Low-Temperature ALD of Silicon Nitride Films Using DIS and TIS Precursors: A Strategy for Substrate Protection and High-Density Films

Myeong-Hun Lee[1] , Tae-Heon Kim[2], Min-Chan Kim[2], , Chang-Kyun Park[2]
and **Jin-Seong Park[1],***
Division of Materials Science and Engineering, Hanyang University, 222 Wangsimni-ro
Seongdonggu, Seoul, 04763, Republic of Korea
* (Tel.:+82-02-2220-4800, E-mail: jsparklime@hanyang.ac.kr)

Recently, various types of memory are being actively researched and developed to meet market demands for high performance and low power consumption. In emerging memory technologies, significant changes in cell materials and structures have made the gate spacer film increasingly important for protecting the cell material. Silicon nitride film has been used as gate spacer due to high density and reliable properties. ALD at high temperatures (>700°C) using DCS (Dichlorosilane, SiH_2Cl_2) has been the conventional method for deposition. However, this method can cause damage to the cell material, necessitating the development of alternative approaches to minimize such damage[1]. We investigated ALD process with DIS(SiH2I2) and TIS(SiHI3) in lower temperature(<300℃) to prevent the damage by chlorine and high temperature. We first examined the ALD window of DIS, focusing on process temperature and plasma power. Our results show that higher temperatures lead to lower impurity levels, resulting in a Si/N ratio close to 75% at 300°C, which is ideal for SiNx films. Additionally, lower plasma power resulted in lower impurity levels, with a Si/N ratio stabilizing at 75% under 100W plasma power. When analyzing film roughness, lower plasma power also led to smoother films, which is beneficial for device performance. We then compared the activation energies of DIS and TIS, finding that TIS exhibited a lower activation energy than DIS. We also studied the effect of varying TIS ratios (0%, 1%, 4.4%) on film properties. The growth per cycle (GPC) and refractive index (R.I.) showed minimal changes with different TIS ratios, but the film density increased with higher TIS content, despite similar impurity levels. This increase in film density, coupled with the lower activation energy of TIS, suggests that TIS-added films may provide enhanced SiNx gate spacer films that can effectively prevent initial damage and better protect the cell material during post-processing steps.

Reference

1) Xin Meng, Atomic Layer Deposition of Silicon Nitride Thin Films: A Review of Recent Progress, Challenges, and Outlooks, 2016,
2) Daehyun Kim, Low temperature atomic layer deposition of high quality SiO2 and Si3N4 thin films, 2019

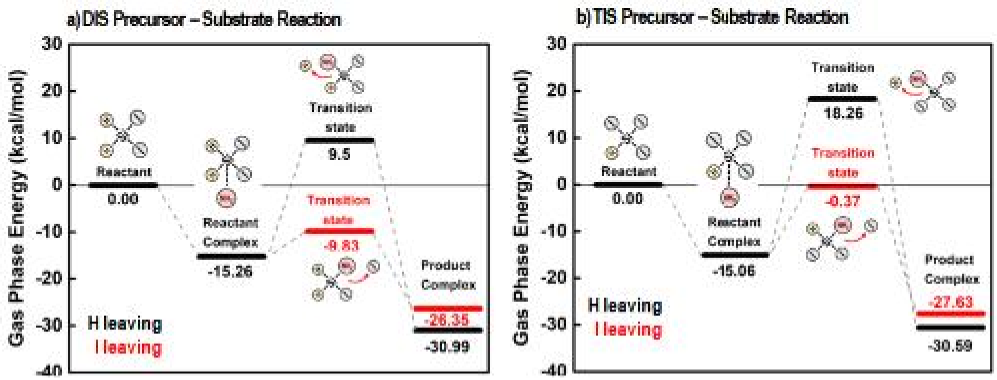


Figure1. ALD Mechanism with DIS and TIS by precursor dose reaction which shows Iodine leaving makes Hydrogen terminated surface.

