

Measurement of Characteristics of di/dt and Discharge Mode in Negatively Pulsed Plasma

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Introduction

Breakdown

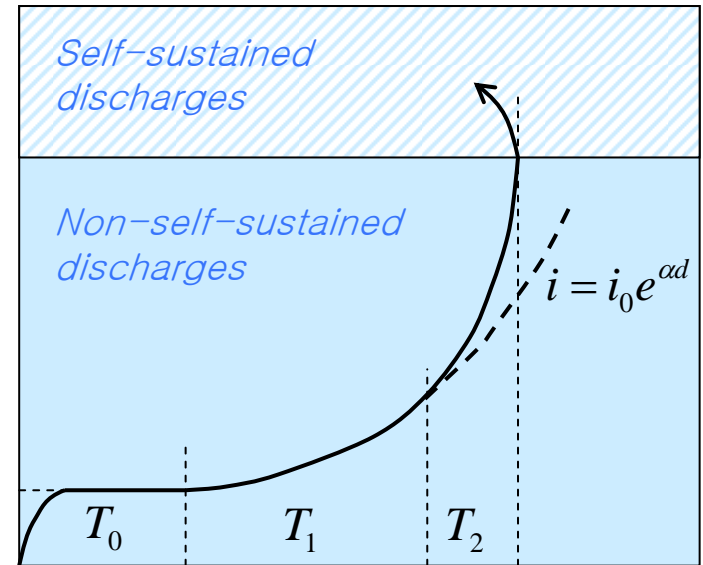
Nonsustaining Discharge



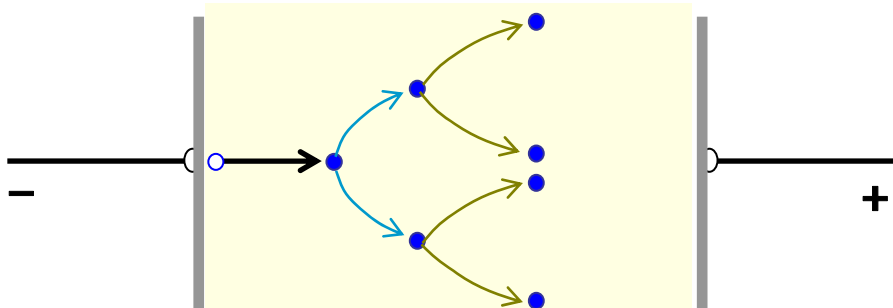
Self-sustaining Discharge

The condition for the discharge to be self-sustained,

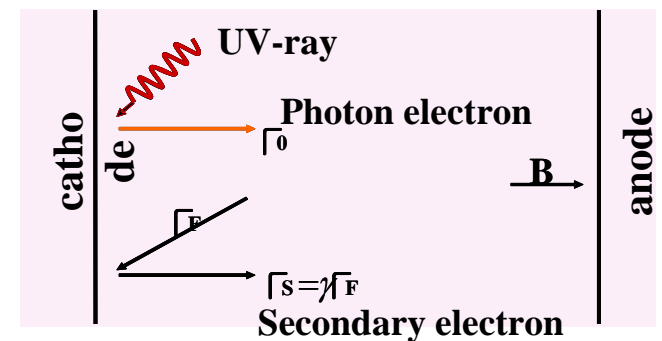
$$\mu = \gamma(e^{\alpha d} - 1) \geq 1$$



