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Hiroshima University, Advanced Sciences of Matter, Room 401N

Etching Properties and Optical Emission Spectroscopy of NH_3 Added C_5F_8 Pulse-Modulated ICP Plasma

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Etching Mechanism for CW Plasma

CW plasma

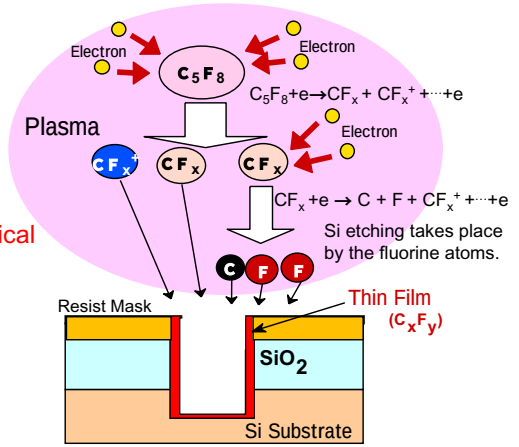
High electron temperature

↓

• High amount of F radical
• Thin protection film

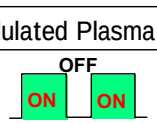
↓

Low selectivity (SiO_2/Si)



Etching Mechanism for Pulse-Modulated Plasma

Pulse-Modulated Plasma



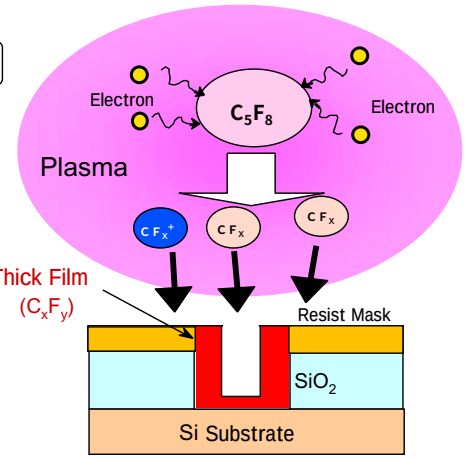
Low electron temperature

↓

•Reduced F radical
•Thick protection film

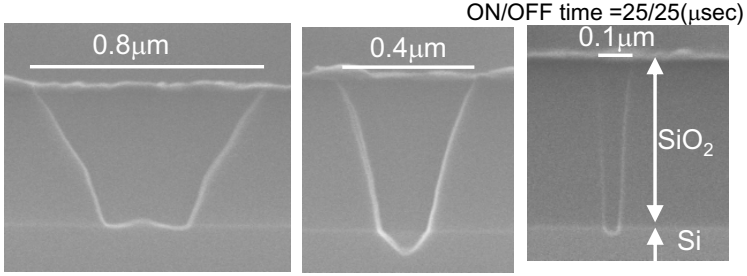
↓

High selectivity(SiO_2/Si)



Etching Shape Comparison with Hole Size

Gas : c-C_5F_8:O_2:Ar=11:4:60(sccm)
ON/OFF time =25/25(μsec)

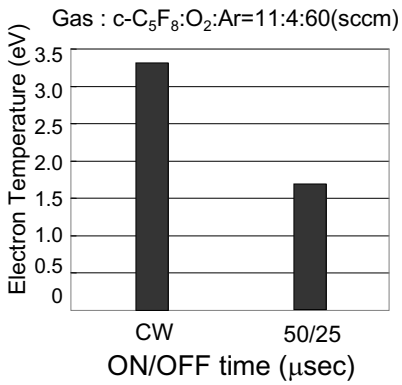


Shape of the hole depends on the hole size.
the number of additional ions, which are reflected from the sidewall and reach the bottom surface of the hole, becomes small for the small hole size.

Electron Temperature Measurement by Langmuir Probe

Comparison of electron temperature
CW ICP vs pulse-modulated ICP

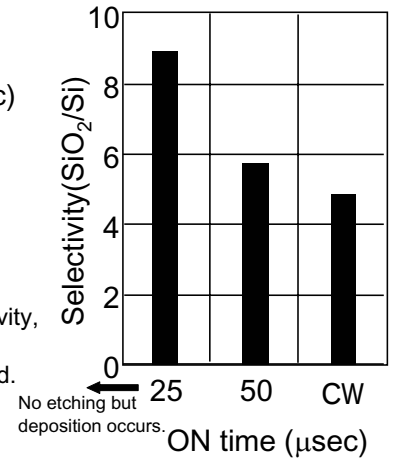
- Electron temperature decreases by pulse modulation
- Pulse modulation is expected to improve etching selectivity



Effect of Pulse-Modulated Plasma

Gas : c-C_5F_8:O_2:Ar=11:4:60(sccm)
Plasma :Pulse-modulated ICP
(OFF time :25μsec)
Pressure:15 mTorr

- Pulse modulation improves etching selectivity, but we couldn't get required selectivity.
- Improvement by pulse modulation is limited.



