Magnetron Discharge Characteristics for the improvement of IEC Performance

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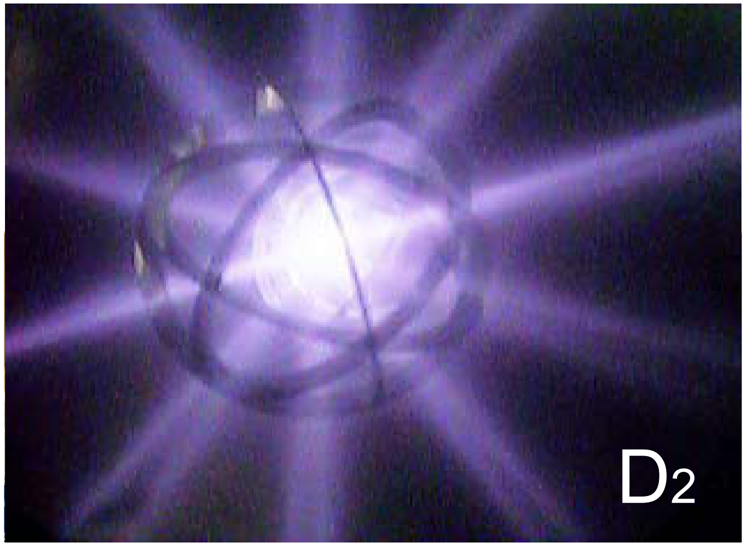
IECF device



transparency ：~96%

cathode
made of Ta
I.D. : 50 mm
O.D. : 60 mm
thickness : 0.3 mm

6 rings

Vacuum chamber
(anode）
SUS 304
I.D. : 340 mm
thickness ：3 mm

Objectives (1)

So far

- Ions were produced mainly by glow discharge.

↓

P, *V*, and *I* can not be chosen as independent variables.

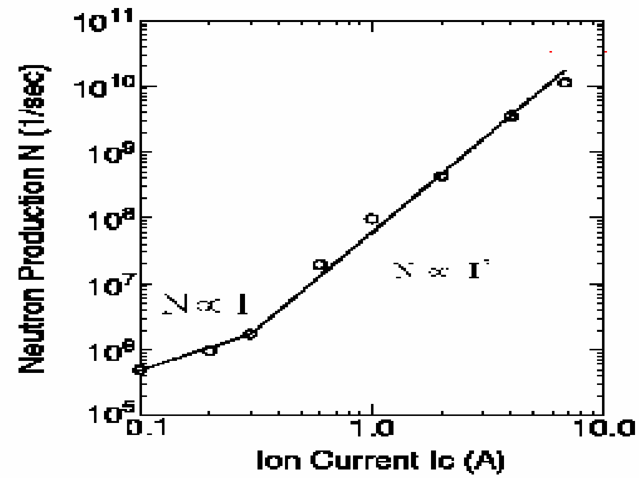
- A beam-background colliding fusion was dominant.

To get higher neutron production rate

Low *P*, high *V*, and large *I* operation is required.

↓

A beam-beam colliding fusion would be dominant.



Simulation study predicts $N \propto I^3$ [1]

[1] M. Ohnishi, et al., “Correlation between potential well structure and neutron production in inertial electrostatic confinement fusion”, Nucl. Fusion **5** (1997) 611-619.

Objectives (2)

To attain a low pressure operation

→ Using external ion sources

↓ However

Most of them complicate the IECF device.

