Surfacewave After-glow Plasma Production in Resonance Point by VHF for Low Electron Temperature

Plasma Electronics SH Lab.

Background・Objective

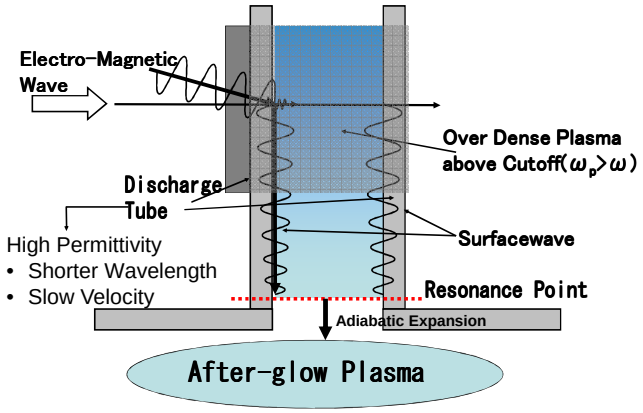
For next generation of semiconductor processes, Atomic Layer Deposition(ALD) and Monolayer etching (Layer-by Layer Etching) are highly required to suppress damages. For this purpose, an extremely low electron temperature plasma is suitable. In the present study, one plasma source is proposed.

In the present work, a surfacewave after-glow plasma production is studied. In the resonance point of surfacewave, the power is interrupted there, and thus after-glow is expected to produce.

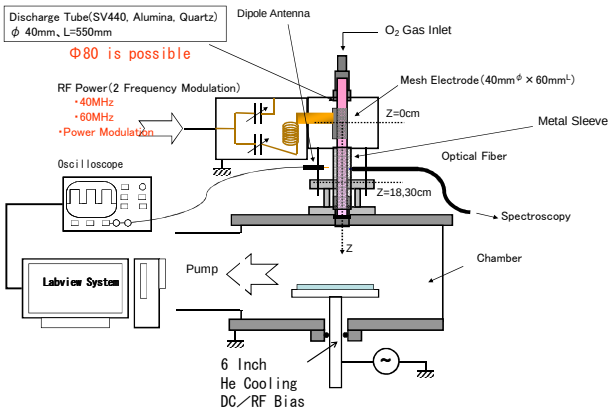
Key Technology

(1) For the simplicity of plasma source, VHF power is employed.
(2) For high density plasma, high permittivity discharge tube is used.
Discharge Tube Materials : K140 Ceramic (ε_s=140)
: SV440 Ceramic (ε_s=44)
: Alumina(ε_s=9.8)
: Quartz (ε_s=3.8)

Production Mechanism of SW

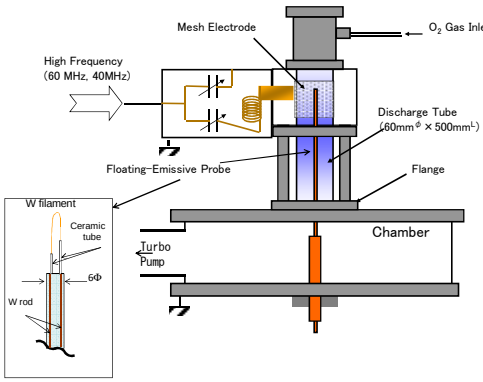


Experimental Apparatus I



Experimental Apparatus II

Diagnostics by New Floating Probe System



Measurements of OI Emission Lines

(1) Originated from electron impact and neutralization of O⁻ with O⁺

$$\left.\begin{array}{l} \text{O I} \quad 777\ nm\left(3p^5P \rightarrow 3s^5S\right)\left(E_k = 10.74eV\right) \\ \text{O I} \quad 845\ nm\left(3p^3P \rightarrow 3s^3S\right)\left(E_k = 10.74eV\right) \end{array}\right\}$$

