Ion sheath evolution for grid electrode structures in PSII

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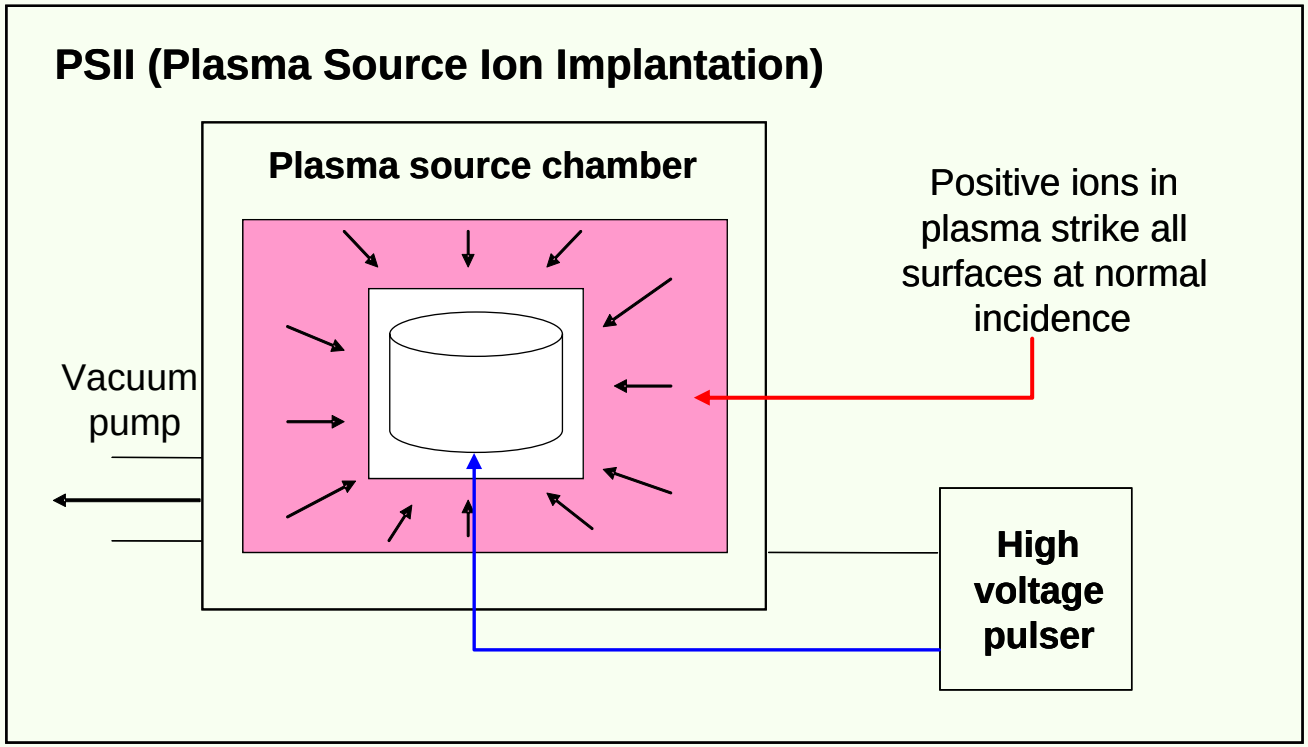
Introduction

- **Objective**

: To understand the extent of propagation of the sheath for grid electrode.

- **Plasma Source Ion Implantation**

: Non-line-of-sight technique for surface modification of materials



Introduction

- ***Ion matrix sheath thickness***

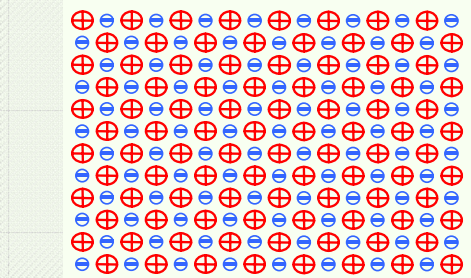
$$s_0 = \left(\frac{2\varepsilon_0 V_0}{en}\right)^{1/2} = \lambda_{De}\left(\frac{2V_0}{T_e}\right)^{1/2}$$

- ***Child Law sheath***

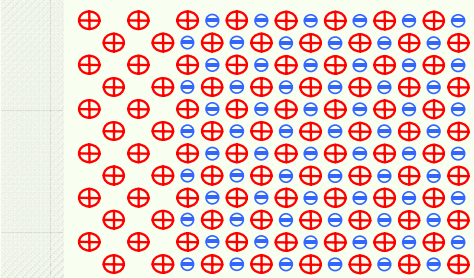
$$j = \frac{4}{9}\varepsilon_0\left(\frac{2e}{M}\right)^{1/2}\frac{V_0^{3/2}}{s^2} = en_s u_B$$