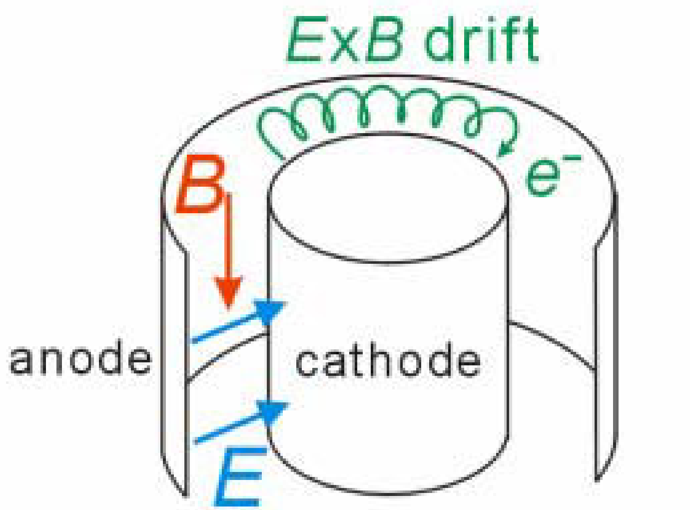
For the applications including a portable neutron source, the device has to be compact and simple.

In this study,we propose use of **magnetron discharge plasmas** as an ion source.

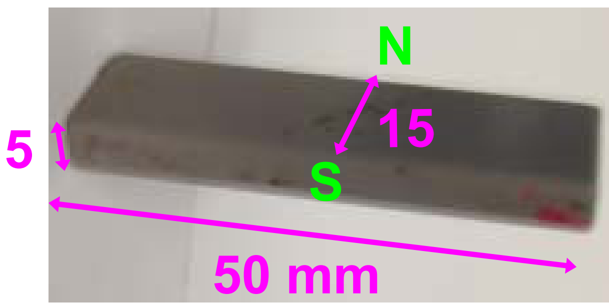
↓

The device is composed of extremely compact and simple instruments.

