Analysis of Plasma Characteristics and Substrate Damage Using a Dual-Frequency PE-ALD Process with 13.56 MHz and 100 MHz

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Compared to other deposition methods, ALD processes are widely applied in mass production due to their high step coverage, atomic-level thickness control, and uniform film deposition. However, thermal ALD requires high temperature (>400°C) to achieve high-quality properties when depositing nitride films such as SiN_x, AlN, TiN, and TaN. This has led to the application of plasma-enhanced ALD (PE-ALD). It offers enhanced reactivity and higher deposition rates, even at low temperatures. However, it also presents several technical challenges, including plasma-induced substrate damage and limited step coverage in increasingly thinner and deeper structures. To address these issues, the use of very high frequency (VHF) plasma is required.

We have studied plasma characteristics and substrate damage during the deposition of silicon nitride (SiN_x) films using a PE-ALD process at low temperatures (≤200°C) with very high-frequency plasma. In this process, the use of 100 MHz alone resulted in insufficient discharge and poor uniformity due to standing wave effects, and thus a dual-frequency approach was applied by combining 13.56 MHz with 100 MHz to improve plasma stability. Plasma characteristics, such as electron temperature (T_e), ion flux, and ion density, were characterized using a Langmuir probe. Plasma-induced substrate damage was examined using TEM, and film thickness and refractive index (RI) were measured using ellipsometry.

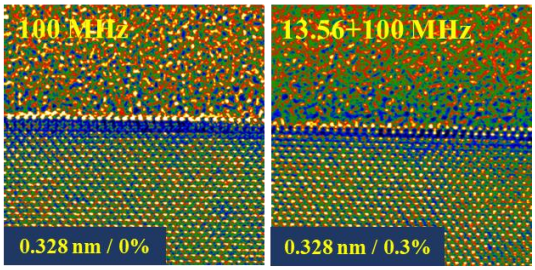

Fig. 1. TEM images of samples deposited the two-step PE-ALD at 60MHz.

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References

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