$$s = \frac{\sqrt{2}}{3}\lambda_{De}\left(\frac{2V_0}{T_e}\right)^{3/4}$$

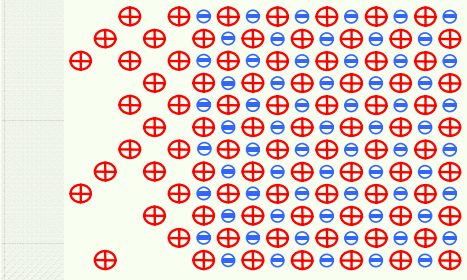
1. **t = 0 uniform plasma**



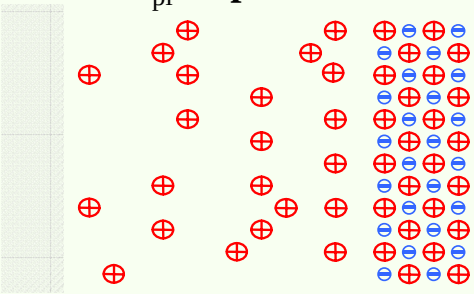
2. **t ~ $1/\omega_{pe}$ ion matrix sheath**



3. **t~ $1/\omega_{pi}$ expanding sheath**



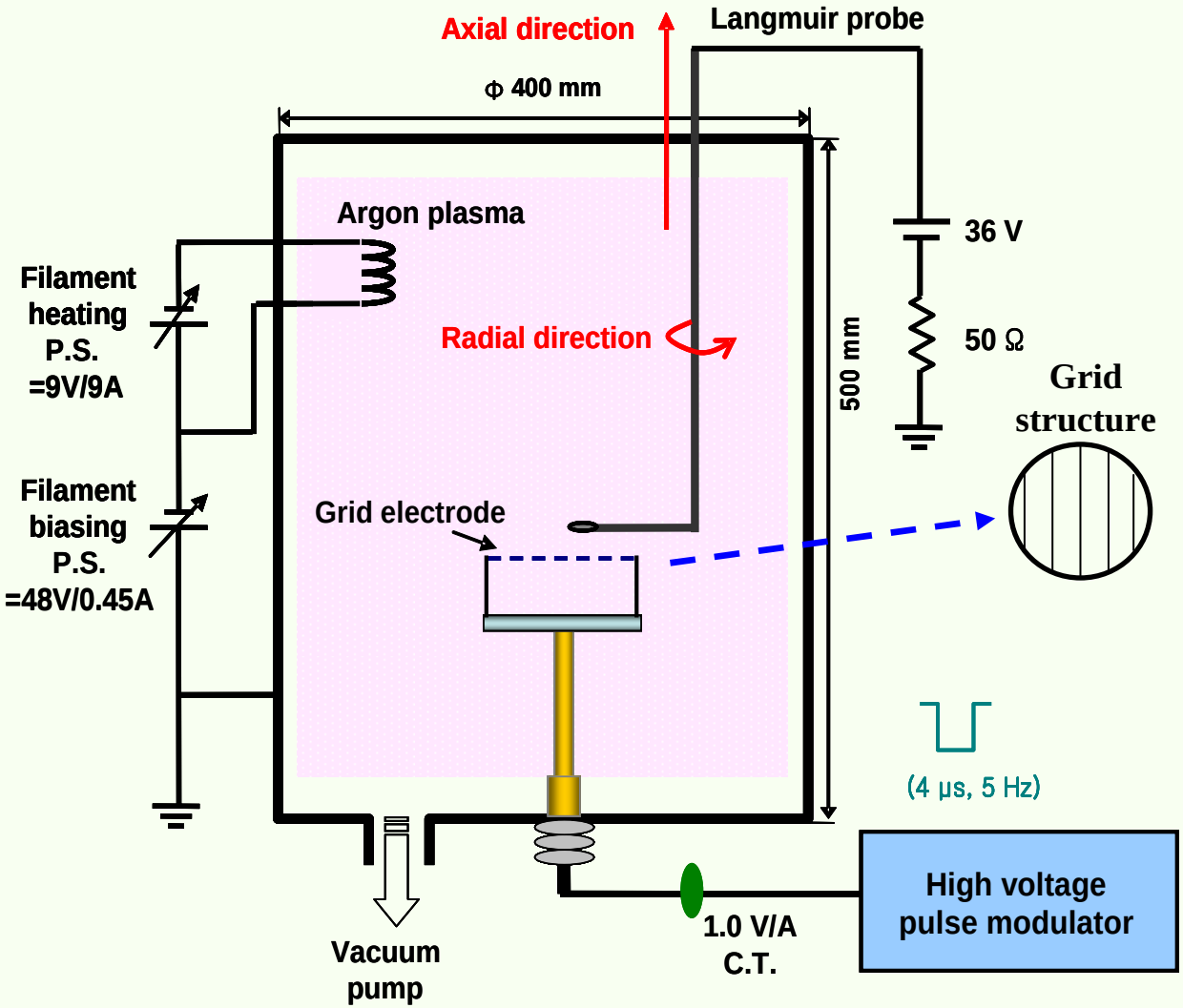
4. **t~$5/\omega_{pi}$ expanded sheath**



- Sheaths are related with plasma parameters and applied voltage.