Magnetron discharge

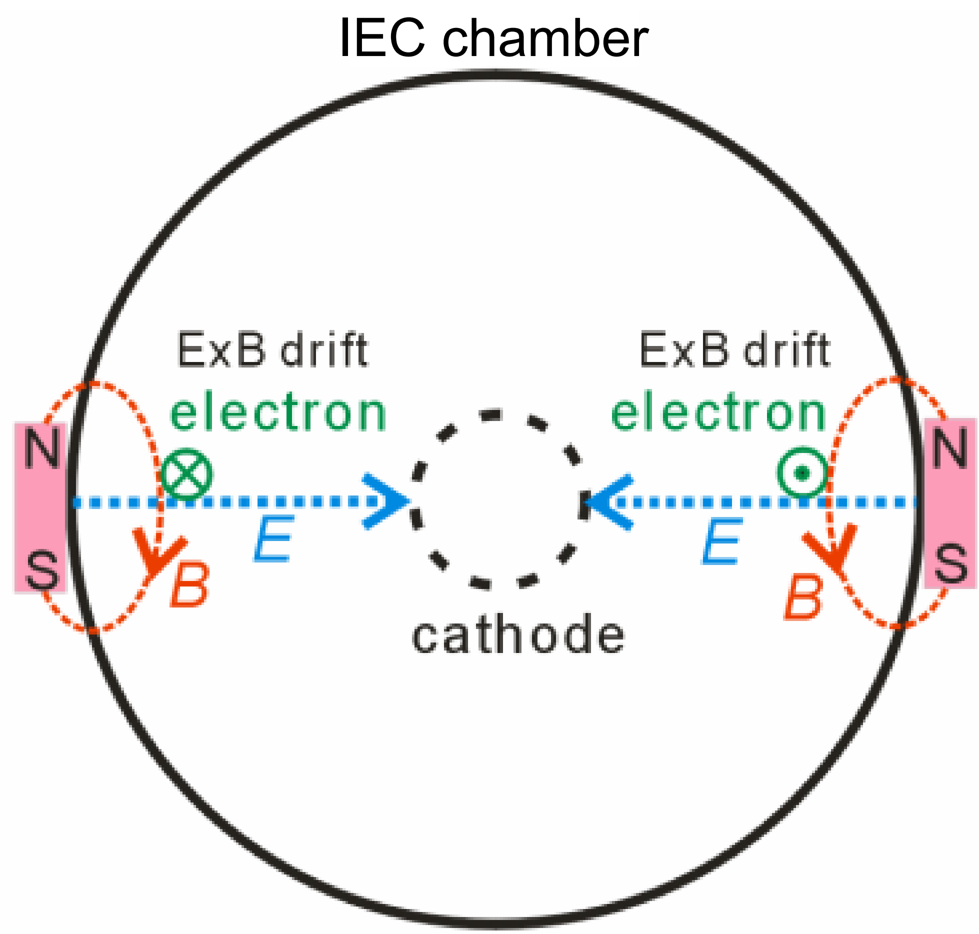


Principle of magnetron discharge



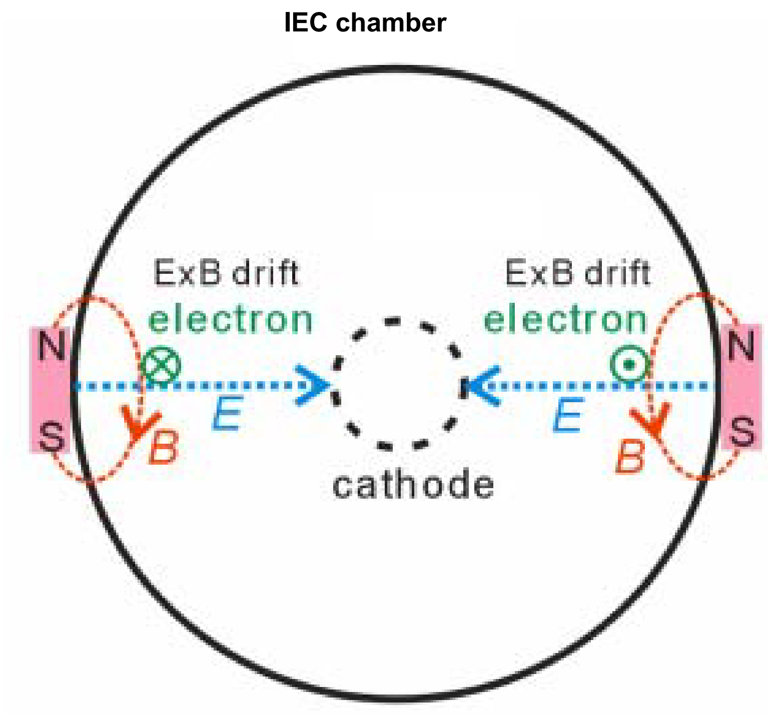
Max 3000 gauss (Sm-Co)

