FURTHER REDUCTIONS IN THE COST OF CLEANING CVD CHAMBERS: OPTIMIZATION OF REMOTE NF_3 PLASMA PROCESSES

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INTRODUCTION

Increasingly, NF_3 is the process gas of choice for cleaning CVD chambers. Use of NF_3 essentially eliminates PFC emissions, enabling semiconductor manufacturers to achieve their PFC reduction targets. In addition to near-zero PFC emissions, remote NF_3 plasmas exhibit faster clean times, and less chamber damage than traditional in situ PFC plasmas. The combined environmental and process benefits, which cannot be achieved with traditional fluorocarbon-based (e.g., C_2F_6, C_3F_8, c-C_4F_8, and C_4F_8O) processes, have driven the development of NF_3-based chamber cleans.

BACKGROUND

In an effort to further reduce the cost of cleaning CVD chambers, we have optimized an Applied Materials' Producer BPSG clean process. Optimization involves identifying those processes having lower gas usage, yet which effectively clean the chamber in the same amount of time. Previous experience with C_2F_6-based chamber cleans show there are opportunities to reduce PFC usage for production processes.

FINDINGS

Our strategy is to measure response surfaces for the gas usage and clean time as a function of NF_3 flow rate (1000 to 2000 sccm), Ar/ NF_3 ratio (0.75 to 1.25), and pressure (1.0 to 4.0 torr). Quadrupole mass spectrometry (QMS) was used as a process monitor since there is no F atom emission downstream of the remote plasma source. These QMS measurements were made at the CVD chamber for fast response time. Clean times are determined from the F_2 and SiF_4 concentration profiles.

Examination of the response surfaces shows that faster clean times are favored by higher NF_3 flow rates, higher Ar/ NF_3 ratios, and lower pressures. NF_3 usage, however, is insensitive to NF_3 flow rate and Ar/ NF_3 ratio (except at the lowest NF_3 flow rates and Ar/ NF_3 ratios). This is because lower NF_3 flow rates result in longer clean times (at constant pressure and Ar/ NF_3 ratio): NF_3 usage is the product of flow rate and clean time. Within the NF_3 flow rate and Ar/ NF_3 ratio space, therefore, the NF_3 usage surface is flat because the reduced flow rate is balanced by an increase in the clean time. NF_3 usage is primarily controlled by the pressure: lower pressures result in reduced NF_3 usage.

The sensitivity of NF_3 usage and clean time to the process parameters suggests that faster cleans using less NF_3 are possible by increasing the NF_3 flow rate, increasing the Ar/ NF_3 ratio, and lowering the pressure. There are, however, limits on the conditions that can be achieved with the Producer CVD chamber. Because the pumping speed is limited, the base pressure (i.e., throttle

valve fully open) increases with higher total gas throughput (i.e., higher NF_3 and Ar flow rates). There is therefore a trade off between pressure and total flow rate.

SUMMARY

Processes were identified that reduce NF_3 usage by 23 % with no impact on the clean time. Alternatively, the chamber can be cleaned 25 % faster using the same amount of NF_3 as the baseline process. Remote NF_3 plasma technology and process optimization are important strategies to reduce emissions and provide lower cost of ownership for future semiconductor processing.