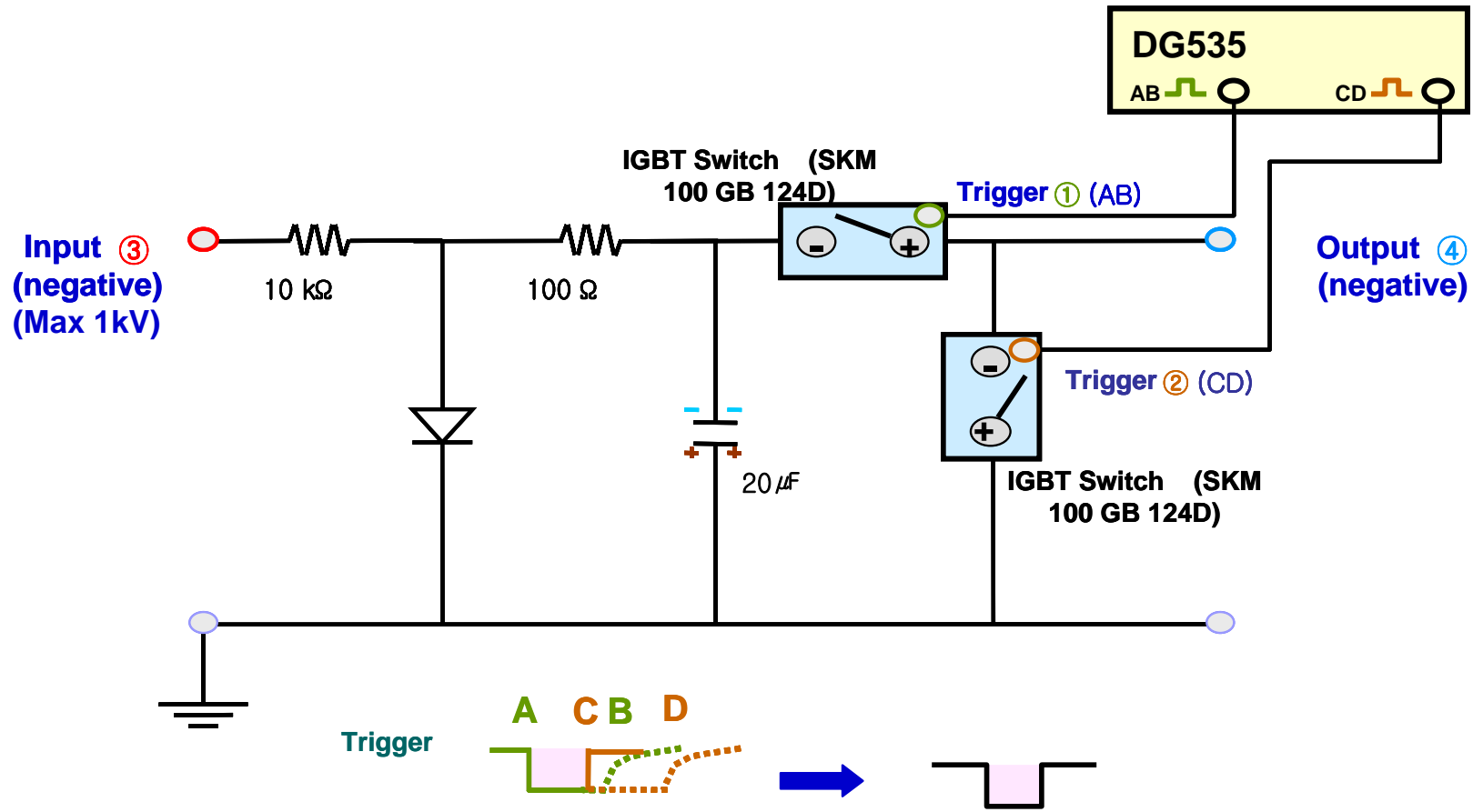
α -discharge process



γ -discharge process



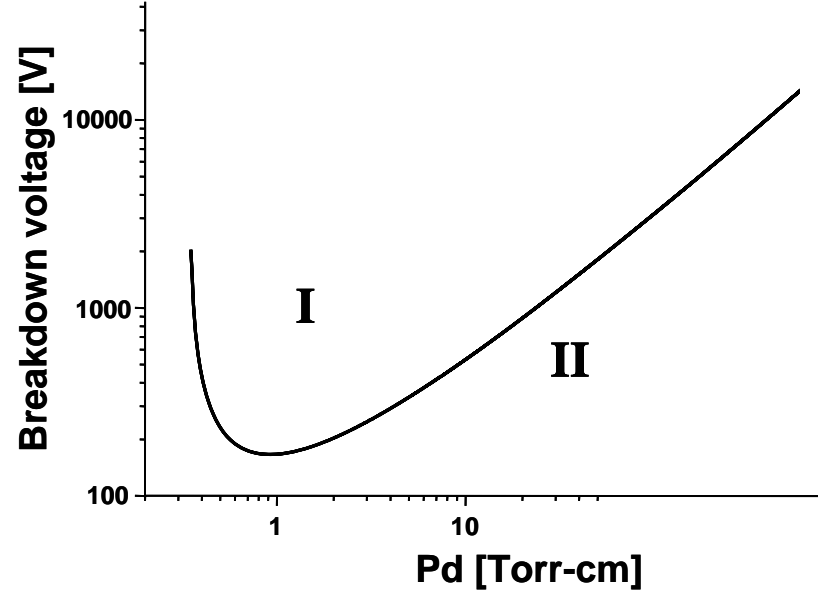
Experimental setup



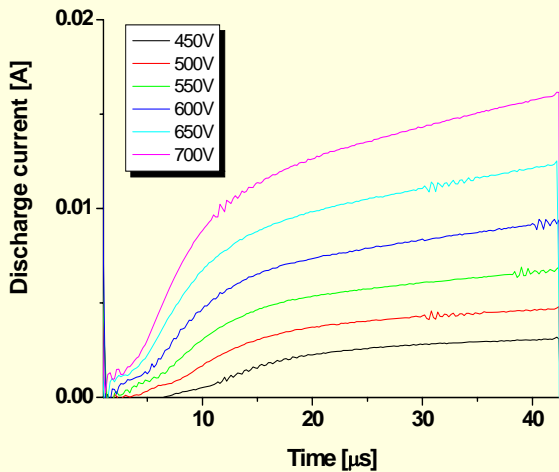
Current characteristics for time evolution

◆ Experimental region: Region I

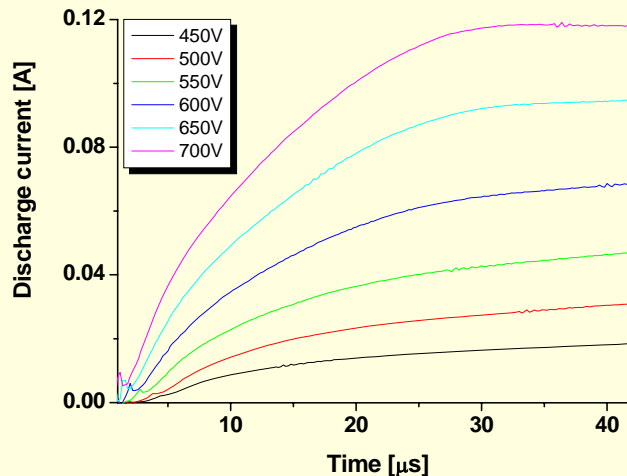
- Base pressure: 5.5mTorr
- Neutral filling gas pressure: 110mTorr~500mTorr
- Electrode's diameter: 5cm and 10cm
- Gas distance: 2cm and 8cm
- Electrode bias voltage: 450V~700V
- Repetition rate: 10Hz