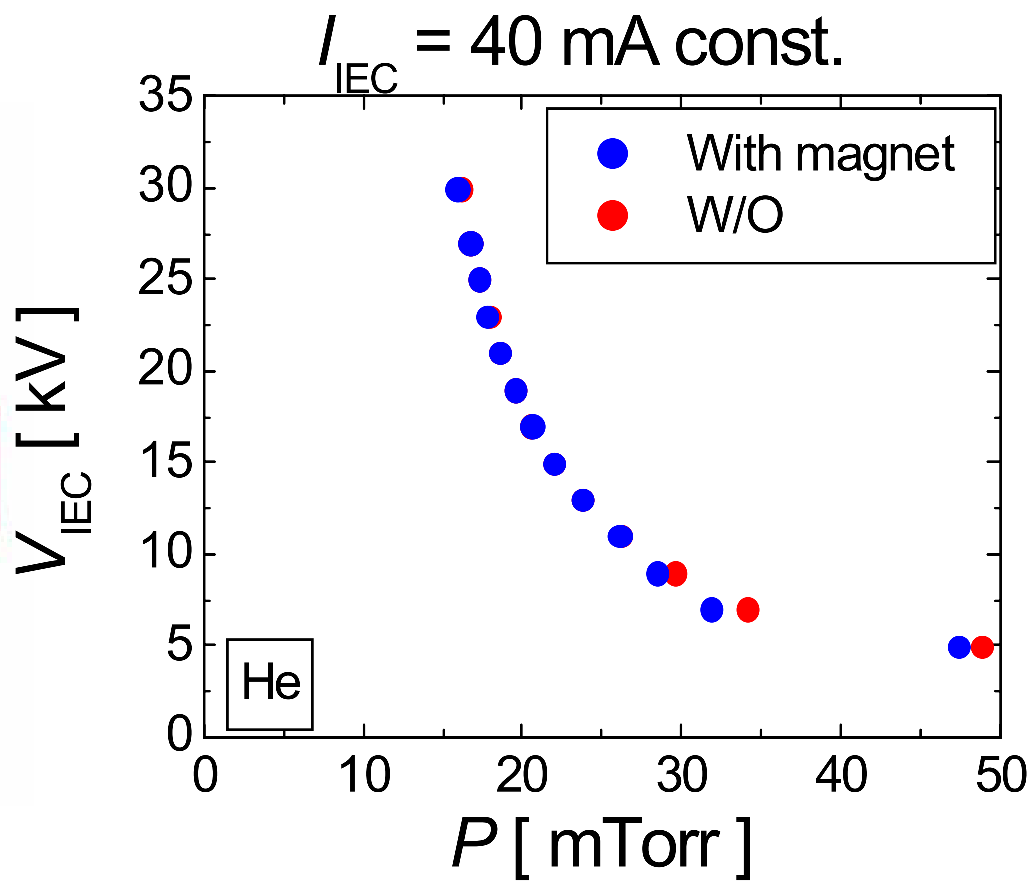
Magnet for magnetron discharge



Application to IEC

IEC discharge with equator magnet array

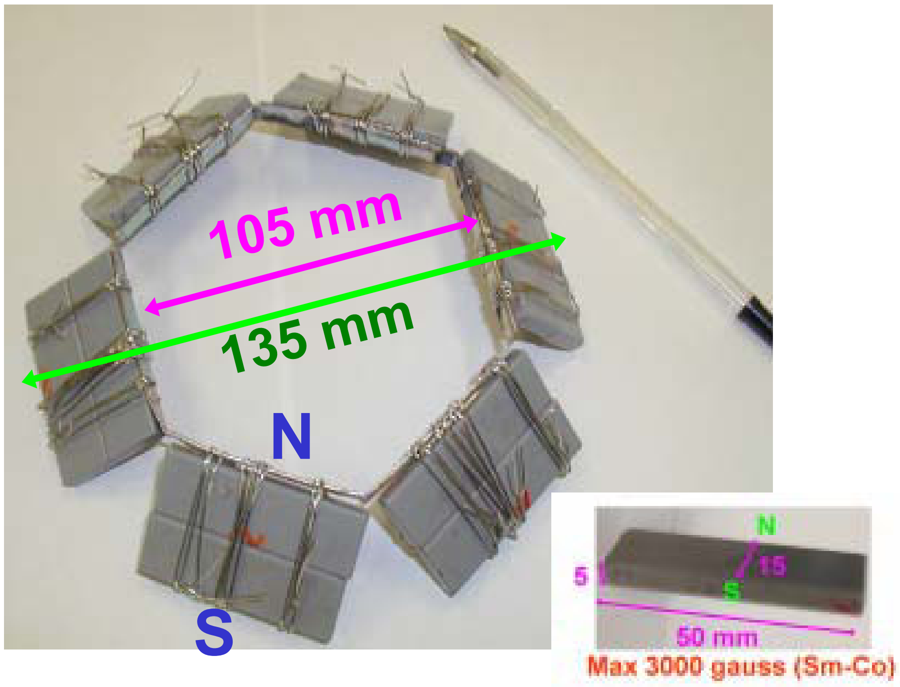




