A Novel TSV Etching using NLD and VHF CCP Plasma For 3-D Stacked Devices.

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Abstract

In this study, the etch development of high etch rate and high aspect ratio for the fabrication of various diameters of thru silicon via is described. There are a lot of applications about TSV's methods. There TSV need to meet strict requirements with respect to high etch rate, sidewall roughness and undercut. For diameter of vias down to 10um a SiO2 hard mask based SF6/O2 etch approach is used by magnetic neutral loop discharge plasma (NLD plasma). This system can be used for oxide etching and Si etching. In the case of oxide etching, some magnetic coil currents are applied to generate magnetic neutral loop in the vacuum chamber in order to high density plasma in the low pressure below 1 Pa. On the other hand, in the case of Si etching, the pressure is raised up to 2~10 Pa. As a result, an etched profile of TSV with diameter of 1.5 um and the etched depth of 11.5 um, aspect ratio is 7.6, was achieved. The etch rate is about 4.5 um/min. For diameter of vias up to 10um, a resist mask based and SF6/O2 etch approach is also used by very high frequency coactivity coupled plasma. VHF CCP etching system was used to high-pressure process, more than 50Pa, as a purpose to high etch rate of up to 10um pattern's TSV etching. As a result, a vertical profile of TSV with diameter of 50 um and the etched depth of 50 um, aspect ratio is 1.0, was achieved. The etch rate is about 45 um/min. NLD and VHF CCP processes are non-cycle etch methods, and to successfully smooth pattern TSV.

Keywords: TSV, DRIE, plasma

Advanced NLD Plasma Etcher

The high-density of thru silicon via (TSV) is indispensable to the utilization and improvement in performance of 3D-LSI. Advanced high aspect ratio TSV etching technologies are required for high-density TSV formation. We have developed a new etching system for TSV application. This system is a planer type magnetic neutral loop discharge (NLD) plasma[1~3], which is named as advanced NLD (fig.1). For high rate silicone etching, it is very important to understand not only the high density of the plasma generation but also the high density of fluorine atoms. In this study, a novel RF antenna 'Multi Stacked rf

Antenna' has also been developed for the purpose of high rate etching. This antenna consists of multistage spiral turn rf antennas to reduce self-inductance (L), and is increased from turn of spiral to extend the inductive coupling discharge region. The L feature of this antenna is 0.95 uH and it is a low L antenna compared to the standard spiral antenna (1.7uH). As a result of performing the electron density measurement of the NLD plasma using this MS antenna, it succeeded in the high-density plasma production of $1x10^{12}$ / cm^3 by the process pressure of 7 Pa (fig.2). Next, the Si etching process development was performed using the advanced NLD etcher. Si etching characteristics employing advanced NLD plasma were studied with respect to distance from an antenna. As a result, the etching rate improved 4 times more compared to the standard NLD. Finally, the diameter of 2.0 um was attained by the anisotropic etching of 8.5 um/min, and the aspect ratio is 7.0 using the advanced NLD etcher (fig.3). The advanced NLD etcher has also dielectric materials etching process. High performances of TSV device have higher etch rates and more complicated hetero-film stacks. NLD etcher carried silicon and oxide stack etching in one chamber, and provided the lowest cost processes (fig 4).

Ultra Self-Confined VHF-CCP

Thru silicon via (TSV) etch process for deep and high-aspect ratio structure has been studied thoroughly for applications such as MEMS devices. Recently, TSV used in 3D-LSI devices, the via diameter and depth would be several tens of microns, and, the package for CMOS image sensors using TSV may have via diameters and depths up to 100 microns. A diameter of above 50um account for 50 % of TSVs. Therefore, development of high etch rate about 80um via is very important for realizing these applications. In this study, a large via size of 50 um etching in a high-pressure process was focused by using very high frequency capacitive coupled plasma (VHF –CCP) with an ultra self-confined system (Fig. 5). This plasma system is simple parallel plate CCP. And the cathode has a structure designed to minimize the stray capacitance (Cs) and impedance (L) to get a high-pressure process of about 100Pa or more. High-pressure process was carried out on the plasma confined, because mean free pass is very short. And, ion energy distribution (IED) is also controllable by low-presser process with VHF bias[4,5]. The bimodal IED changes under high-pressure. The peak of high-energy side is reduced, and a charge exchange peak appears (fig.6). It is considered that the charge exchange is important to anisotropic Si etching with VHF bias. Finally, an etch rate of more than 70 μm/min was realized (fig.7, fig.8). Figure 9 shows optimum etched feature profile of by Ultra Self-Confined VHF-CCP system. It was found that the Si etch rate depended on fluorine radical density and ion energy distribution, so, the high rate was obtained by creating a high fluorine radical density condition by using a high pressure condition of 100Pa using a VHF-CCP reactor with an ultra confined system and SF_6 gas chemistry.