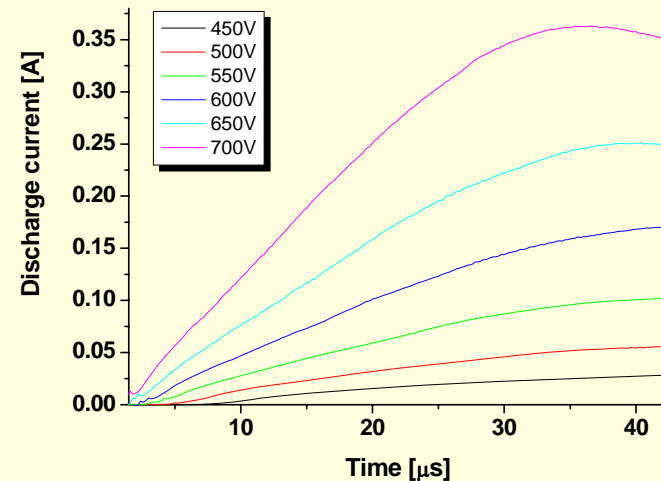
Gas pressure: 110mTorr



Gas pressure: 300mTorr



Gas pressure: 500mTorr



di/dt characteristic for discharge condition

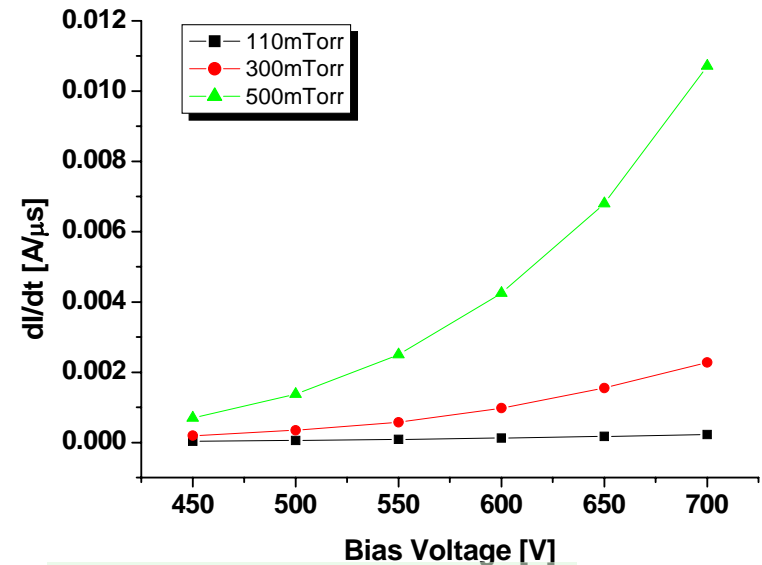
Case I: V is proportional to di/dt from $P \propto V^2$

Case II: Gas pressure is proportional to di/dt
from cross section increasing

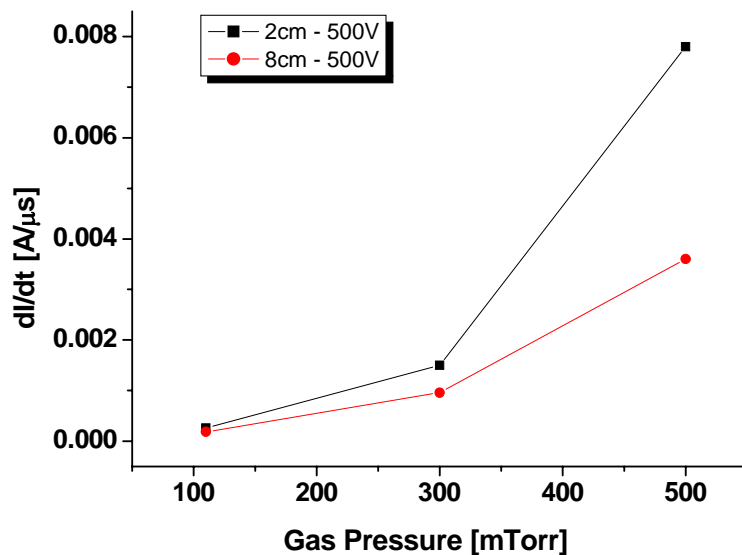
Case III: $\left(\frac{dI}{dt}\right)_{2\text{cm}} - \left(\frac{dI}{dt}\right)_{8\text{cm}} = k$ (k is constant)

