEM showing no carbon and fluorine signature.