Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supporting Information

High Growth Rate and High Wet Etch Resistance Silicon Nitride Grown by Low Temperature Plasma Enhanced Atomic Layer Deposition with a Novel Silylamine Precursor

Harrison Sejoon Kim,[a] *Su Min Hwang,*[a] *Xin Meng,*[b] *Young-Chul Byun,*[a] *Yong Chan Jung,*[a] *Arul Vigneswar Ravichandran,*[a] *Akshay Sahota,*[b] *Si Joon Kim,*[c] *Jinho Ahn,*[d] *Lance Lee,*[e] *Xiaobing Zhou,*[e] *Byung Keun Hwang* [e] *and Jiyoung Kim*[*a,b]

[a.] Department of Materials Science and Engineering, The University of Texas at Dallas, 800 West Campbell Road, Richardson, Texas 75080, United States

[b.] Department of Electrical Engineering, The University of Texas at Dallas, 800 West Campbell Road, Richardson, Texas 75080, United States

[c.] Department of Electrical and Electronics Engineering, Kangwon National University, 1 Gangwondaehakgil, Chuncheon-si, Gangwon-do 24341, Republic of Korea

[d.] Department of Materials Science and Engineering, Hanyang University, 222 Wangshimni-Ro, Seongdong-Gu, Seoul 04763, Republic of Korea

[e.] DuPont, 3700 James Savage Rd., 1382 Building, Midland, Michigan 48640, United States

Corresponding Author

* E-mail: jiyoung.kim@utdallas.edu.

(a)

TDSA Exposure Time (s)	GPC	stdev	R.I.	stdev
1	0.84294	0.001494	1.96167	0.00492
3	0.94406	0.002239	1.96733	0.00415
10	1.00572	0.002871	1.96656	0.00332

(b)

Deposition Temperature (°C)	GPC	stdev	R.I.	stdev	WER	stdev
240	0.08375	0.00129398	1.944444	0.005769	0.92	0.032787
270	0.08429	0.00149362	1.961667	0.004924	0.847778	0.035473
300	0.0828	0.00181539	1.957889	0.004256	0.965	0.015
330	0.09052	0.00176317	1.949889	0.002522	0.965	0.025166
360	0.08622	0.00201620	1.948	0.004272	1.272222	0.134536

Fig. S1 Tabulated values for the errors in GPC, R.I., and WER. (a) GPC and R.I., and their error values in Fig. 3a. (b) GPC, R.I. and WER, and their error values in Fig. 3b, Fig. 3c, and Fig. 5, respectively.