$$(I)_{2\text{cm}} - (I)_{8\text{cm}} = kt \ll 1$$

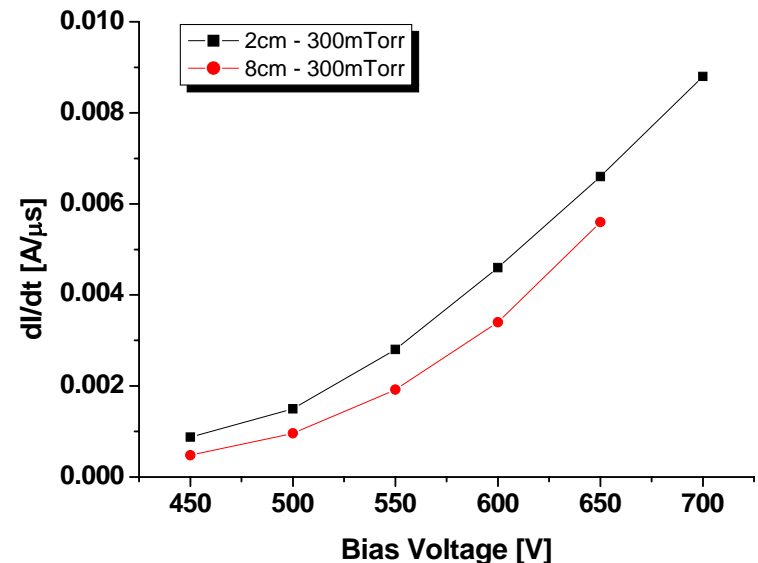
Case I Gap distance: 2cm, Electrode's diameter: 5cm



Case II: Electrode's diameter: 10cm

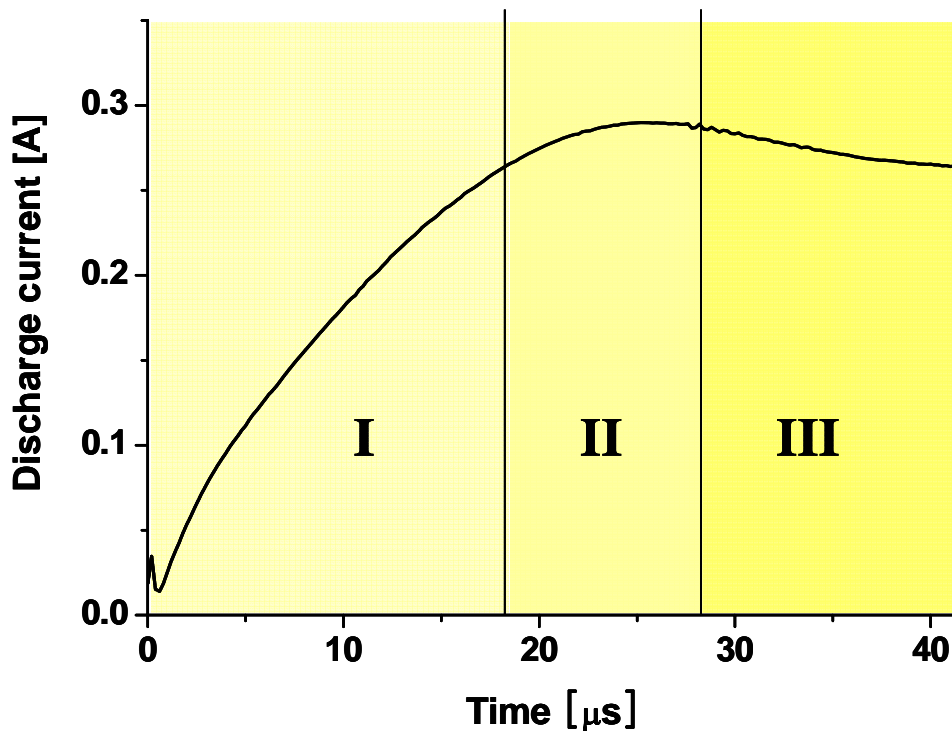


Case III: Electrode's diameter: 10cm

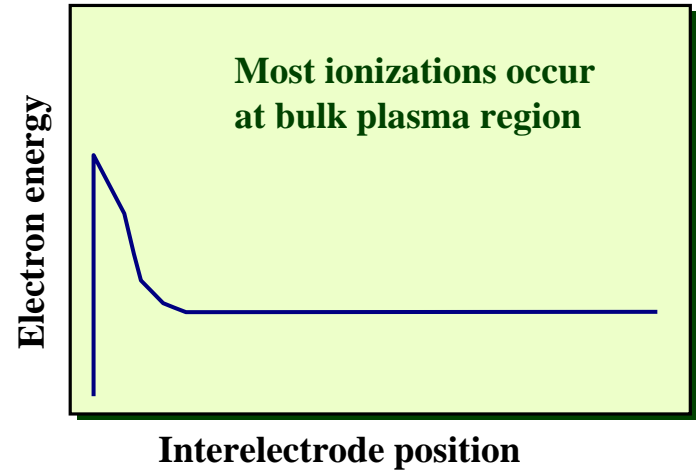


Discharge mode for time evolution

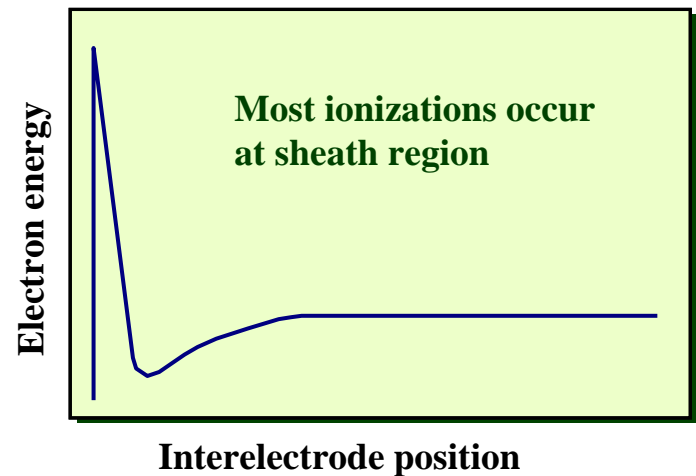
- ◆ Region I: α -discharge mode
- ◆ Region II: co-exist discharge mode
- ◆ Region III: γ -discharge mode



