Control Contaminations of Supercritical CO_2 Drying Process for Nano-scale Memory Manufacturing

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Introduction

The design rule of the recent memory device is rapidly shrinking. In particular, preventing the pattern collapse in drying process is the most critical task for controlling defects because high aspect ratio nano-scale structures can be large enough to cause pattern collapse.
The drying technology using supercritical CO_2 fluid has been investigated in order to apply it to a semiconductor manufacturing process for years because of its excellent properties such as zero surface tension, inert gas and easy to handle it [1, 2, 3].
However, there are many technical problems to apply supercritical CO_2 drying process with controlling nano-scale defects to a 300mm wafer manufacturing.
In our study, a large number of particles were detected on a 300mm wafer by supercritical CO_2 drying processing. The process control of particles and defects on nano-scale is necessary to achieve high yield of the memory device manufacturing. The authors aimed at supercritical CO_2 drying process enabling particle control of less than 40nm size in order to apply it to 300mm wafer memory manufacturing.

Experimental

300mm wafer process was performed by using supercritical CO_2 supply system which has purification unit of CO_2 gas. Supercritical CO_2 supply flow was shown in Figure.1. The 300mm vessel chamber was adjusted 10MPa at 50 degree Celsius at the supercritical-phase of CO_2. The CO_2 cylinder prepared 4N(99.99%) grade (Showa Denko Gas Products Co., Ltd.). 300mm bare-Si wafer <100> was prepared in the vessel, and processed by supercritical CO_2 fluid at constant process time. The number of particles on the wafer was measured by Surfscan SP3 (KLA-Tencor).

Results and Discussion

Figure.2 showed particle counts on the wafer at over 38nm size in case of supercritical-phase CO_2 processing and gas-phase CO_2 processing. It found that the number of the particles on the wafer differed from lot to lot of the CO_2 cylinders. However, these particles were mostly removed by O_2 plasma ashing at 250 degree Celsius. On the other hand, the number of the particles with gas-phase CO_2, without changing supercritical-phase CO_2, did not increase. The results showed that the wafer was contaminated by organic substances (oily matters, unsaturated organic substances) transported with high-density liquid-phase CO_2 and supercritical-phase CO_2 from CO_2 raw materials. Commonly, organic substances in the raw materials CO_2 cylinders were contaminated at CO_2 production process, and the residues of the organic substance in the CO_2 cylinder varied from CO_2 manufacturers. About contamination problem of the organic substances in the CO_2, we succeeded to supply extremely purified CO_2 by optimizing the adsorbent of the CO_2 purification system, and achieved decreasing nano-size particles on the wafer post supercritical CO_2 processing. Even though low-grade CO_2 were used, it can be performed eliminating nano-size particles.

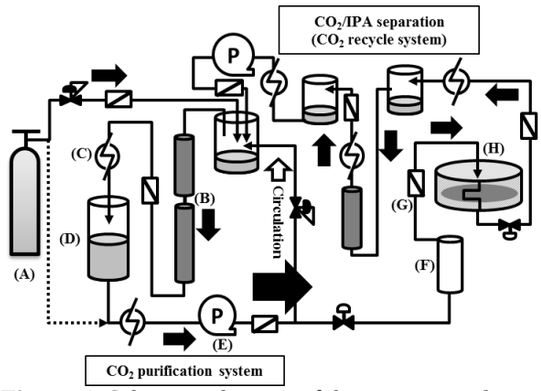

Figure. 1 Schematic diagram of the experimental setup for Supercritical CO_2 drying. (A) CO_2 cylinder; (B) Absorbent; (C) Chiller; (D) CO_2 tank; (E) Pump; (F) Pre-Heater; (G) Final filter; (H) 300mm wafer chamber.

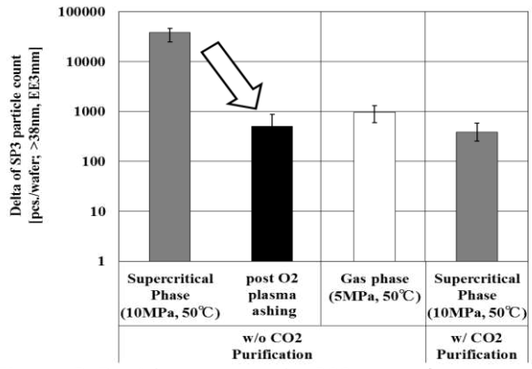

Figure. 2 Particle counts on the 300mm wafer post processing with supercritical-phase or gas-phase of CO_2.

Regarding metallic contamination with supercritical CO_2 drying, especially iron (Fe), nickel (Ni) and chromium (Cr) contamination on the 300mm wafer from stainless steel was able to prevent by aging continuously with supercritical alcohol fluid at high temperature.

Conclusions

Particle contaminations on the wafer post supercritical CO_2 drying process was found to depend strongly on organic substances from the raw materials CO_2 cylinder. We have successfully shown that supercritical CO_2 drying process with CO_2 recycle-purification system can be achieved in the nano-scale memory manufacturing.

References

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