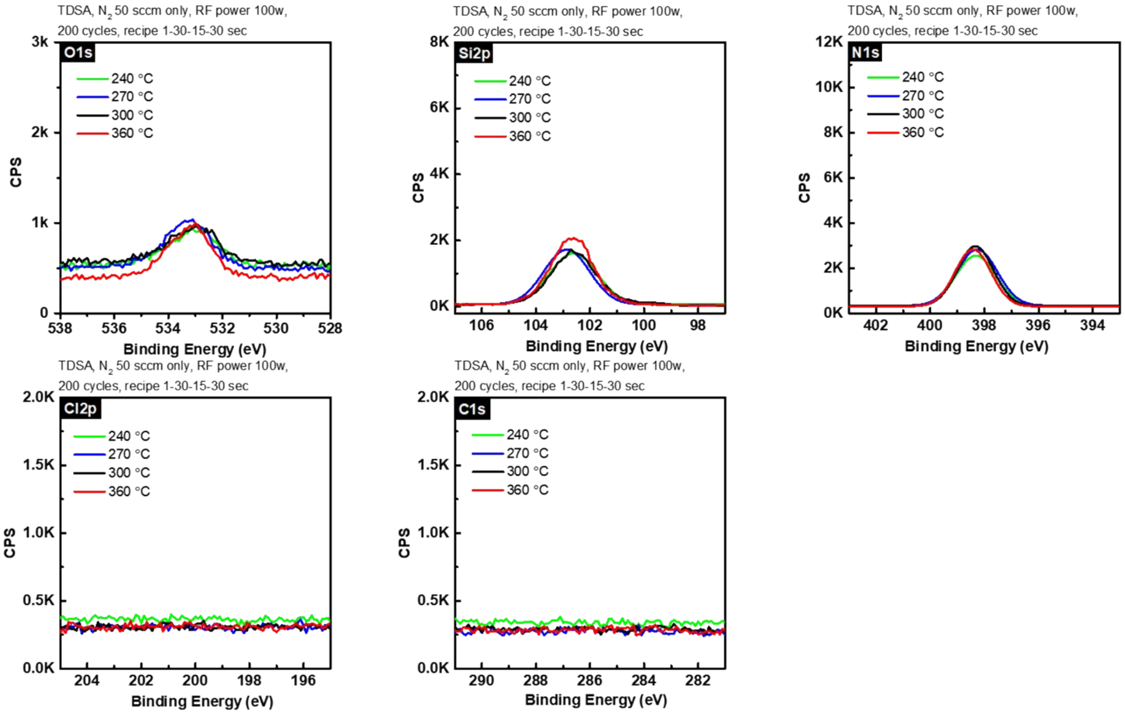
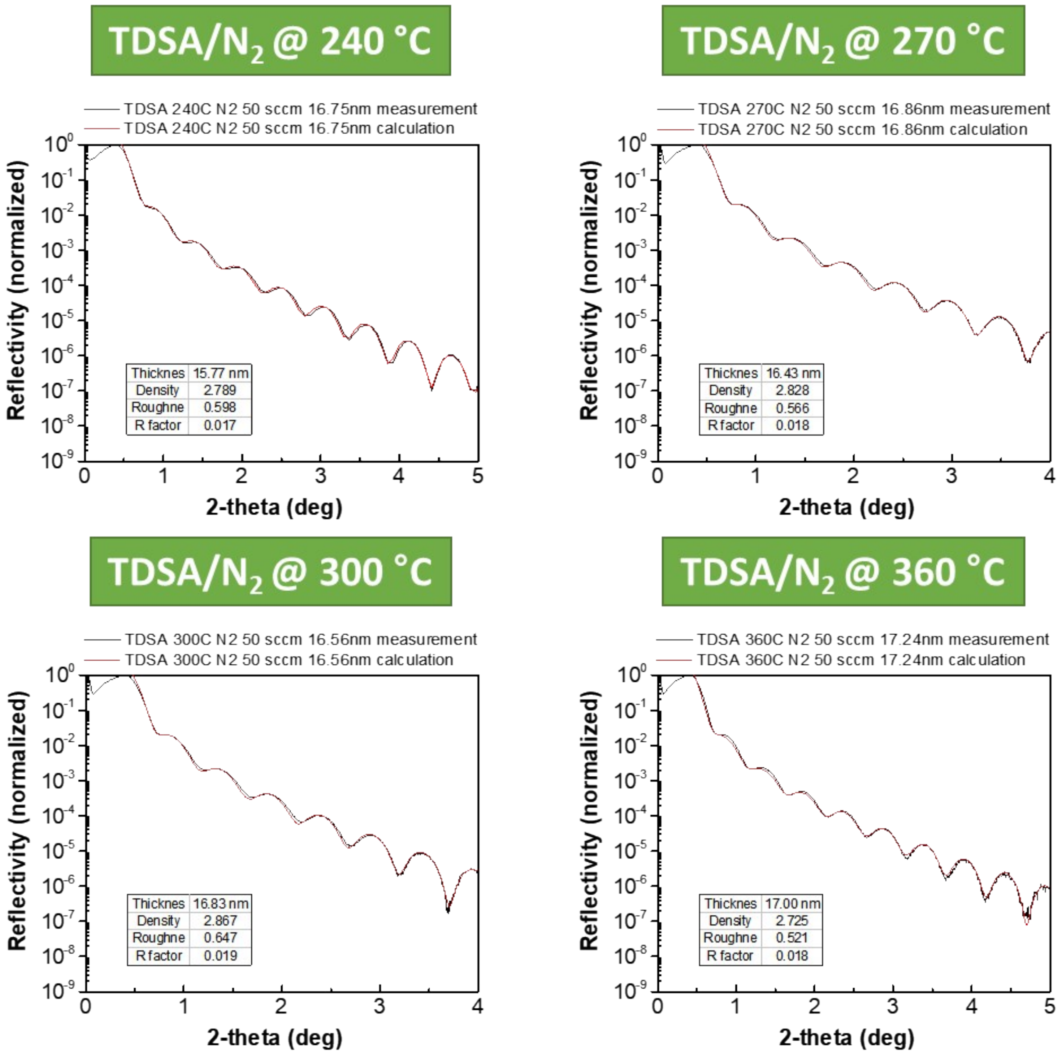


Fig. S2 XPS spectra acquired after removing ~2 nm of air-oxidized top layer by 1 min of Ar$^+$ sputtering. The spectra are taken from PEALD SiN$_x$ using TDSA with N$_2$ HCP at a power of 100 W with process temperatures of 240 °C, 270 °C, 300 °C, and 360 °C.