Electron energy profile in α -mode



Electron energy profile in γ -mode

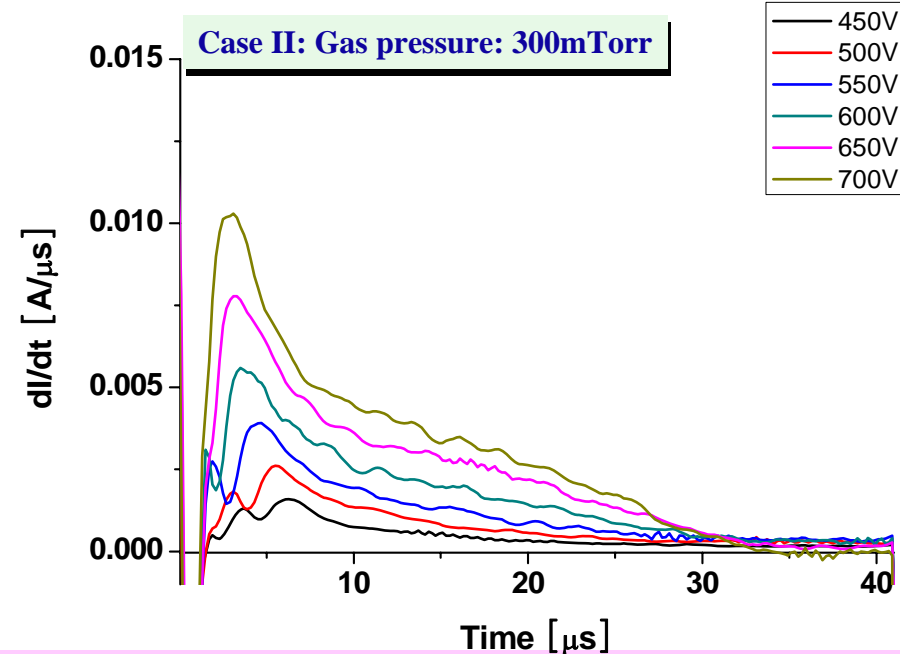
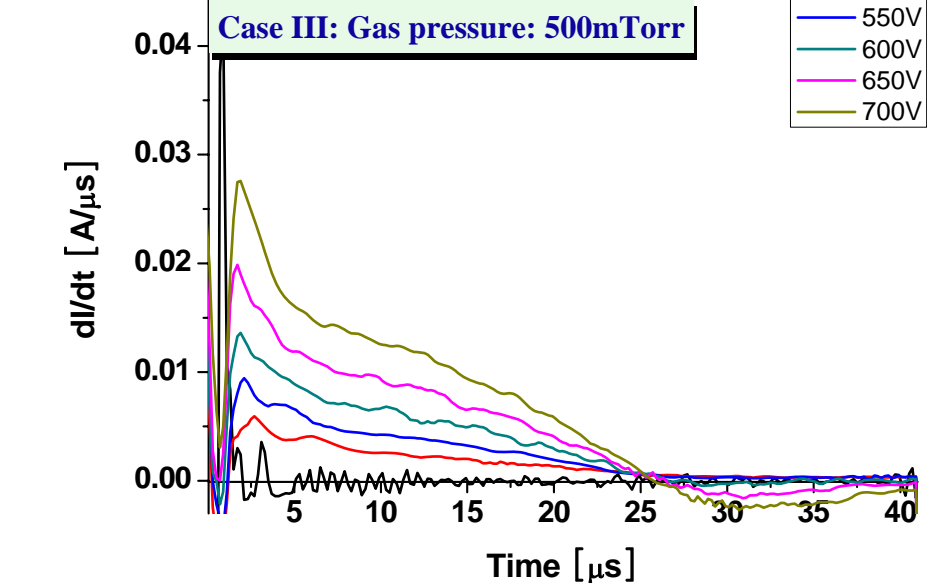
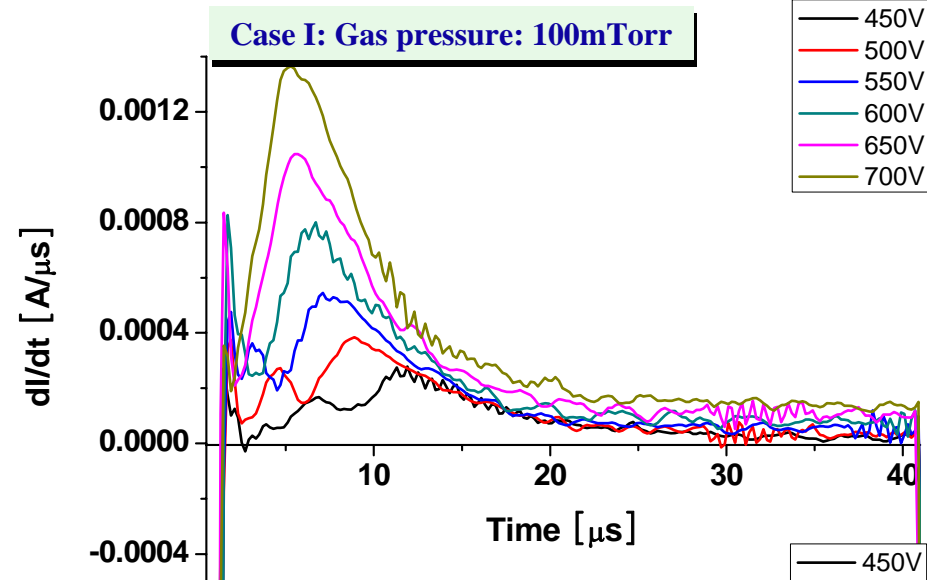


