Abstract—10um x 100um TSV was prepared by deep reactive ion etching process. Barrier and seed layer were deposited by physical vapor deposition process and prior to Cu electroplating, Ni was electroplated on seed layer. Cu electroplating was optimized for solid TSV filling. To remove excessive Cu on field area, chemical mechanical polishing process is used in conventional TSV fabrication process. In this study, new excessive Cu removal process was developed. Electroplated Cu and Ni had poor adhesion and this characteristic was applied to remove excessive Cu from Ni surface.

Keywords—through silicon via, electroplating, overburden

I. INTRODUCTION

To fill high aspect ratio of TSV, bottom-up filling is required, which is established in Damascene technology. But TSV is much larger in diameter and deeper in depth than Damascene structure. New electroplating process and chemicals are developed for TSV metallization. Major components of TSV electroplating chemical are Cu ion based on Cu sulfuric acid, chloride and additives. Three additives (suppressor, accelerator and leveler) are used and balanced concentration of electroplating chemical components enables bottom-up TSV Cu filling. While TSV is filled with Cu, wafer surface area also electroplated with Cu simultaneously. Excessive Cu so called Cu overburden causes wafer warpage during electroplating and annealing and it has to be removed by chemical mechanical polishing (CMP) for following process. Though electroplating chemical concentration is well balanced and optimum TSV Cu electroplating process is developed, 2-3um thickness of Cu overburden is formed on wafer surface including Cu seed layer. And usually larger TSV requires longer process time and electric charge. So overburden thickness could be thicker as TSV size becomes larger and longer CMP process causes high cost, longer process time and lower throughput. In particular, for via-last TSV technology that wafer has warpage after temporary bonding for backside process, thick Cu overburden worsen wafer warpage causing non-uniform CMP. Cu residues between TSVs make electrical short failure and further CMP process can damage dielectric liner and hard mask exposing bare Si wafer.

A few approaches were tried to remove or reduce Cu overburden. Cu overburden can be removed by isotropic wet etching using diluted sulfuric acid and hydrogen peroxide (dSPM). In this method, TSV Cu was not damaged because Cu hump at TSV and Cu overburden on wafer surface have different Cu height [1]. Very thin Ta deposition on top of seed layer so called Ta-flash also can be used to reduce Cu overburden. This method is to inhibit Cu electroplating on Ta because of overpotential difference between Cu electroplating on Cu and Cu electroplating on Ta [2].

In this study, we suggested new approach to remove Cu overburden for TSV Cu electroplating process. Some materials make natural oxide on it when exposed to air and deposited film on these materials has weak adhesion because of native oxide. This surface oxide is not preferred in thin film and metallization process and thus chemical removal or Ar sputtering process is applied to remove oxide layer. But adhesive properties of native oxide can be utilized for TSV Cu electroplating. Weak adhesion between films can provide easy removal of films. Ni was electroplated on seed layer and its adhesion to electroplated Cu was evaluated.

II. TSV FABRICATION

Fig. 1 shows the conventional TSV fabrication process. Hard mask with 200 nm thickness was deposited at 400°C and photoresist with 6um thickness and glh-line process were used for TSV lithography. TSV was formed by deep reactive ion etching (BOSCH process) followed by 8kA dielectric liner oxide deposition for electrical isolation. 2kA Ti as barrier layer and 8kA Cu as seed layer were deposited by physical vapor deposition (PVD) process. Cu electroplating is carried out to fill TSV structure, followed by Cu annealing. Excessive Cu on wafer surface is removed by CMP.

Figure 1. Conventional TSV fabrication process
In Fig. 2, TSV fabrication process was nearly identical to conventional TSV fabrication process. After barrier and seed layer deposition, material with native oxide can be deposited by PVD, CVD and electroplating process. In this study, Ni was electroplated prior to TSV Cu electroplating. Constant direct current at 3ASD was applied to deposit conformal 2kA Ni layer along wafer surface. Cu electroplating process was applied for TSV metallization. Stepwise increasing current and TSV chemical with three additives were used for bottom-up TSV filling. After TSV Cu electroplating, Cu layer on wafer surface can be easily removed resulting in no Cu overburden and no Cu residue on wafer surface.

III. RESULTS

A. Cu removal test

While electroplated Cu and Ni have poor adhesion, continuous and mirror-like Cu film was formed on wafer surface without any defects such as entrapped air or crack (Fig. 3(a)). Kapton adhesive tape was used to test adhesion between electroplated Cu and Ni. After attaching Kapton adhesive tape on wafer surface, it was slowly pulled at about 5cm/sec rate. As can be seen in Fig. 3(b), electroplated Cu was easily peeled from Ni surface. Remained Cu was also easily removed as a Cu foil without applying strength. After electroplated Cu peeling, Cu residue was not shown and only clean Ni surface can be seen (Fig. 3(c)). Cu seed layer at wafer edge exclusion zone was remained because Ni and Cu were not plated at this zone.

B. TSV electroplating

Fig. 4(a) is the microscope image of TSV after barrier/seed layer deposition. Wafer has bright and mirror-like Cu film deposited on wafer surface.
like surface. After 2kA Ni electroplating at 3ASD, wafer shows rougher surface than barrier/seed layer (Fig. 4(b)). It's because Ni chemical in this study was optimized for low stress film which doesn't include additives like leveler and brightener. Stepwise increasing current from 0.02ASD to 0.2ASD was applied for TSV Cu electroplating. Compared to conventional TSV electroplating, Fig. 4(c) shows rough surface due to rough Ni surface with 0.5um Cu protrusion. Cu film at filed area were removed by Kapton adhesive tape. There is no Cu residue on wafer surface and interface between TSV and wafer filed area is clear.

To fill up TSV, normal electroplating condition was applied and result is shown in Fig. 5. In X-ray image, TSV center is slightly brighter than another area, which means TSV has small voids. It could be because of electrical conductivity difference of Ni and Cu seed layer. In normal TSV electroplating, current pass through Cu seed layer. But in this study, Ni which has lower electrical conductivity than Cu seed layer, is plated on barrier and seed layer prior to TSV Cu electroplating. It seems that overpotential change caused by Ni resulted in void defect formation in TSV. Electroplating parameter were optimized for defect-free TSV filling.

IV. CONCLUSION

10um x 100um TSV was prepared by conventional TSV fabrication process consisting of 2kA hard mask, deep Si etching for TSV formation, barrier and seed layer deposition. Material with native oxide can be deposited on
Cu seed layer by PVD, CVD and electroplating. Electroplated Ni was used in this study. Subsequent TSV Cu electroplating was carried out using stepwise increasing current from 0.02ASD to 0.2ASD. Native Ni oxide provides weak adhesion to electroplated Cu on wafer surface. And electroplated Cu can be easily removed from wafer surface. This approach has advantages of easy Cu overburden removal, no residual Cu on wafer surface resulting in no electrical short failure between TSVs and cost effectiveness to shorten CMP process.

REFERENCES