- Comparing to the matrix sheath size, the Child law sheath is larger by a factor of order $(V_0/T_e)^{1/4}$

Schematic of experimental setup



Experimental condition

Base pressure

$= 1.0 \times 10^{-5}$ Torr

Neutral pressure

$= 1.0 \times 10^{-4} \sim 2.0 \times 10^{-4}$ Torr

Plasma parameters

$n_e \approx 1.5 \sim 2.4 \times 10^{9}\ cm^{-3}$

$T_e \approx 3 \sim 5.4$ eV

$\Phi_p \approx 2.5 \sim 3$ V

Grid electrodes

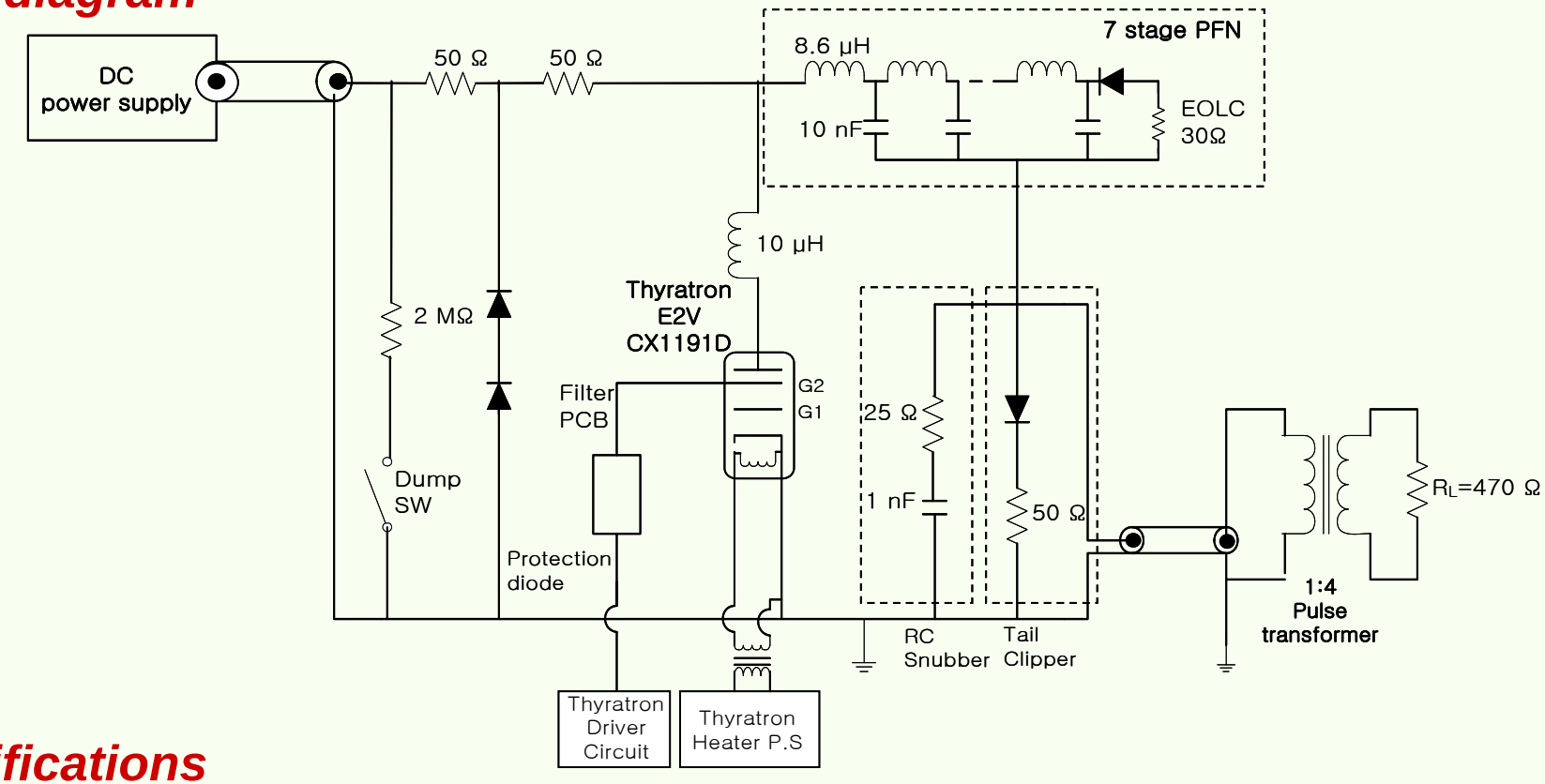
Wire diameter = 1 mm

Electrode diamemter = 120 mm

Grid hole = 20 mm, 30 mm

High voltage pulse modulator

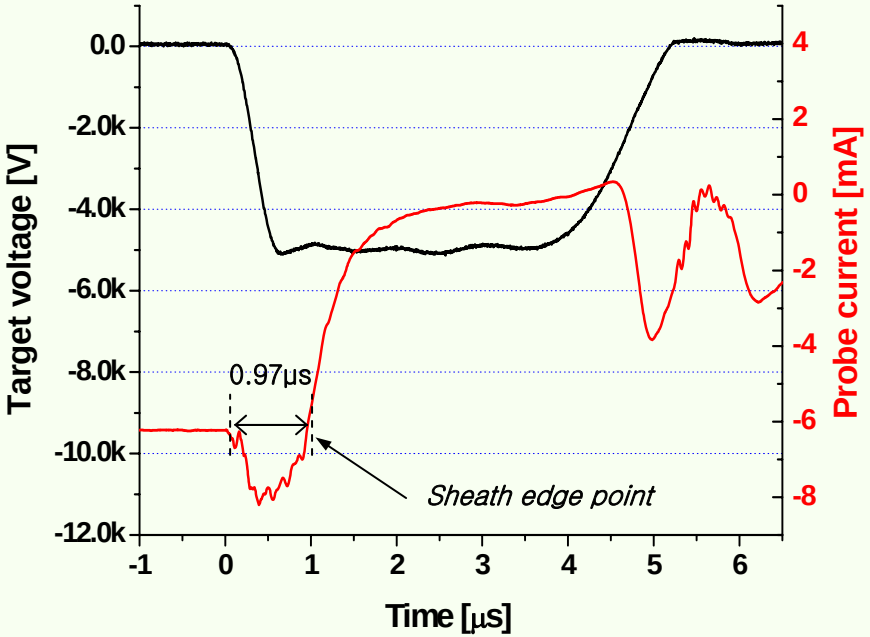
Circuit diagram

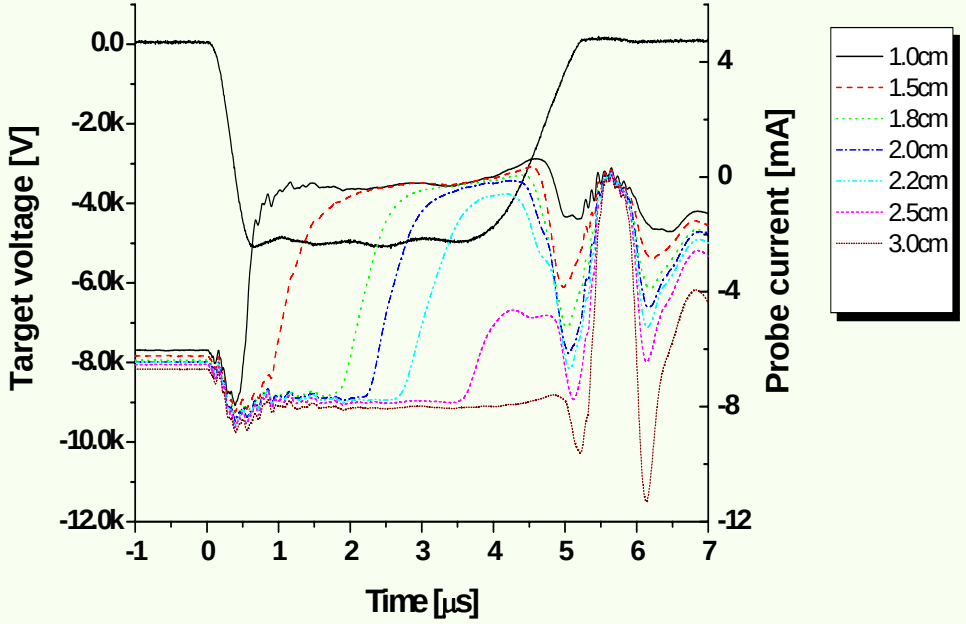


Specifications

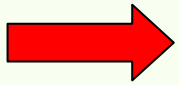
Peak voltage = 45 kV	Pulse width = 4 μs	PFN impedance = 29.37 Ω
Peak current = 96 A	Step-up ratio = 4	Load impedance = 470 Ω