Mode transition for time evolution

◆ Electrode's diameter: 5cm

◆ Gap distance: 2cm

- Case I and Case II except 700V are α -mode
- Case II of 700V and Case III of 650~700V are γ -mode (sign of dI/dt inversion)
- γ -mode discharge occurs at the similar time



Mode transition for time evolution

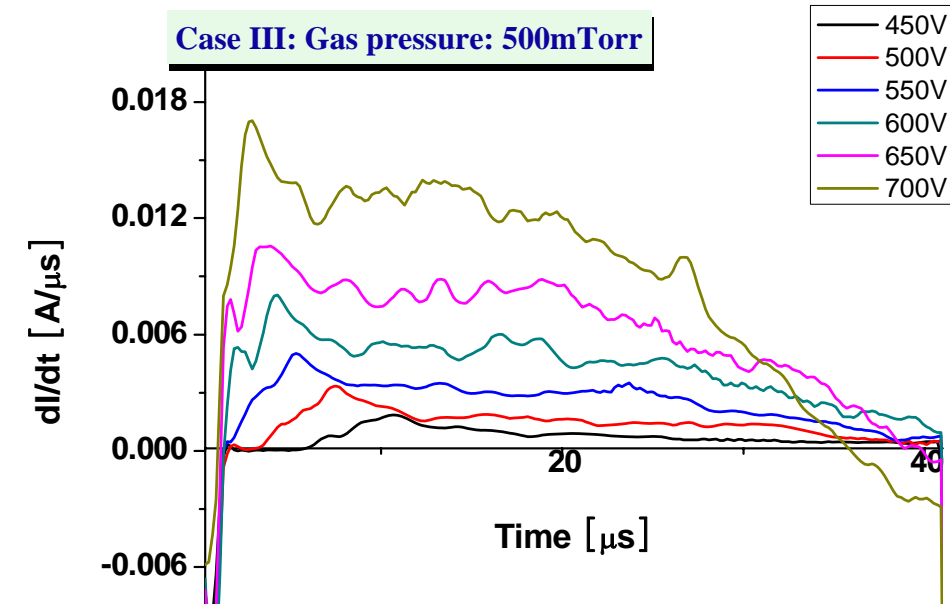
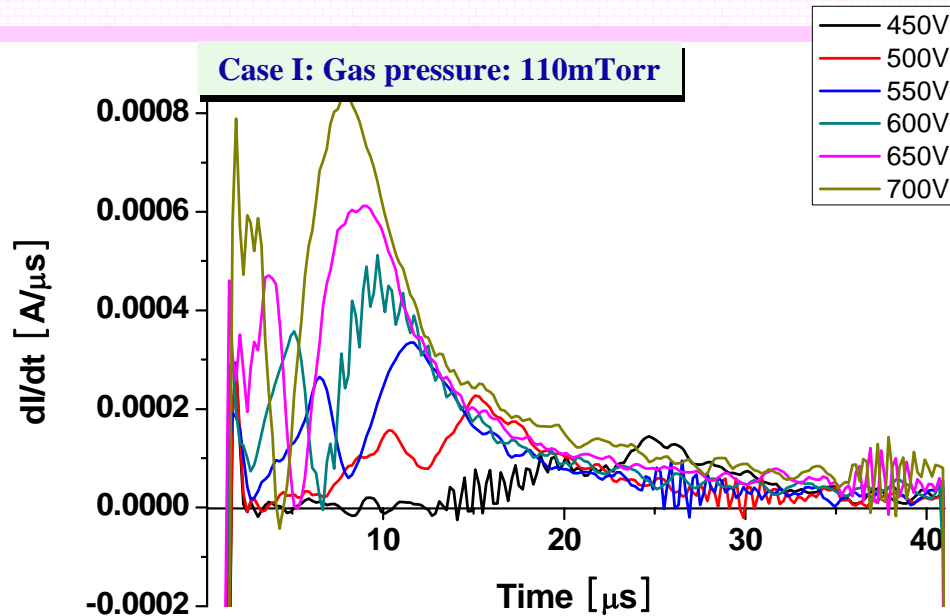
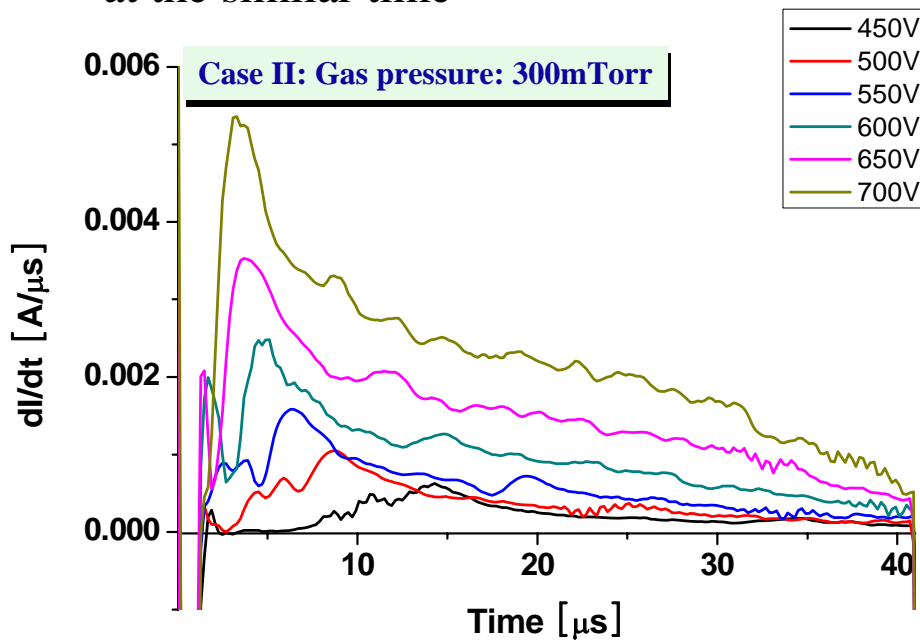
◆ Electrode's diameter: 5cm

