Novel Dry Cleaning Using Si$_3$H$_4$ with the New Single-Wafer Reactor

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In recent ULSI technology, low temperature process has been playing important role obtaining high speed performance of the devices. Several methods were proposed to obtain low temperature epitaxial growth, but still use hydrogen prebaking in temperature of 900 °C [1].

We have succeeded in the development of a novel dry cleaning technique by using Si$_3$H$_4$ as pretreatment gas under low-pressure (4 Torr) and low-temperature (820 °C) with the new single wafer reactor without special treatments such as UV-light irradiation or plasma enhancement.

Figure 1 shows the new single-wafer reactor we developed, has the advantages of flexibility and controllability. The ejection head is formed from an inverted conical housing whose open end is covered by a circular perforated plate. Wafer is placed on a resistance heating susceptor of SiC coated graphite. Figure 2 shows the growth sequence. Wafer was treated with 2% HF solution. Si$_3$H$_4$ treatment of 1 minute was done under the condition of Si$_3$H$_4$ 0.8 SCCM, H$_2$ 4 SLM, 4 Torr, and 780-820 °C. Then, epitaxial layer was grown under the condition of Si$_3$H$_4$ 1.6 SCCM, H$_2$ 4 SLM, 4 Torr, and 780 °C.

Figure 3 shows surface morphology of the obtained epi-layers observed by Nomarski microscope. Without Si$_3$H$_4$ treatment (a), very rough surface was observed. With Si$_3$H$_4$ treatment (b,d), smooth surface were observed and defect was decreased with increasing in the treatment temperature. Treatment temperature of 820 °C is resulting in low defect density level.

Figure 4 shows the results of SIMS analysis of these films. Figure 3 (a) ~ (d) are corresponding to Fig. 4 (a) ~ (d). From Fig. 4, oxygen and carbon existed at the interface between deposited Si layer and substrate in case of no Si$_3$H$_4$ treatment. Increasing in Si$_3$H$_4$ treatment temperature, oxygen and carbon were reduced and were almost negligible at 820 °C.

From these results, it is apparant for the first time that Si$_3$H$_4$ treatment of 820 °C have oxygen and carbon removing ability. Cause of this ability is considered as reduction reaction between native oxide including carbon contamination and Si$_3$H$_4$. Si$_3$H$_4$ treatment can reduced pretreatment temperature from 900 °C to 820 °C with our new single-wafer reactor.

Our new single-wafer reactor and low-temperature process is advantageous for production of future high performance ULSIs.

Si$_3$N$_4$ Treatment: Si$_3$N$_4$, 0.8 sccm, H$_2$ 4 slm, 780-820°C, 4 torr, 1 min
Growth: Si$_3$N$_4$, 1.6 sccm, H$_2$, 4 slm, 780°C, 4 torr, 20 min

Fig. 1 The new single-wafer reactor

Fig. 2 The growth sequence

Fig. 3 Nomarski microphotographs
(a) without Si$_3$N$_4$ treatment, (b) Si$_3$N$_4$ treatment at 780°C, (c) Si$_3$N$_4$ treatment at 800°C, and (d) Si$_3$N$_4$ treatment at 820°C.

Fig. 4 SIMS profiles of the obtained films