Measurement of ion sheath evolution





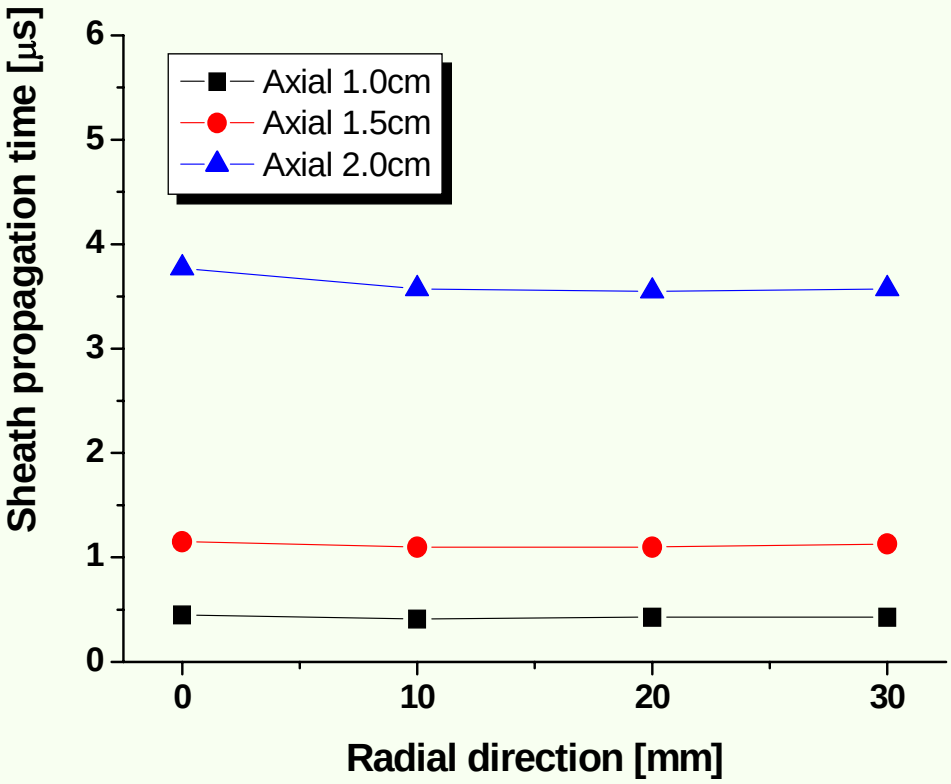
A sudden decrease in the probe current



Sheath edge arrival !!