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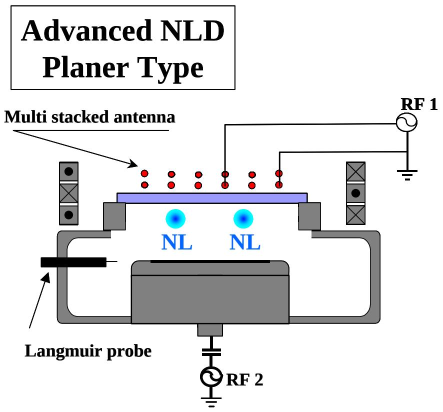

Fig. 1 NLD etching system

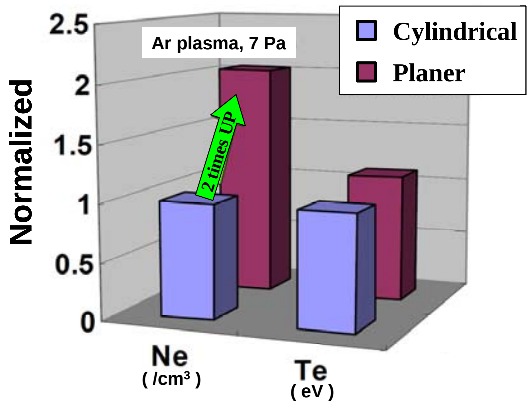

Fig. 2 The electron density and electron temperature in NLD plasma.

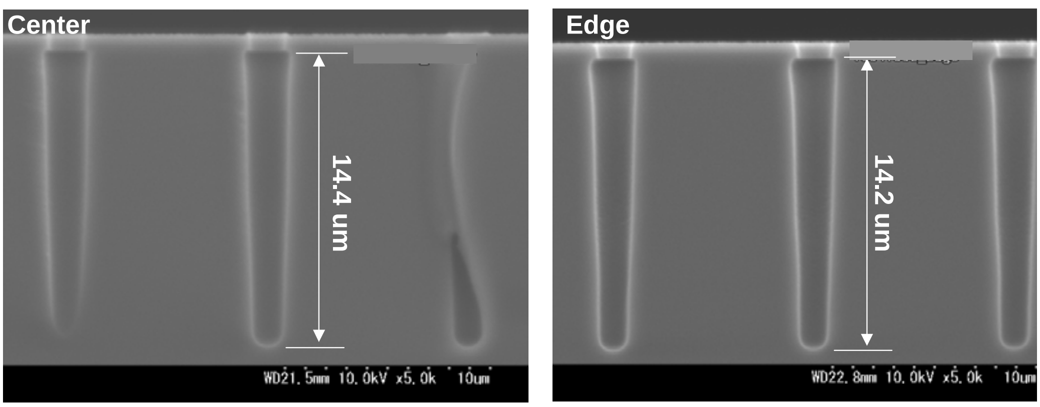

Fig. 3 TSV etching using the advanced NLD for 3D-LSI.