NH_3 Addition

High molecule polymer radical → Large adsorption probability

- Taper angle
- Selectivity

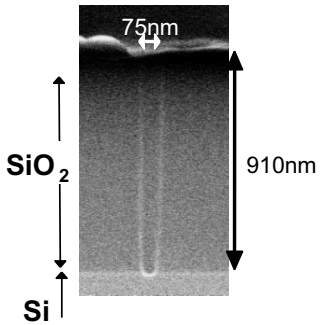
Trade off

NH_3 addition

- Reduce protection film thickness (Ion bombardment and chemical etching)
- Oxygen adding → Reduce selectivity
  NH_3 is replaced with oxygen
  → Selectivity improved.

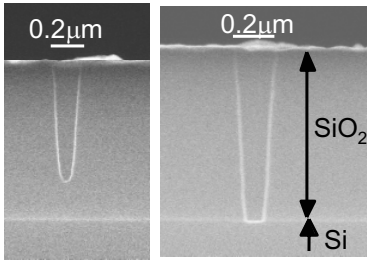
SEM of Contact Hole etched with NH_3

- NH_3 added (2sccm)
- Selectivity(SiO_2/Si)≅80
- High aspect ratio (>10)



Comparison of Adding Gas (H_2, NH_3)

C_5F_8/Ar/X = 11/60/2 (sccm)



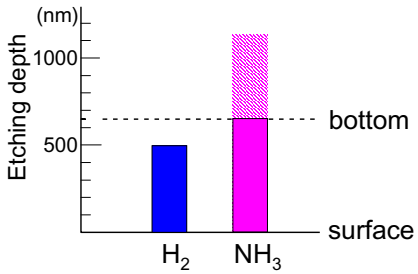
H_2 added NH_3 added

(150% etching)

Etchstop is suppressed by NH_3 addition instead of H_2.

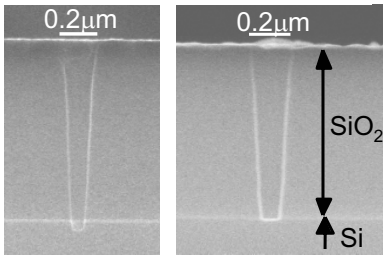
$NH_3 \rightarrow NH + 2H$ ···· large etch rate

$H_2 \rightarrow 2H$ ···· small etch rate



Comparison of Adding Gas (O_2, NH_3)

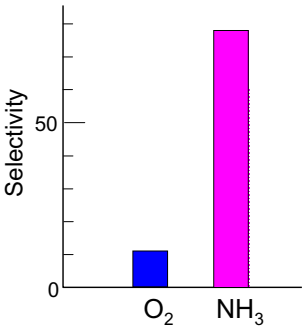
C_5F_8/Ar/X = 11/60/2 (sccm)



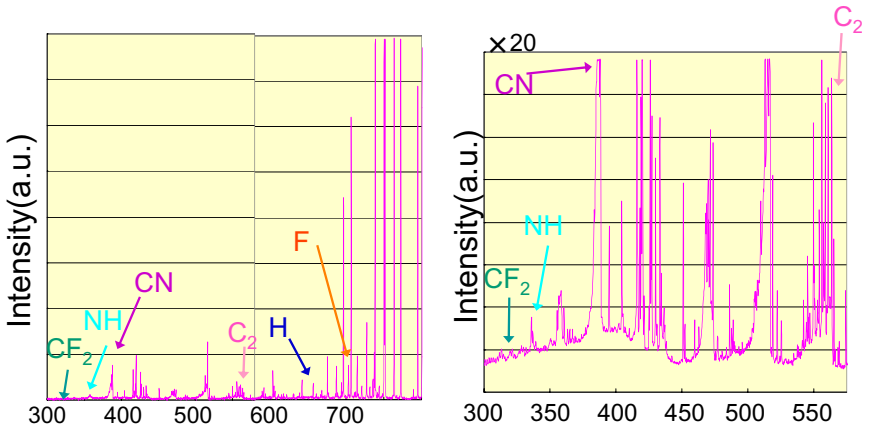
O_2 added NH_3 added

(150% etching)

