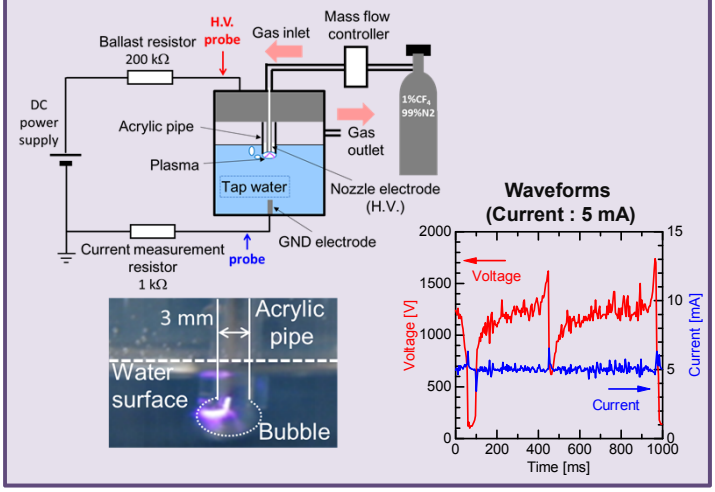
HIGH REMOVAL RATE OF CF_4 USING DC PLASMA WITHIN BUBBLES AND TRAPPING OF FLUORINE

Summary

<Background ; CF_4 is widely used in semiconductor manufacturing processes; however, CF_4 emissions must be reduced because of their large global-warming potential. >
CF_4 was removed at the rate of 96.7%, using an atmospheric-pressure DC plasma within gas bubbles. Emission spectra showed that the mean electron energy might be 3 eV and the gas temperature might be 3000～3400 K. Electron energy distribution function shows that the electrons in this plasma might have sufficient energy to decompose CF_4. Thermodynamic equilibrium compositions indicate that the gas temperature of this plasma might be sufficient for CF_4 decomposition. We consider that the water around bubbles is effective in humidifying the discharged gas, lowering the temperature required to decompose CF_4 and capturing the fluorine to achieve high removal rate.

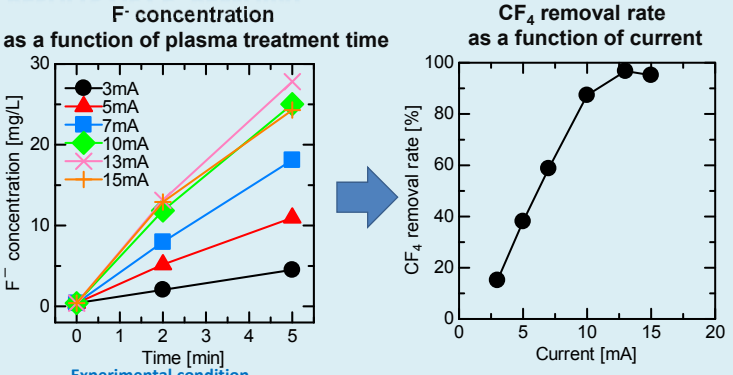
Experimental Setup

DC PLASMA WITHIN BUBBLES



Results

RESULTS OF CF_4 REMOVAL



Experimental condition

Gas: 1%CF_4, 99%N_2
Gas flow rate: 10 sccm
Solution: Tap water 50 mL
Current: 3, 5, 7, 10, 13, 15 mA

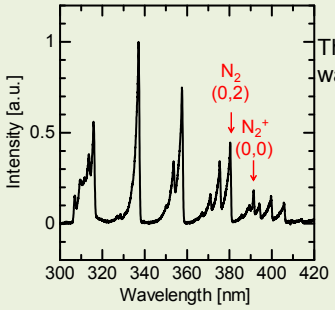
- The fluorine atoms detached from CF_4 are captured in the water.
- The maximum removal rate of 96.7% was obtained.

Discussions

DECOMPOSITION BY ELECTRON COLLISION

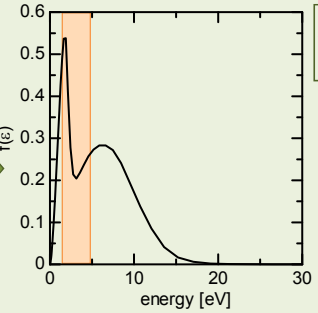
Deduction of electron energy by the intensity ratio of N_2 spectra

Emission spectrum of 1%CF_4/N_2base



The electron energy was estimated at 3 eV.

Electron energy distribution function (by BOLSIG+)



Electrons with the energy of 2~5 eV exist.

BOLSIG+ condition

Gas : 1%CF_4, 96%N_2, 3%H_2O
The mean electron energy : 3 eV
E/N : 126 Td

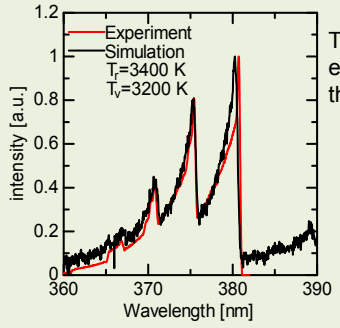
CF_4 can be decomposed by electron collision.

Reaction	Dissociation energy [eV]
$CF_4 + e \rightarrow CF_3 + F^-$	4.8
$CF_3 + e \rightarrow CF_2 + F + e$	3.0
$CF_2 + e \rightarrow CF + F + e$	4.6
$CF + e \rightarrow C + F + e$	2.7

THERMAL DECOMPOSITION

Deduction of the gas temperature of the plasma

Emission spectrum of 1%CF_4/N_2base at 15 mA

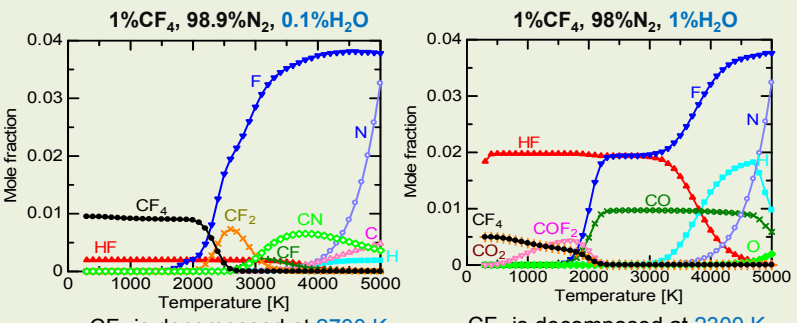


The gas temperature was estimated at 3000~3400 K at the current range of 5~15 mA.

Current [mA]	Gas temperature [K]
5	3000
10	3200
15	3400

CF_4 can be thermally decomposed.

Thermodynamic equilibrium composition(by MALT)



CF_4 is decomposed at 2700 K.

CF_4 is decomposed at 2300 K.

- Increasing H_2O concentration decreases CF_4 decomposition temperature. Thus, H_2O contributes effectively to CF_4 decomposition.
- At the experimental current, H_2O concentration is estimated at several percent.[1] Therefore, CF_4 is decomposed at 2300 K at least in the state of thermal equilibrium.

[1] N Takeuchi, Y Ishii and K Yasuoka, *Plasma Sources Sci. Technol.* **21**, 015006 (2012).

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