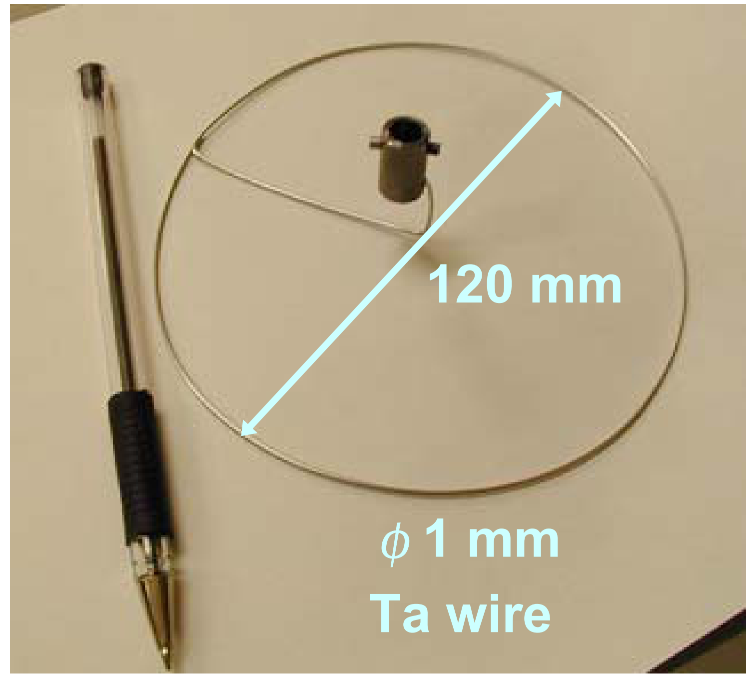
The magnets doesn't have much effect on the discharge characteristics.

Electrons reach the chamber without crossing magnetic field and carrying out ExB drift.