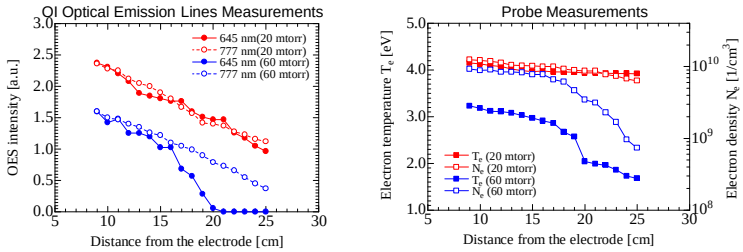
(2) Originated from plasma electron impact alone

$$\text{O I} \quad 645\ nm(2p^4 5s \rightarrow 2p^4 3p)(E_k = 12.65\text{eV})$$

＊From NIST

Experimental Results ① Axial Dependence of Plasma Parameters

Quartz Discharge Tube, 60MHz, 100W

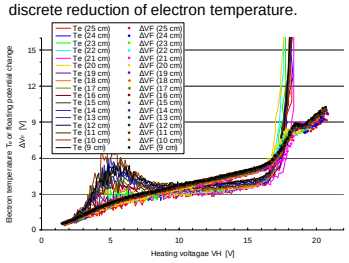


At the pressure of 60mTorr, a discrete reduction of OI 645 nm line intensity and correspondingly rapid change of electron temperature is obtained at about 20cm, indicating after-glow plasma production .

Experimental Results② Probe Raw Data and Its Axial Dependence

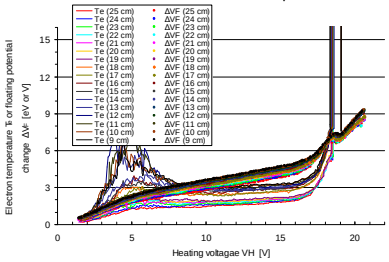
Quartz Discharge Tube,20 mtorr,100 W

A new floating probe measurement indicates no discrete reduction of electron temperature.

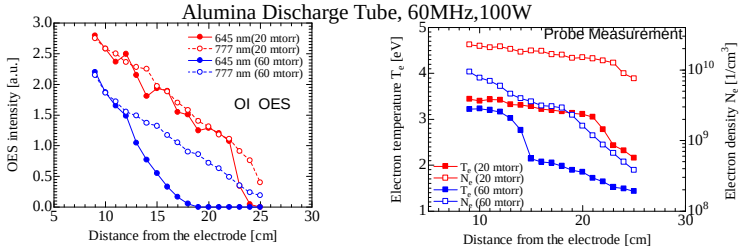


Quartz Discharge Tube, 60 mtorr,100 W

A new floating probe measurement clearly indicates a discrete reduction of electron temperature.

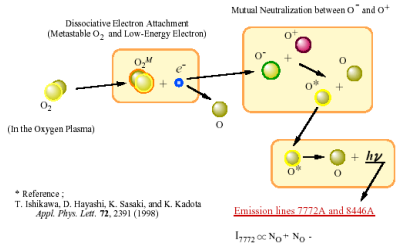


Alumina Discharge Tube, 60MHz,100W



It is more remarkable, in Alumina Discharge tube, compared with Quartz Discharge Tube for discrete reduction with larger magnitude to occur.

Consideration



* Reference ;
T. Ishikawa, D. Hayashi, K. Sasaki, and K. Kadota
Appl. Phys. Lett. **72**, 2391 (1998)

$I_{7772} \propto N_{O^+} \cdot N_{O^-}$

The OES measurements in both OI 777nm and OI 645 nm lines show a big difference and the OI 777 nm is only observed in after-glow region. This indicates that the negative oxygen ion O- is formed in the region and its neutralization with O+ is responsible. This also indicates that the O- negative ion formation is occurred I n the after-glow region.

Remarks

(1)A discrete reduction of electron temperature is observed in downstream of a surfacewave oxygen plasma, indicating an after-glow plasma where OI emission line shows a rapid change as well.

(2) The emission line of OI 645 nm which is originated from the electron impact disappeared rapidly in the region, whereas the OI 777nm is not so rapid in decay, indicating the negative ion O- is formed in the after-glow.

(3) From above, VHF surfacewave after-glow plasma is expected as a next generation plasma source of low electron temperature.

(4) It is shown, that a new floating probe works well in a insulated plasma, such as in discharge tube, so as to be able to measure a rapid change of electron temperature in the after-glow region.

Any question is always welcome, please contact us by Email below.

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