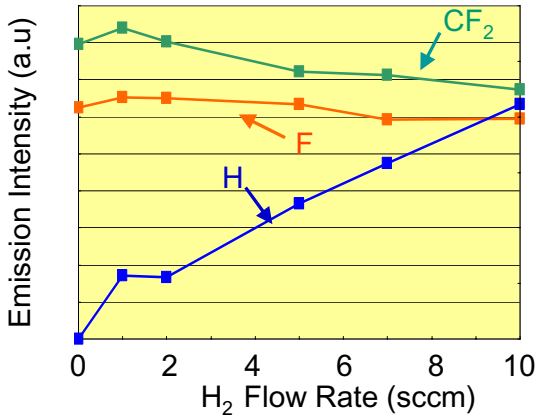
Selectivity is decreased by O_2 addition.

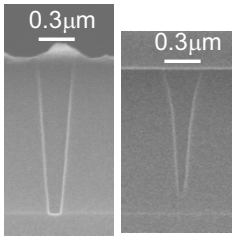


Optical Emission Spectroscopy (OES)



OES Intensity vs H_2 Flow Rate

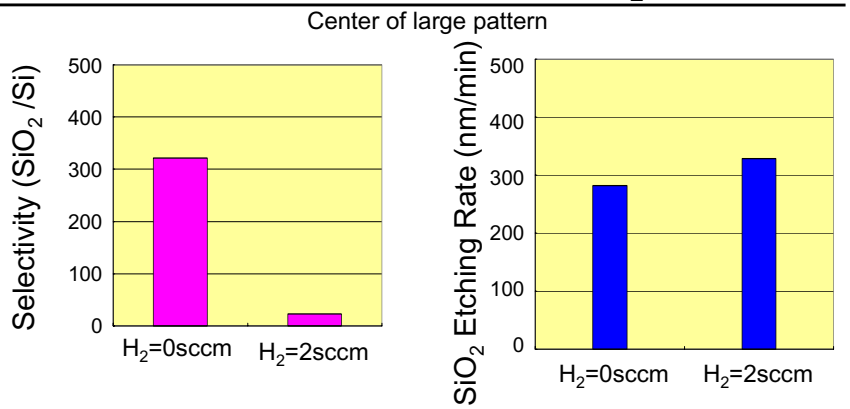




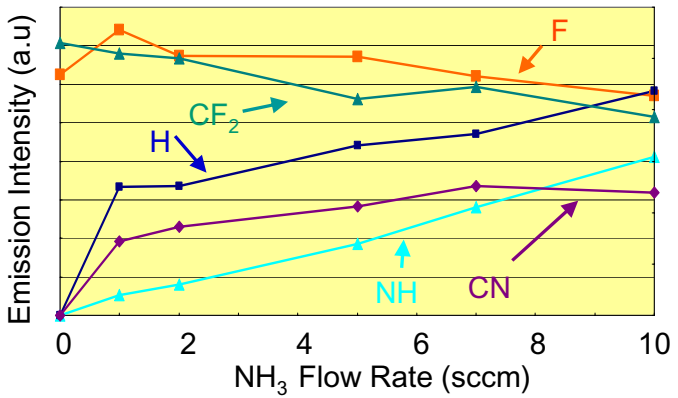
H is increasing. ⇨Etching of polymers takes place.

⇨ Vertical sidewall is obtained.

Comparison of Adding Gas (H_2)



OES Intensity vs NH_3 Flow Rate

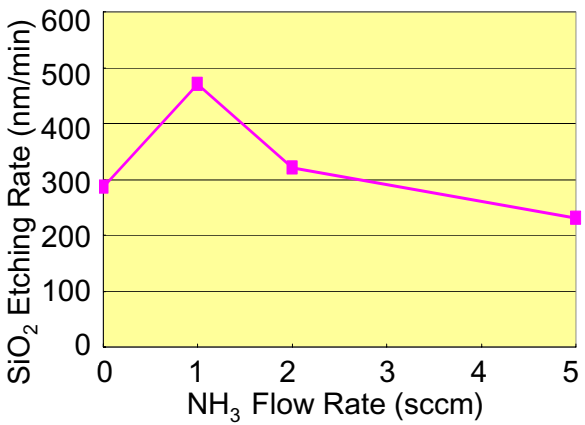


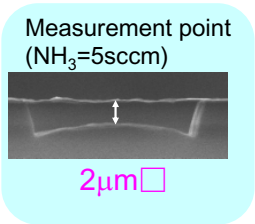
CN (precursor of HCN, FCN) is increasing. HCN and FCN are volatile* . ⇒ Deposition film thickness is reduced.