Instruments for magnetron discharge with an anode

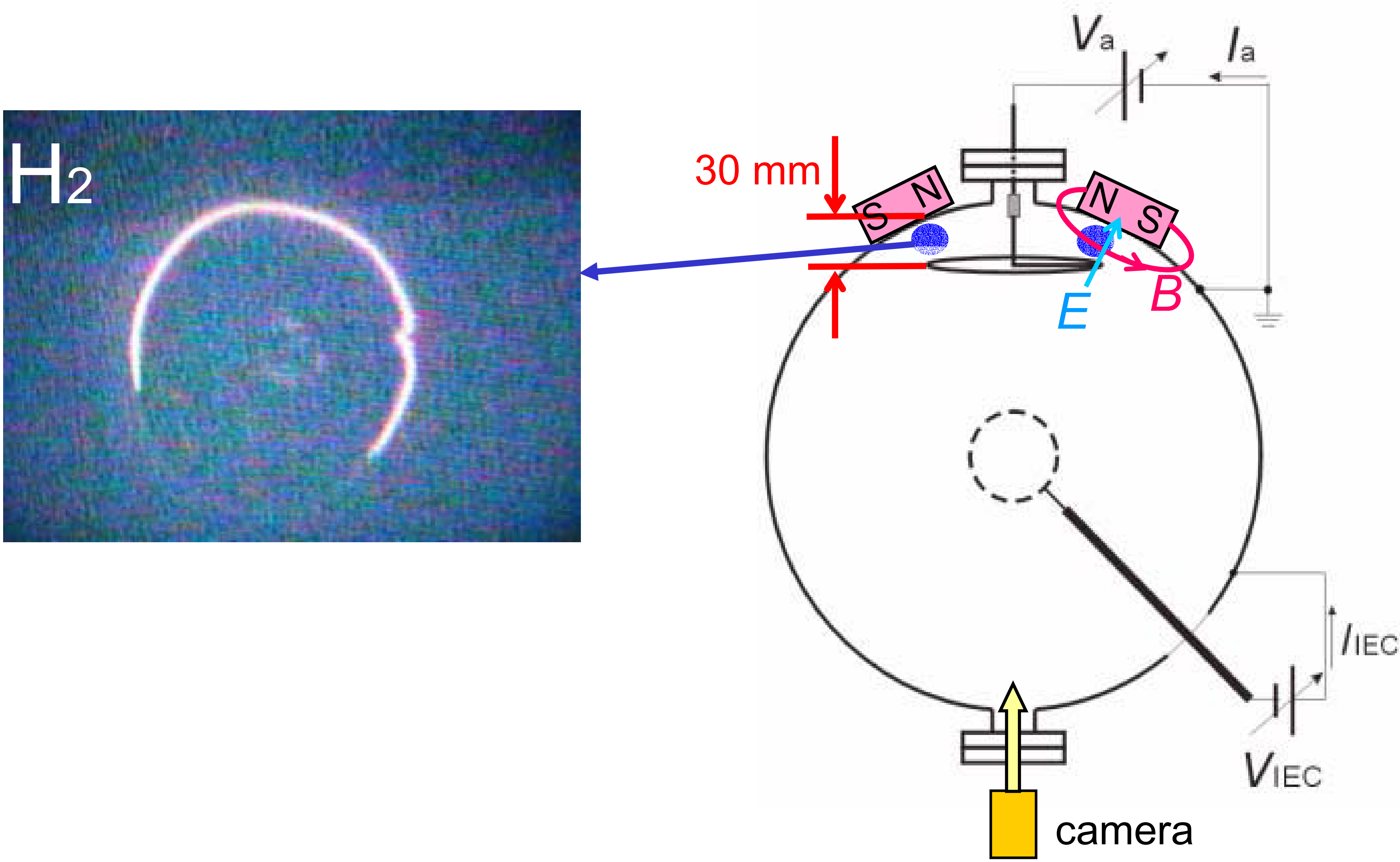


A permanent magnet array
(ring array)