Results – (1) : Planar electrode

Sheath evolution at radial direction

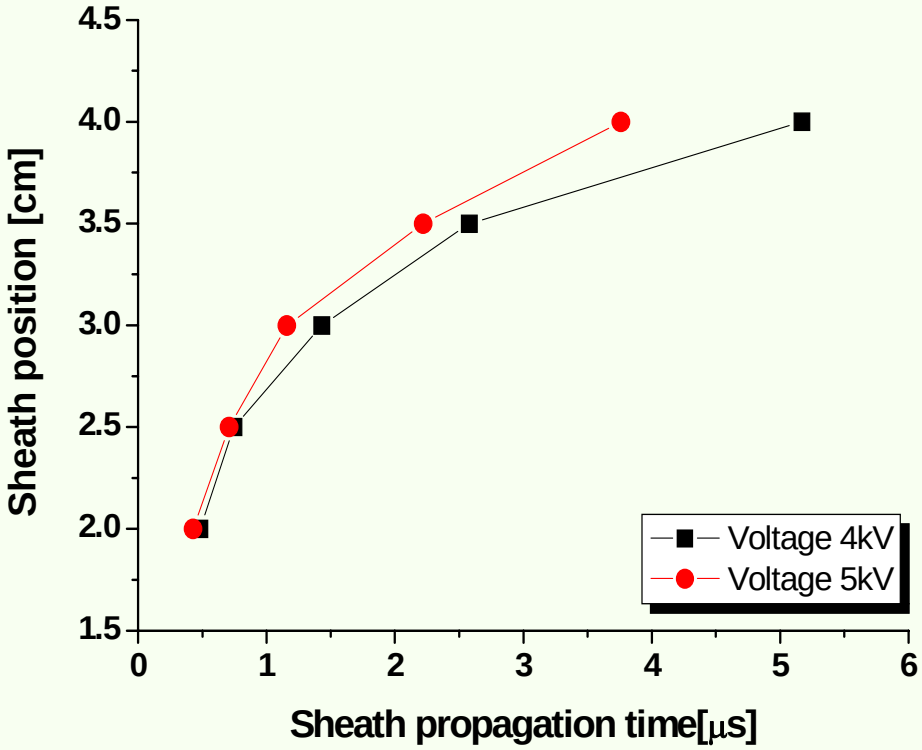


Experimental condition

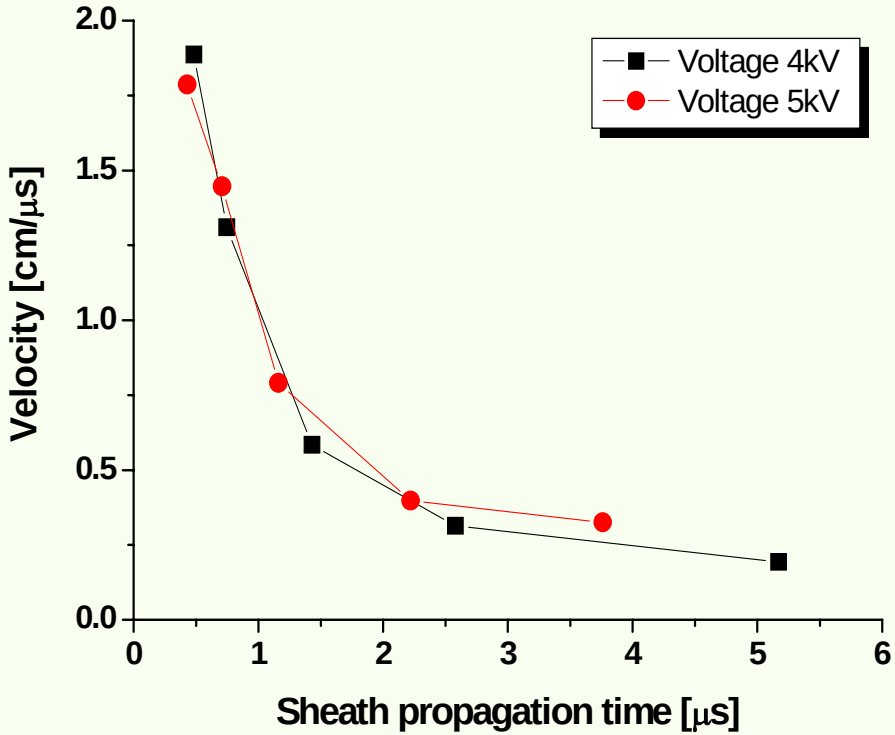
- Target voltage = 5 kV
- Gas pressure = 0.1 mTorr
- Planar electrode
  - material : stainless steel
  - diameter : 100 mm
  - thickness : 3.5 mm