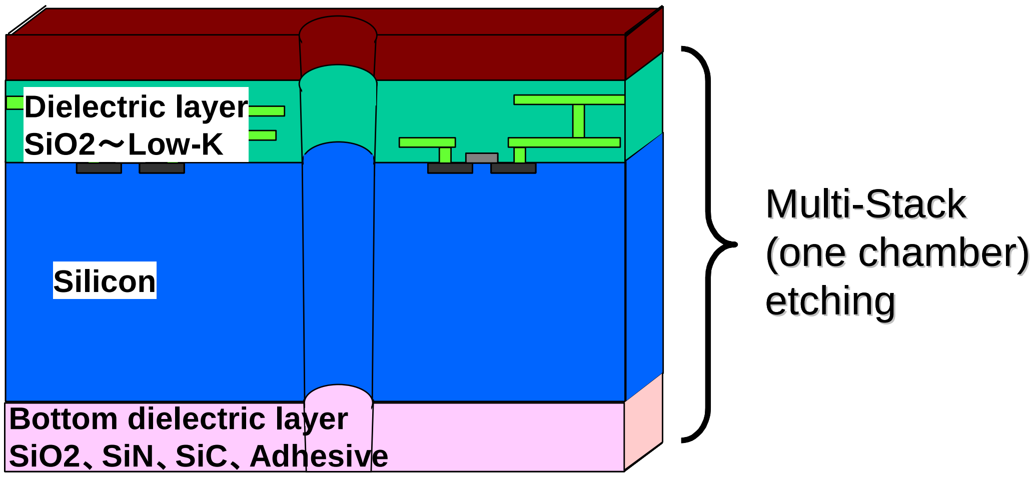

Fig. 4 NLD etching approach.

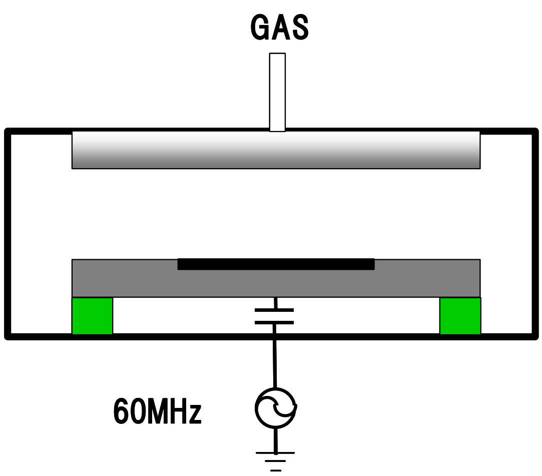

Fig. 5 VHF-CCP etching system

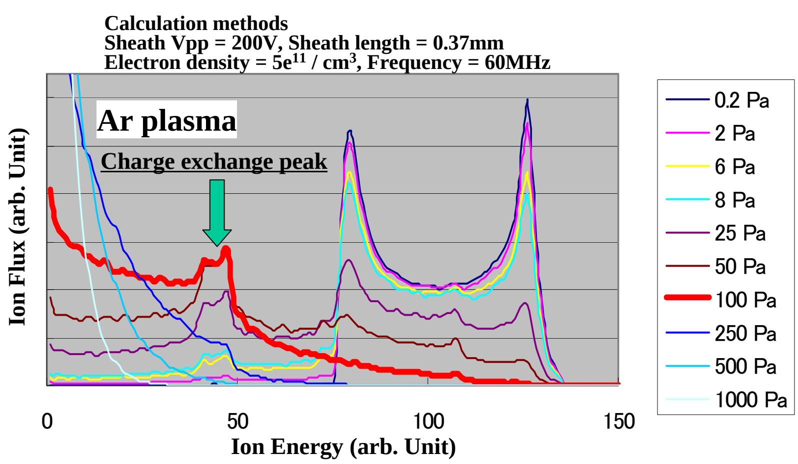

Fig.6 IEDs calculated at the different Ar pressures.

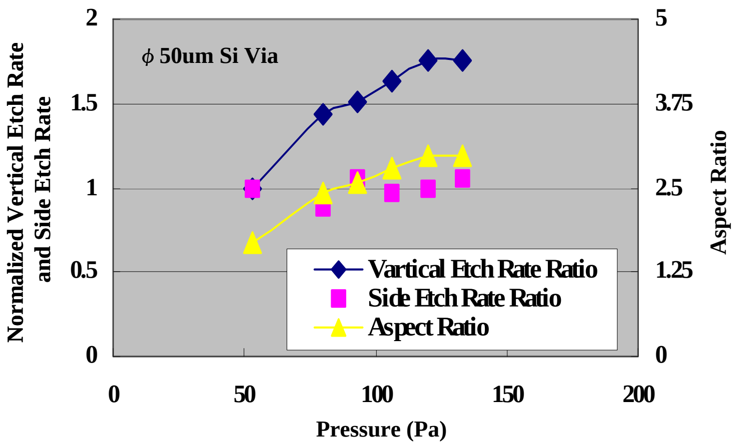

Fig.7 IEDs calculated at the different Ar pressures.