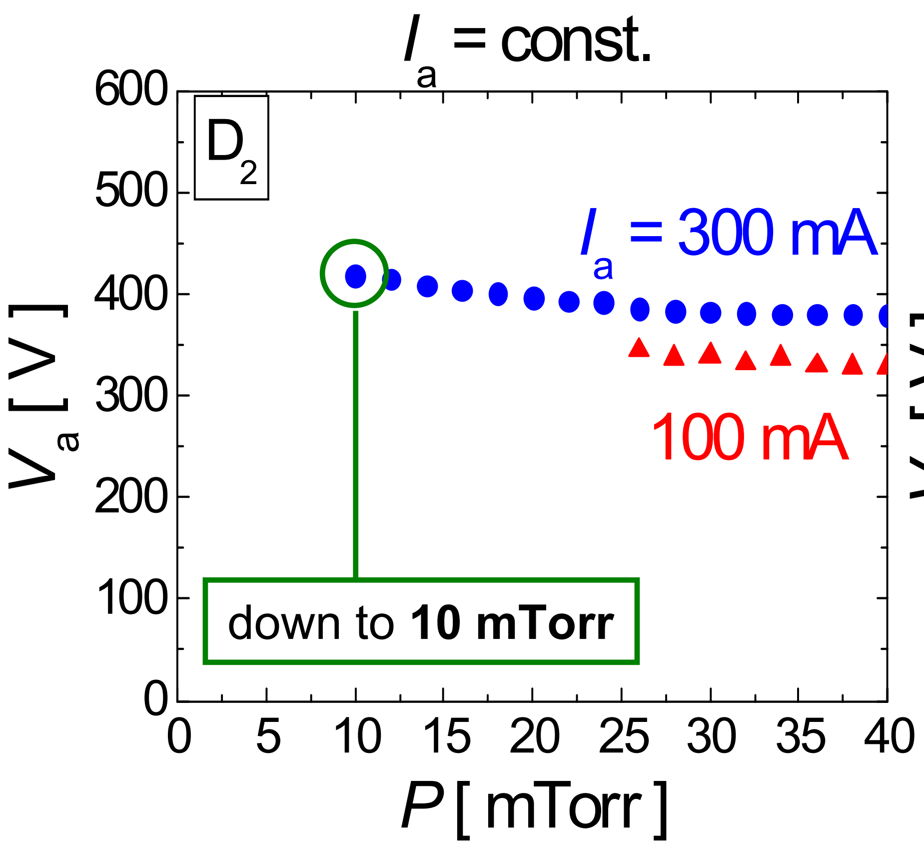


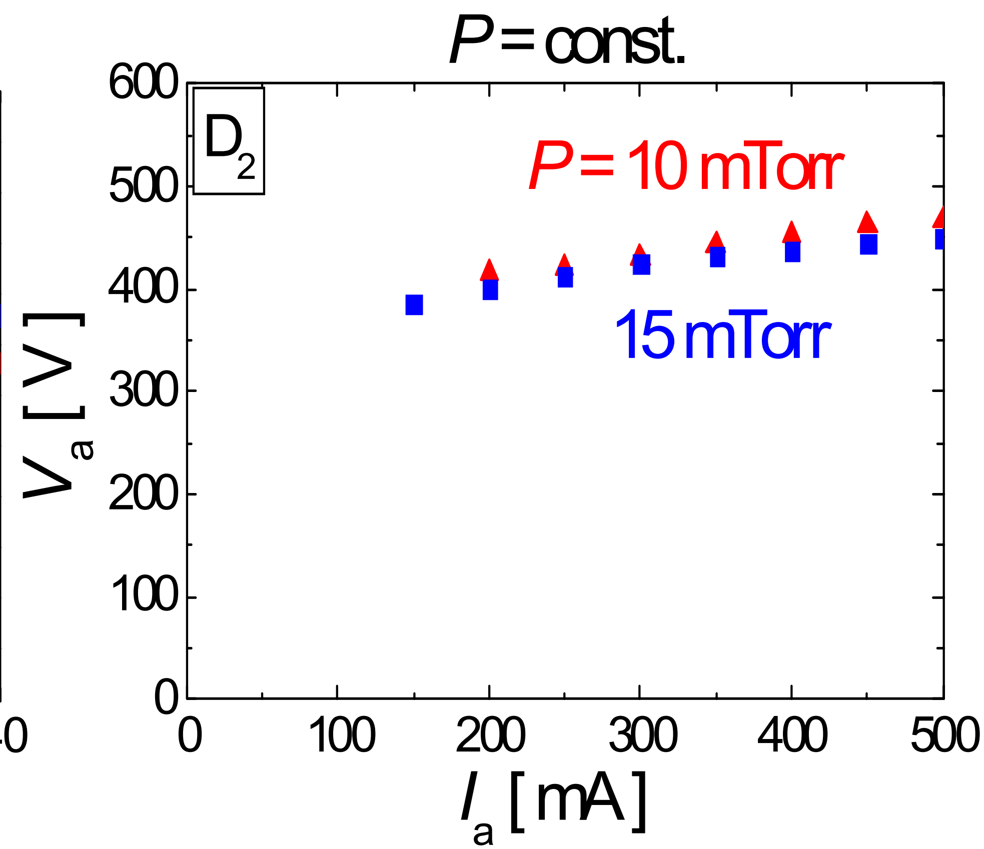
An additional ring anode
in the chamber

Schematic diagram for magnetron discharge with an anode



Magnetron discharge with an anode (V_{IEC} = 0 V)





The magnetron discharge was maintained at 10 mTorr.

Large I_a is needed as P decreases.