Results – (1) : Planar electrode

Sheath evolution at axial direction



Sheath edge velocity at axial direction



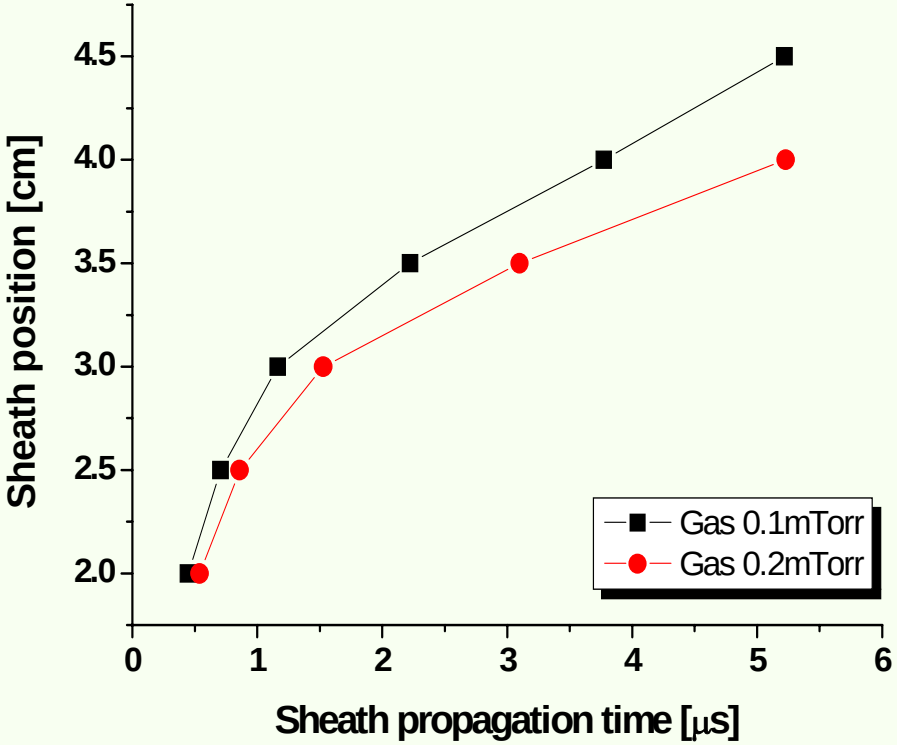
Ion matrix sheath evolution

Target voltage 4 kV → 1.05×10^6 cm/sec

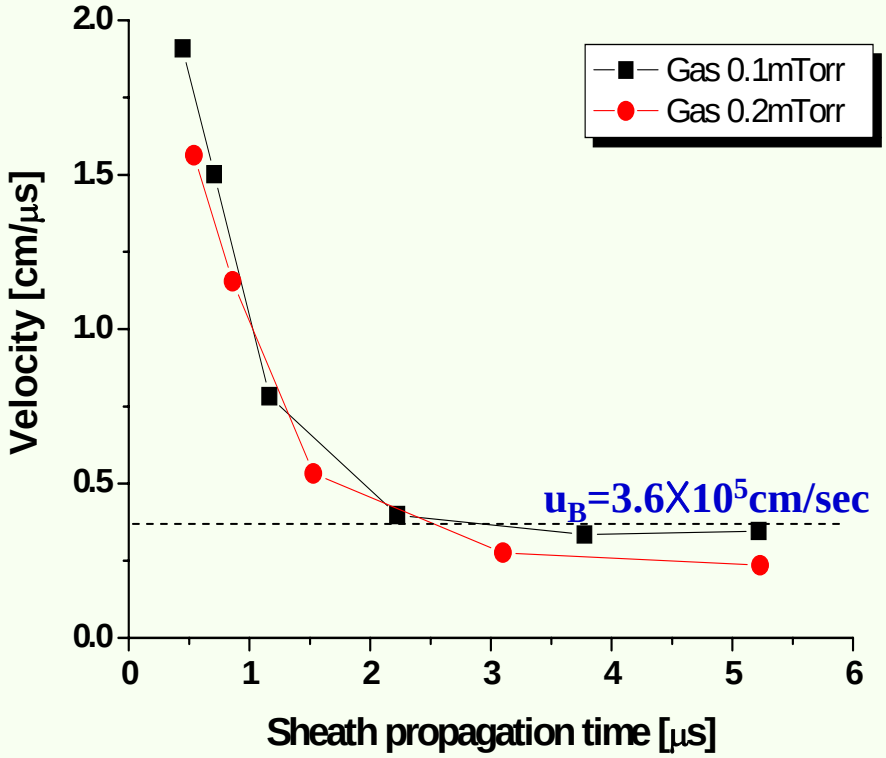
Target voltage 5 kV → 1.37×10^6 cm/sec

Results – (1) : Planar electrode

Sheath evolution at axial direction



Sheath edge velocity at axial direction



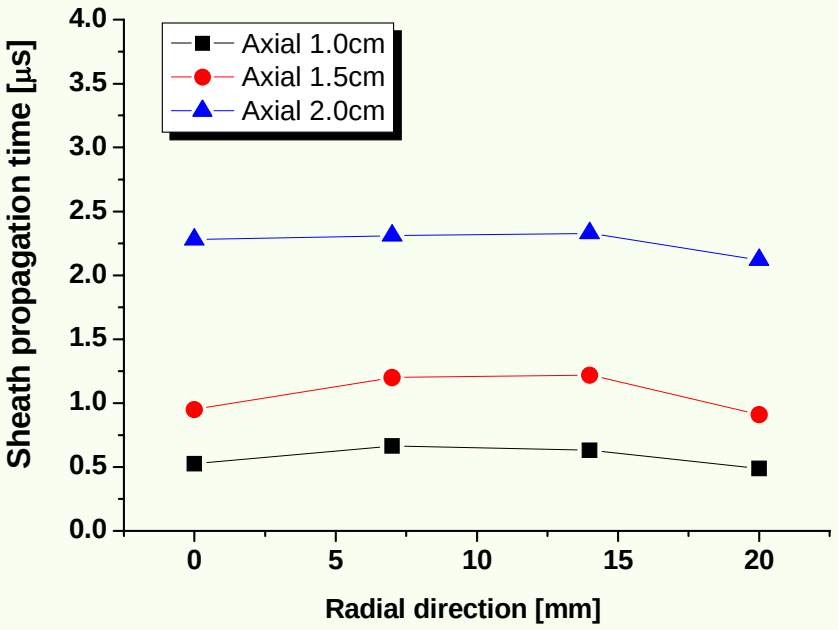
Target voltage 0.1 mTorr → 1.4X10^6 cm/sec

Target voltage 0.2 mTorr → 1.01X10^6 cm/sec

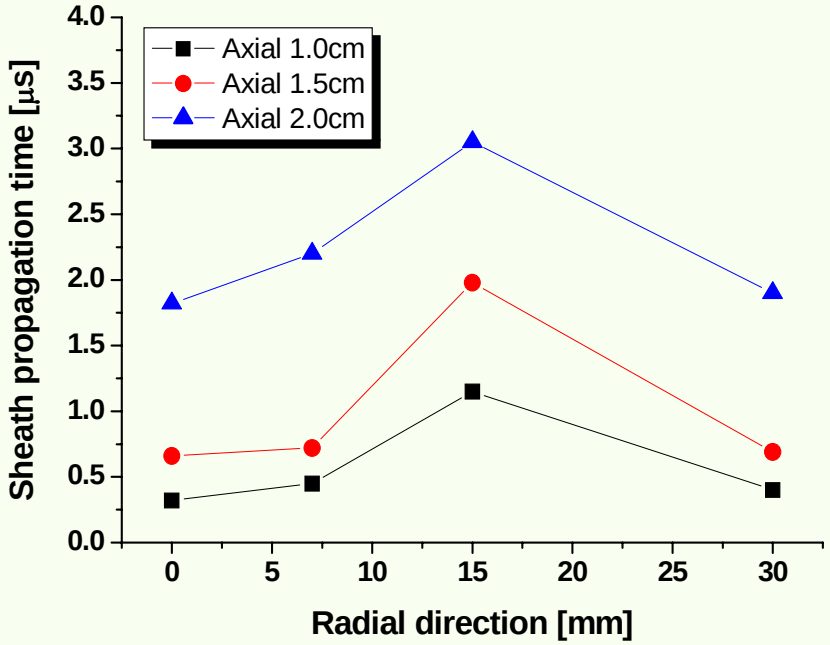
Results – (2) : Grid electrode

◈ **Characteristics of radial sheath evolution: Gas 0.1mTorr , Target voltage 5kV**