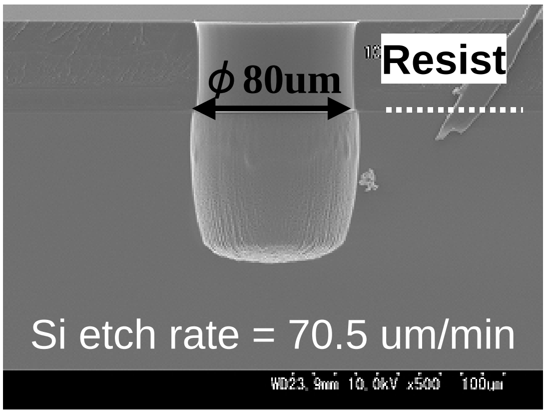

Fig. 8 High etch rate process for CIS and WLP.

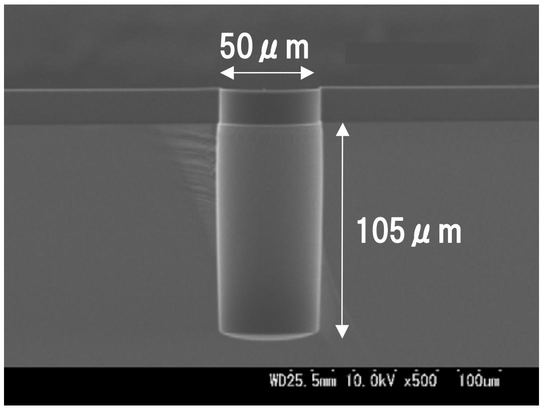

Fig. 9 Large Via photo resist process.

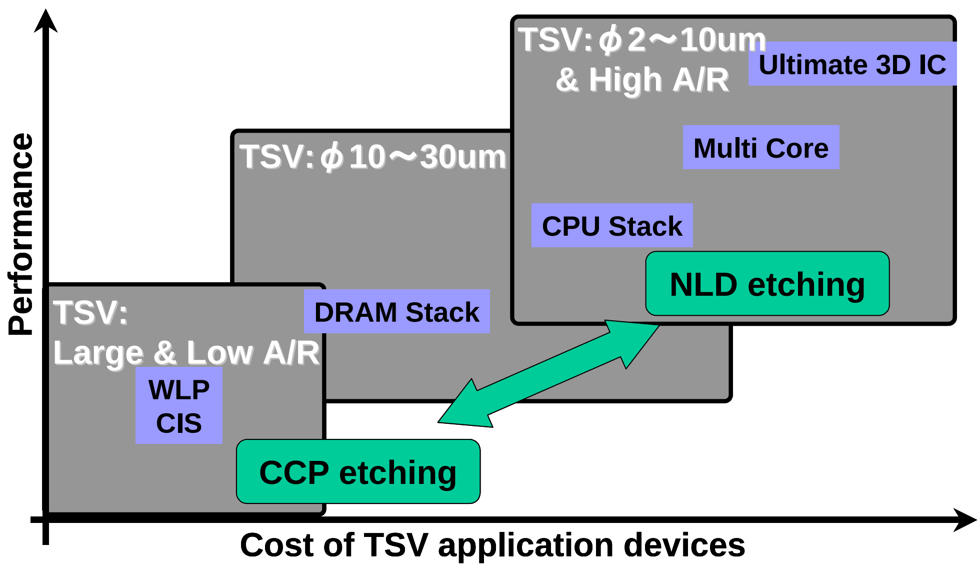

Fig. 10 A Novel TSV Etching using NLD and VHF CCP Plasma for 3-D Stacked Devices.