◆ Gap distance: 8cm

- Case I and Case II are α -mode
- Case III of 650~700V are γ -mode

(sign of dI/dt inversion)

- γ -mode discharge doesn't happen at the similar time

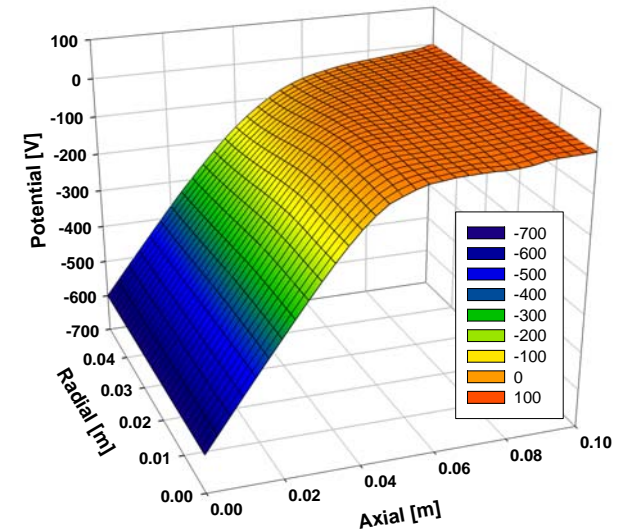


Result of Xoopic Simulation

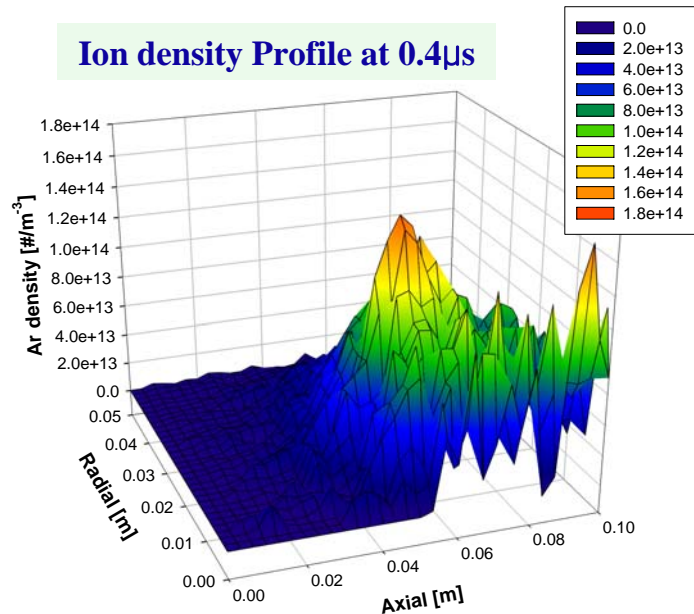
◆ Discharge mode is α -mode

- The sheath thickness is thick
- The sheath potential is sluggish
- A ionization by collision occurs in bulk plasma
- Without ionization at sheath most electrons move in bulk plasma by low electron energy