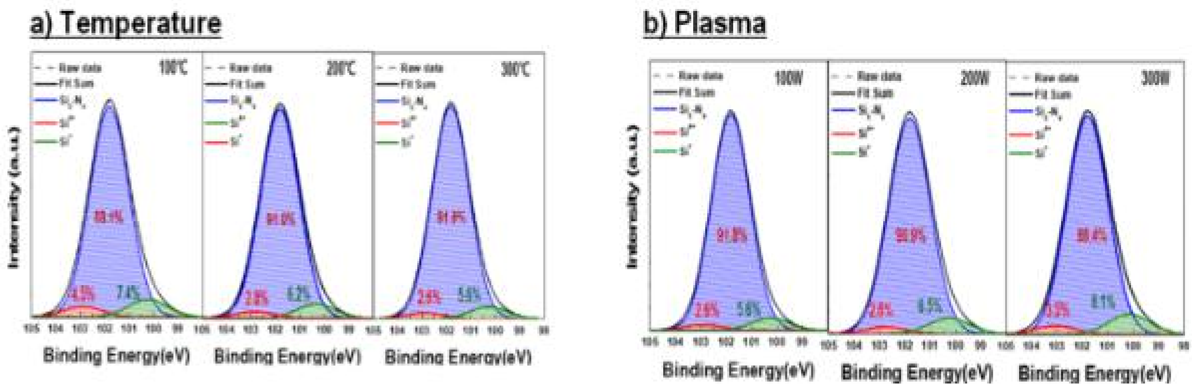
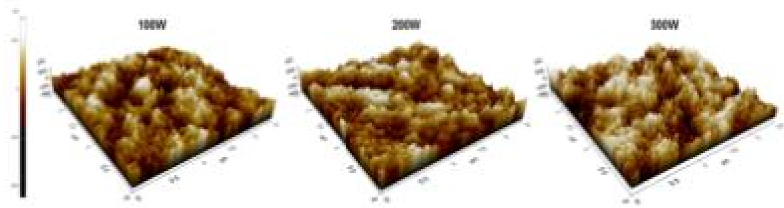


Figure2. ALD Window with DIS which shows impurity level trend by temperature and plasma power(XPS). Higher temperature and lower plasma power showed lower impurity.



	100W	200W	300W
RMS (nm)	0.17	0.18	0.216
Ra (nm)	0.14	0.144	0.174

Figure3. Roughness(AFM) according to plasma power which shows lower power is better.

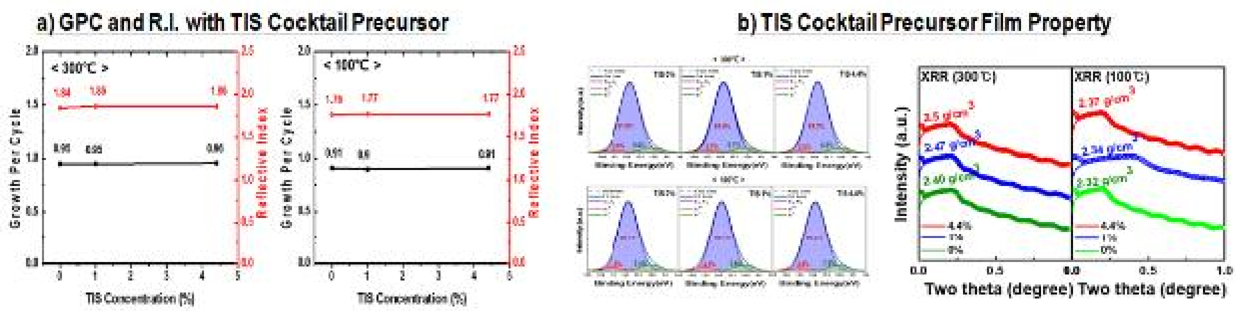


Figure4. a) GPC and R.I according to TIS ratio which shows no difference. b) XPS and XRR according to TIS ratio which shows higher density with higher TIS ratio.