

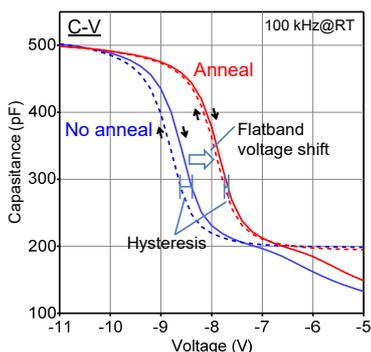
Precise evaluation for SiN films by mercury probe and XPS

Silicon nitride (SiN) films are widely used as various dielectrics due to their versatility. But the electrical properties of SiN films strongly depend on the formation conditions. We characterized the change in the electrical and physical properties of annealed SiN film by mercury probe and XPS. Our comprehensive study enables us to evaluate a relationship between film qualities and electrical properties of SiN films.

1. C-V and I-V properties by mercury probe

Sample: SiN (300 nm)/p-Si
Annealing: 800 °C, 2 hours in N₂

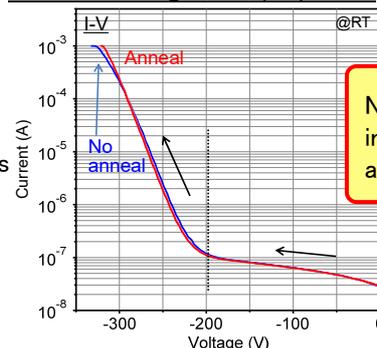
Capacitance-Voltage (C-V) properties



- Decrease in hysteresis width after annealing
→ Decrease in mobile charges
- Positive flatband voltage shift after annealing
→ Decrease in positive fixed charges

Decrease in detrimental mobile charges and fixed charges by annealing
→ Improvement of C-V property

Current-Voltage (I-V) properties



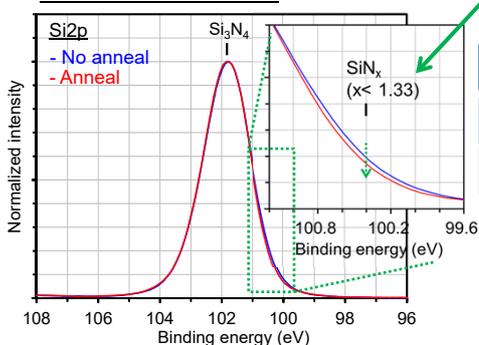
No significant change in I-V property before and after annealing

2. Elemental compositions and chemical states by XPS combined with wet etching

Using wet etching techniques, the states of 1) SiN surface, 2) middle layer and 3) SiN/Si interface were evaluated by XPS.

1) Surface (after removing native oxide)

Chemical states of Si



A very little difference was precisely detected!

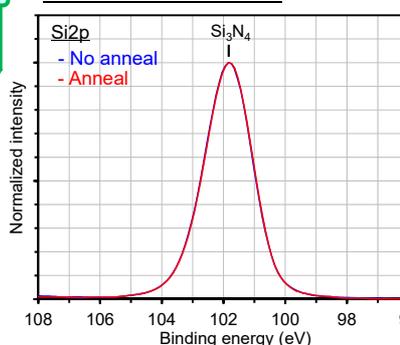
Elemental composition

Surface	N/Si*
No Anneal	1.25
Anneal	1.28

Reduction of Si-rich SiNx on surface by annealing

2) Middle layer (150 nm-depth)

Chemical states of Si



* N/Si ratio was converted using the RBS result of annealed sample to improve an accuracy of quantification by XPS.

Elemental composition

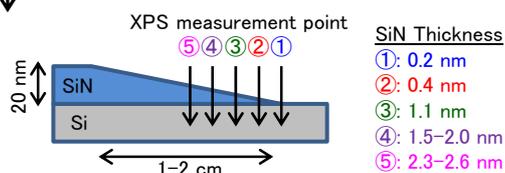
Middle	N/Si*
No Anneal	1.27
Anneal	1.28

No significant change in the middle layer before and after annealing

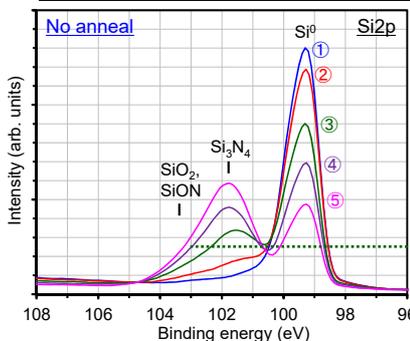
3) SiN/Si interface

Measurement flow

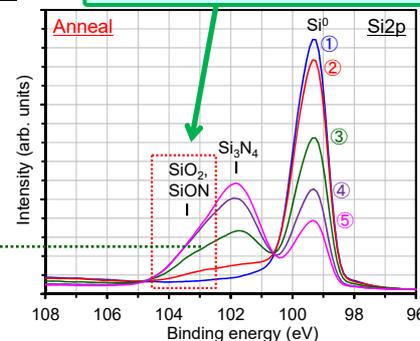
- Thinning SiN films to around 20 nm-thick
- **Graded etching**¹
1. Y. Muraji *et al.*, Jpn. J. Appl. Phys. 41, 805 (2002).
Our **original** technique to create several cm-long slope at thin film on substrate. Detailed interface analysis is available along the slope using XPS.
- XPS for 5 points near SiN/Si interface



Chemical states of SiN/Si interface



Detected ultrathin interfacial layer!



Increase in oxide component after annealing due to residual oxygen in annealing atmosphere → Reduction of fixed charges by interfacial oxidation

Mercury probe and XPS enable us to detect a very little difference of samples. To combine mercury probe with other analyses, electrical properties are related to impurity, defects and chemical states etc.