Grid hole 20 mm



Grid hole 30 mm

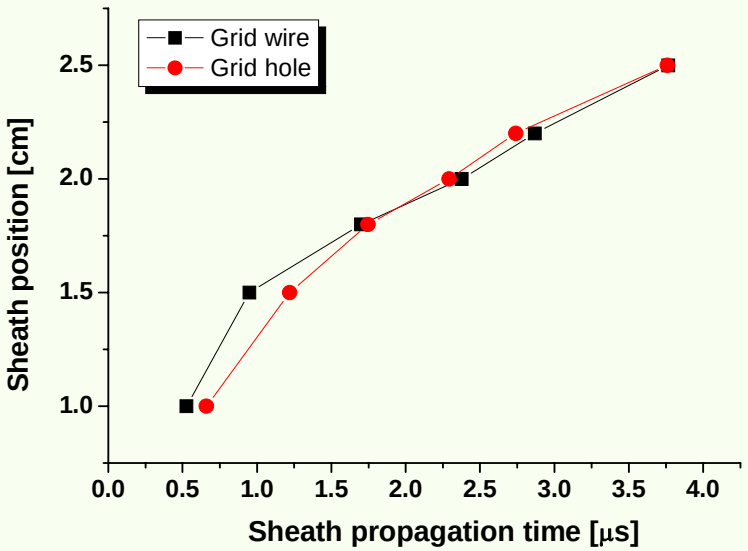


- **Sheath expansion for grid electrode with hole size 20mm is similar to planar electrode.**
- **Grid hole size is the bigger, arrival time of sheath edge is longer.**

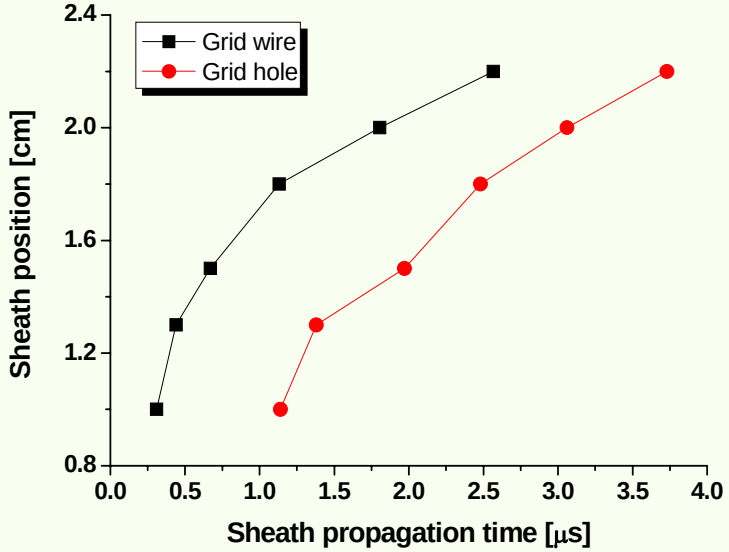
Results – (2) : Grid electrode

◈ Characteristics of axial sheath evolution: Gas 0.1mTorr, Target voltage 5kV

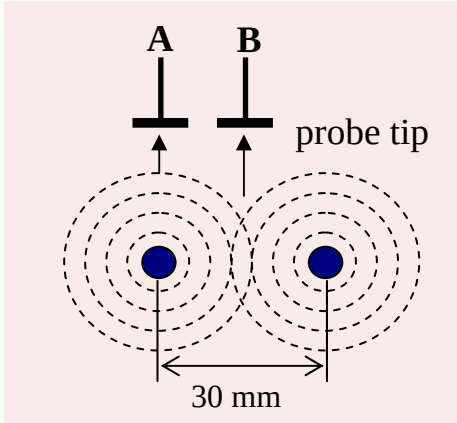
Grid hole 20 mm



Grid hole 30 mm



	Grid hole 20 mm	Grid hole 30 mm
Above wire	Initial stage: u_s=1.2X10^{6}cm/sec Latter stage: u_s=3.4X10^{5}cm/sec	Initial stage: u_s=1.38X10^{6}cm/sec Latter stage: u_s=3.7X10^{5}cm/sec
Above hole	Initial stage: u_s=0.9X10^{6}cm/sec Latter stage: u_s=3.5X10^{5}cm/sec	Initial stage: u_s=6.0X10^{5}cm/sec Latter stage: u_s=3.9X10^{5}cm/sec



Superposition of sheath expansion !!

Conclusion

◈ The aim of this research is to demonstrate the sheath evolution for grid electrode.

◈ Grid electrodes with hole size 20 mm, 30 mm have been used. We have measured the sheath propagation time using Langmuir probe.

◈ In planar electrode, the sheath edge velocity was higher than ion acoustic speed in initial stage(~1.5 μs) and the latter stage was comparable to the ion acoustic speed.

◈ In grid electrode, the sheath edge velocity above grid hole is slower than above grid wire in initial stage. Sheath expansion above grid hole is superposition of expanding sheath from wires.