⇒ Contact hole etching with vertical sidewall is obtained.

* Ref.) T. Tokuyama, "Handoutai dry etching gijutsu", Sangyou Tosho p.73 (1992), (in Japanese).

SiO_2 Etching Rate vs NH_3 Flow Rate

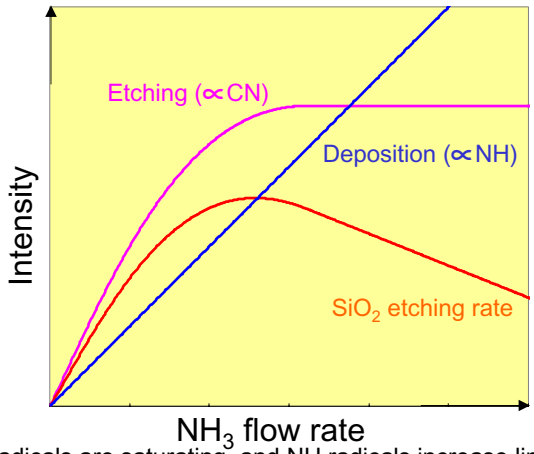




Influence of plasma without reflective ion from sidewall is investigated.

SiO_2 etching rate has maximum at NH_3=1sccm .

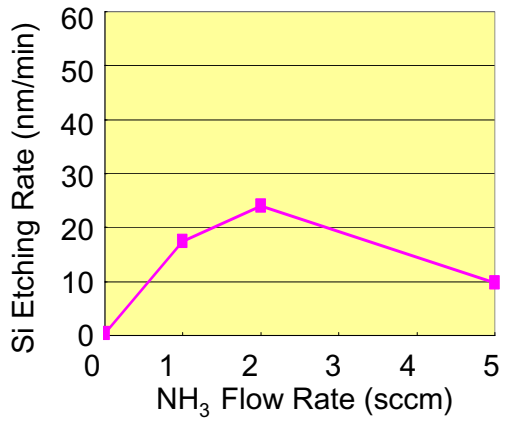
The reason of SiO_2 etching rate



CN radicals are saturating, and NH radicals increase linearly.

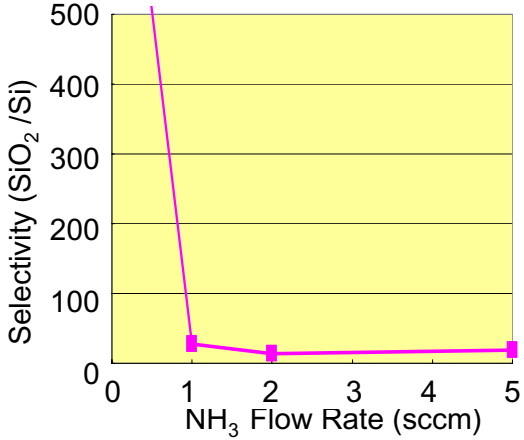
⇒ SiO_2 etching rate curve has a peak.

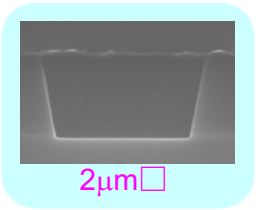
Si Etching Rate vs NH_3 Flow Rate



Si etching rate has maximum at NH_3=2sccm .

Selectivity (SiO_2 /Si) vs NH_3 Flow Rate





SiO_2 and Si etching rates have takes maximum at deferent NH_3 flow rate.
→ represented selectivity

Conclusions

1.Excellent etching properties are achieved with following condition
- Pulse-modulated plasma improves SiO_2/Si selectivity, due to the lowering of electron temperature.
- C_5F_8/Ar added with NH_3 → High aspect ratio (>10) Good selectivity (SiO_2/Si≅80)

2. Optical Emission Spectroscopy measurement revealed that
- CN and NH are generated by NH_3 addition.
- OES result has good correlation with SiO_2 etching rate.

3. CN compound (ex. HCN, FCN) may reduce C_xF_y polymer, and NH (with C_xF_y) may cause C_xN_y polymer.

→Etchstop and selectivity can be controlled by NH_3 addition.