High Throughput Stress-Controlled Silicon Nitride Deposition for Compound Semiconductor Device Manufacturing

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Silicon nitride (SiN_x) is perhaps the most widely used film prepared by plasma-enhanced chemical vapor deposition (PECVD) in III-V and III-N compound semiconductor manufacturing. The excellent electrical, dielectric, and ceramic-like properties of SiN_x prepared by this low temperature technique is responsible for its inclusion in many different areas of device manufacture. The use of SiN_x has extended beyond its traditional application as a surface passivation layer. Some newer and now established applications include hermetic encapsulation, electrical isolation, and as a capping layer for thermal annealing. In addition, the large dielectric constant of SiN_x makes it attractive as the dielectric in metal-insulator-metal capacitors used in high frequency RF GaAs devices.

As the demands for higher volumes in compound semiconductor device manufacturing increase, higher throughputs and lower cost of ownership are consequently sought from key processing equipment including PECVD reactors. To meet this requirement for PECVD, higher film deposition rates and more efficient automated plasma cleaning of the deposition reactor are essential. Also essential is the preservation of both the film quality and the ability to tailor the film properties such as film stress in the new higher deposition rate process regime. The ability to control the SiN_x film stress is extremely important both for device reliability and device performance. In this paper, we present results on new development work to address all of these requirements.

In a previous paper in this conference series, we reported on the He dilution technique to control stress of SiN_x in a production batch PECVD reactor[1] at deposition rates up to about 200 Å/min. Through the addition of He dilution gas to the standard admixture of SiH_4, NH_3, and N_2, the stress of SiN_x can be controlled from tensile through zero to compressive. In the present work, this He dilution technique has been further developed to extend stress control of SiN_x up to deposition rates in the range of 1200 Å/min and higher. All the development work was done on a commercially available PECVD production reactor of conventional parallel plate design with a high power 13.56 MHz RF excitation source. The system was configured for single 150mm wafer handling. As illustrated by the example in Figure 1, successful stress control of SiN_x over the range from about 0 to -500 MPa, compressive has been achieved at a deposition rate of 1200 Å/min.

The second part of the work to be presented in this paper focused on improving the efficiency of the automated plasma clean process. Plasma clean chemistries of SF_6/N_2O and NF_3 were investigated. From a parametric investigation of the process conditions, RF power was identified as the key parameter for plasma clean rate. Figure 2 shows the clean rate as a function of RF power for the two chemistries. In both cases doubling the RF power from standard plasma clean power of 600 Watts reduces the clean time by a factor of 2. Higher power combined with the use of NF_3 show further improvements in clean rate compared to the standard SF_6/N_2O chemistry and it presents an alternative option for a production environment aiming for high throughputs and cost reduction.

Performance data in a manufacturing environment will also be presented in the paper.

REFERENCES

[1] K. D. Mackenzie, B. Reelfs, M. D. DeVre, R. Westerman, and D. J. Johnson, 2004 *CS Mantech Technical Digest*, pp. 319-322 (2004).

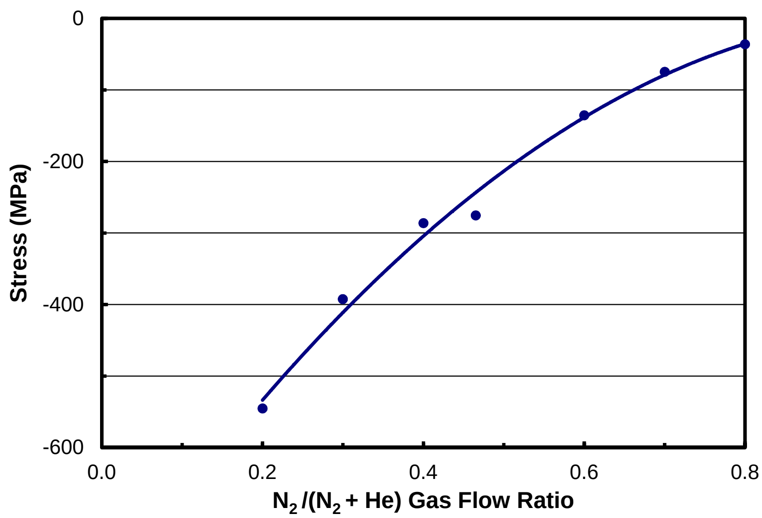

Figure 1. Stress control of high rate PECVD SiN_x by the He dilution technique. The films were deposited at 1200 Å/min at a temperature of 200°C.

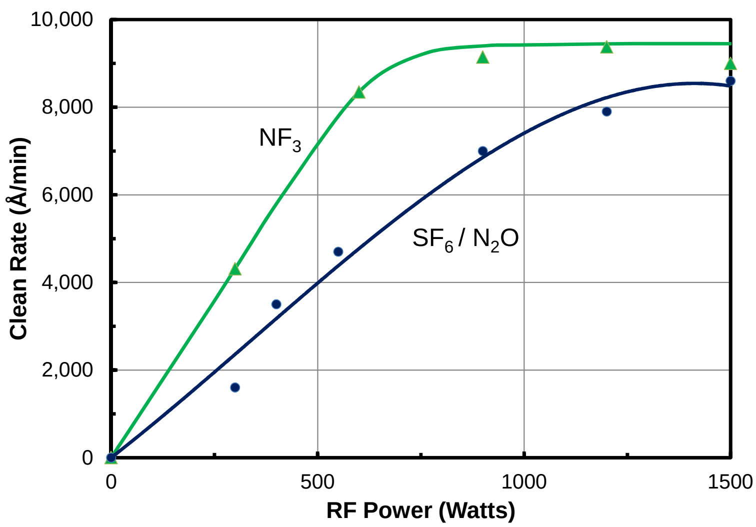

Figure 2. Comparison of plasma clean rates *versus* RF power for plasma chemistries of SF_6/N_2O and NF_3.