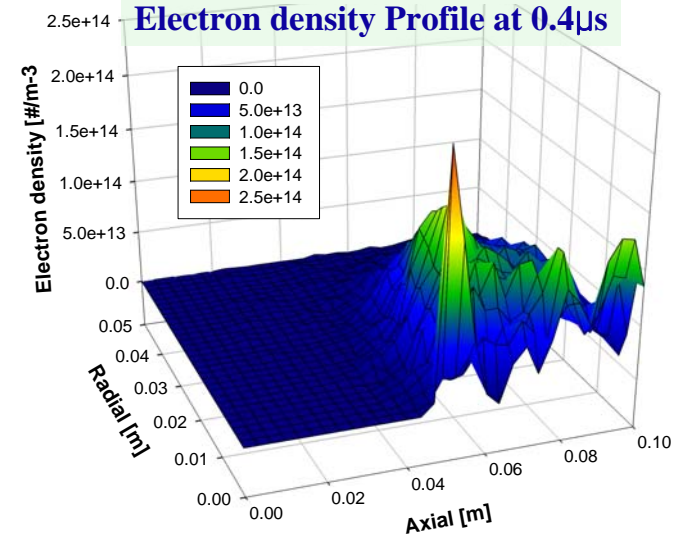
Potential profile at $0.4\mu\text{s}$



Ion density Profile at $0.4\mu\text{s}$



Electron density Profile at $0.4\mu\text{s}$

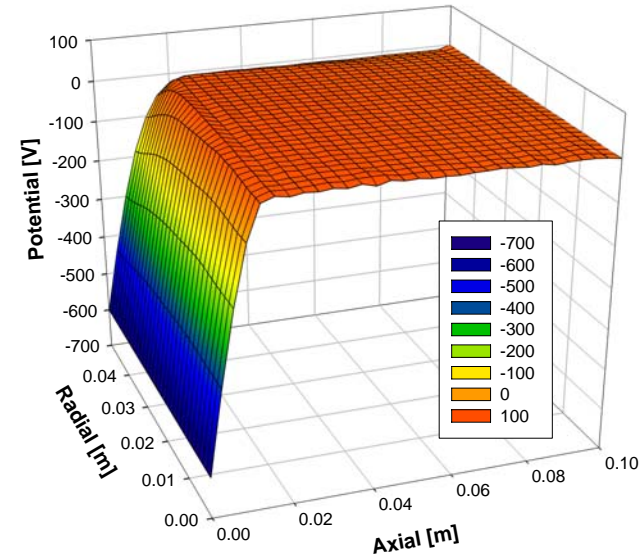


Result of Xoopic Simulation

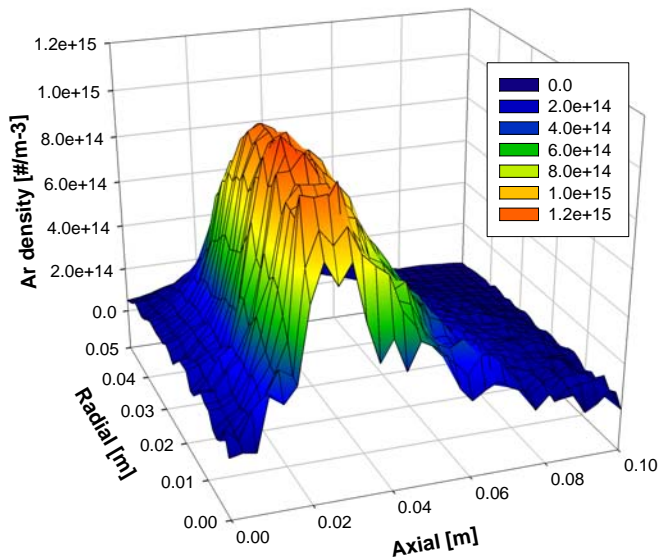
◆ Discharge mode is γ -mode

- The sheath thickness is thin
- The sheath potential is sharp
- Most ionizations by collision occur in sheath
(High electron energy)

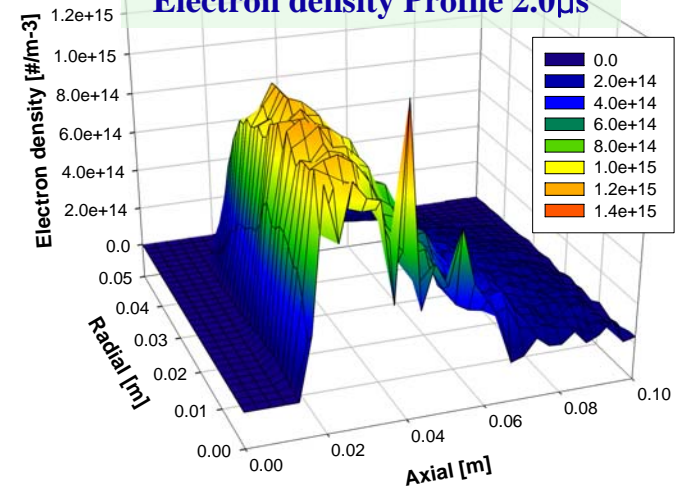
Potential profile at 2.0 μ s



Ion density Profile 2.0 μ s



Electron density Profile 2.0 μ s



Conclusion and future work

Conclusion

We measured the dI/dt value for several conditions and have studied for meaning of dI/dt .

- ◆ Profiles of discharge current for time evolution are three types for discharge.
- ◆ Neutral gas filling pressure and electric field between electrodes are dominant to dI/dt .
- ◆ If gap distance and neutral gas filling pressure are fixed, bias voltage is not dominant to dI/dt .
- ◆ The phase of dI/dt is means to discharge mode.
- ◆ The positive phase of dI/dt is α -mode, and the negative phase of dI/dt is γ -mode.

Future work

- ◆ Measurement of spatial light intensity profile of plasma for time evolution and find discharge-mode characteristics through calculating ionization cross section and experiment's result