Thicknes	15.77 nm
Density	2.789
Roughne	0.598
R factor	0.017

Thicknes	16.43 nm
Density	2.828
Roughne	0.566
R factor	0.018

Thicknes	16.83 nm
Density	2.867
Roughne	0.647
R factor	0.019

Thicknes	17.00 nm
Density	2.725
Roughne	0.521
R factor	0.018

Fig. S3 XRR spectra acquired from PEALD SiN_x using TDSA with N_2 HCP at a power of 100 W with process temperatures of 240 °C, 270 °C, 300 °C, and 360 °C (black lines). Red lines are simulated results to fit measurement data. Inserted tabulated data are the parameters extracted from the calculation results.

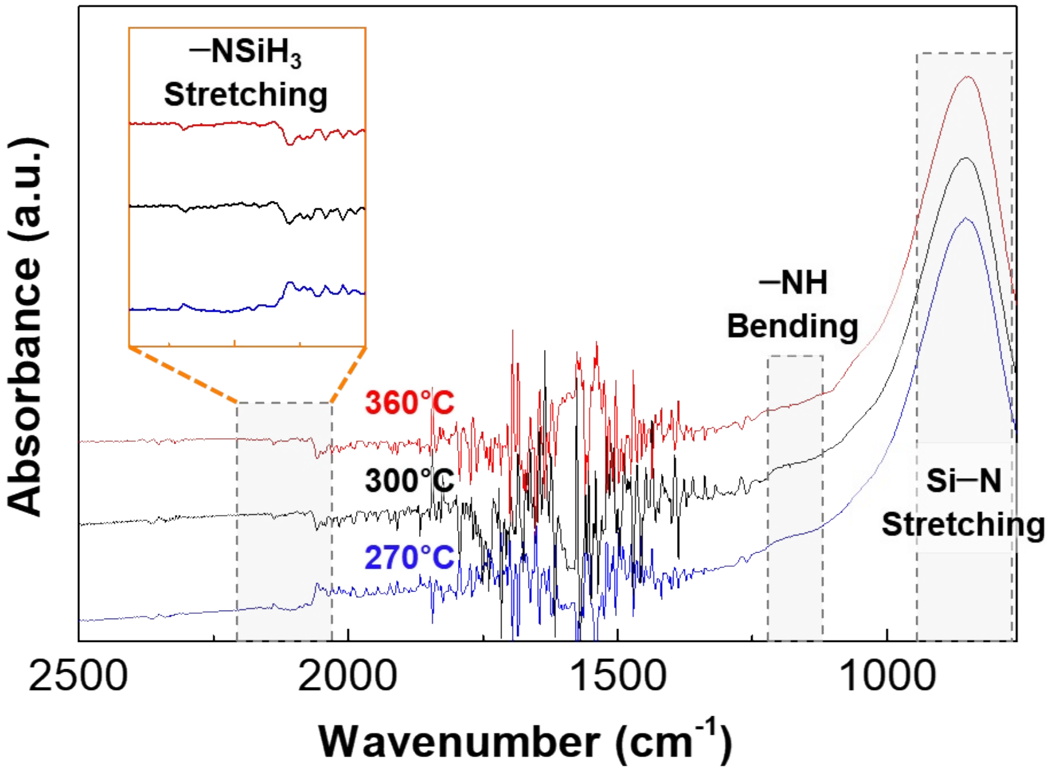


Fig. S4. FT-IR analyses for PEALD SiN$_x$ using TDSA with N$_2$ HCP at a power of 100 W with process temperatures of 270 °C, 300 °C, and 360 °C. Note changes in –NSiH$_3$ stretching mode with temperatures. This indicates TDSA tends to react with the surface by dissociating the N–Si bond in the N–SiH$_2$SiH$_3$ groups of TDSA, making films more Si rich instead of liberating only –SiH$_3$ at a higher temperature.

Thermo Electron FT-IR spectroscopy operating with a Globar IR source and liquid-nitrogen-cooled MCT-A infrared detector is used to perform the vibrational spectroscopic studies. The infrared beam passes through a KBr beam splitter. Spectra are obtained in absorbance mode. For each sample, background spectra are acquired using a silicon piece cleaved from the same wafer on which the deposited silicon nitride film is etched away using DHF (49% HF:H2O = 1:100). The IR data generated from the deposited SiN$_x$ films on silicon substrates are collected with a spectral resolution of 4 cm^{-1} over 100 scans. The background spectra generated from the cleaved piece of silicon are collected with a resolution of 4 cm^{-1} as well. The spectrometer is purged with N$_2$ prior to the measurement to minimize the presence of trapped water in the IR beamline.