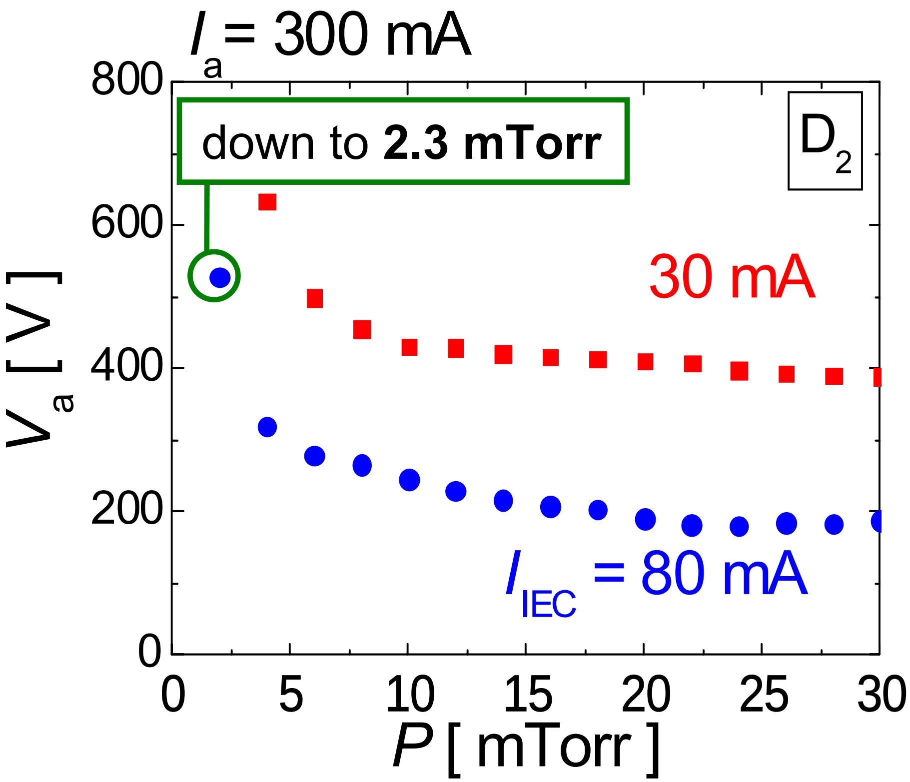
V_a doesn't depend on P.

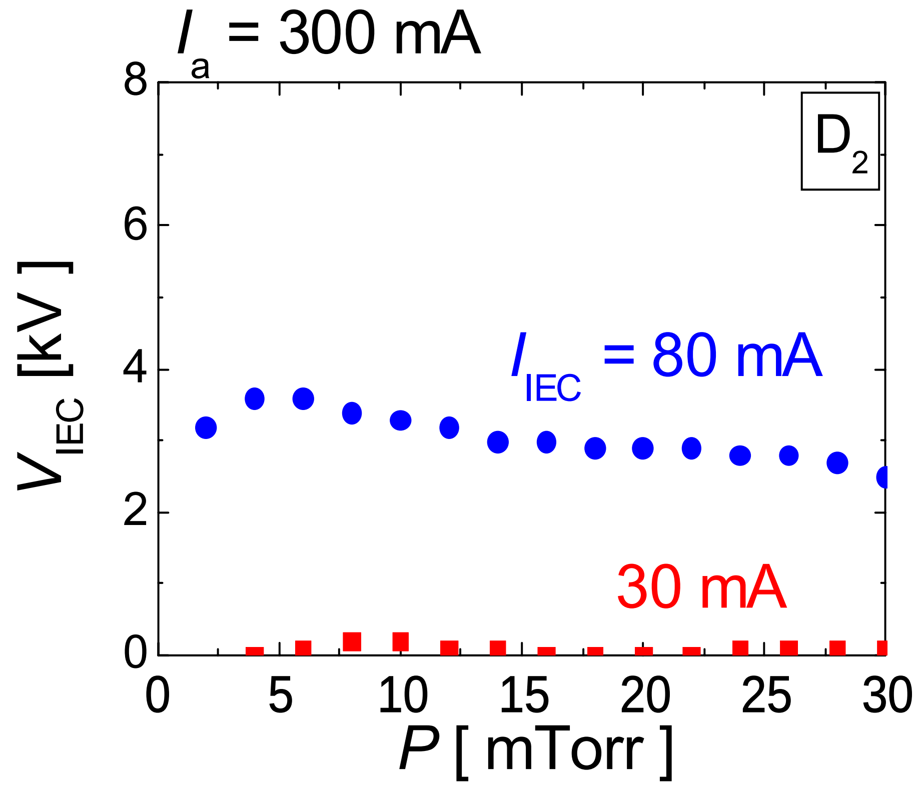
To maintain magnetron discharge, sufficient I_a is needed

Secondary electrons by ion impact with the chamber are needed for the magnetron discharge maintenance.

Glow/Magnetron hybrid discharge with an anode

I_a = 300 mA, I_{IEC} = 30, 80 mA const.





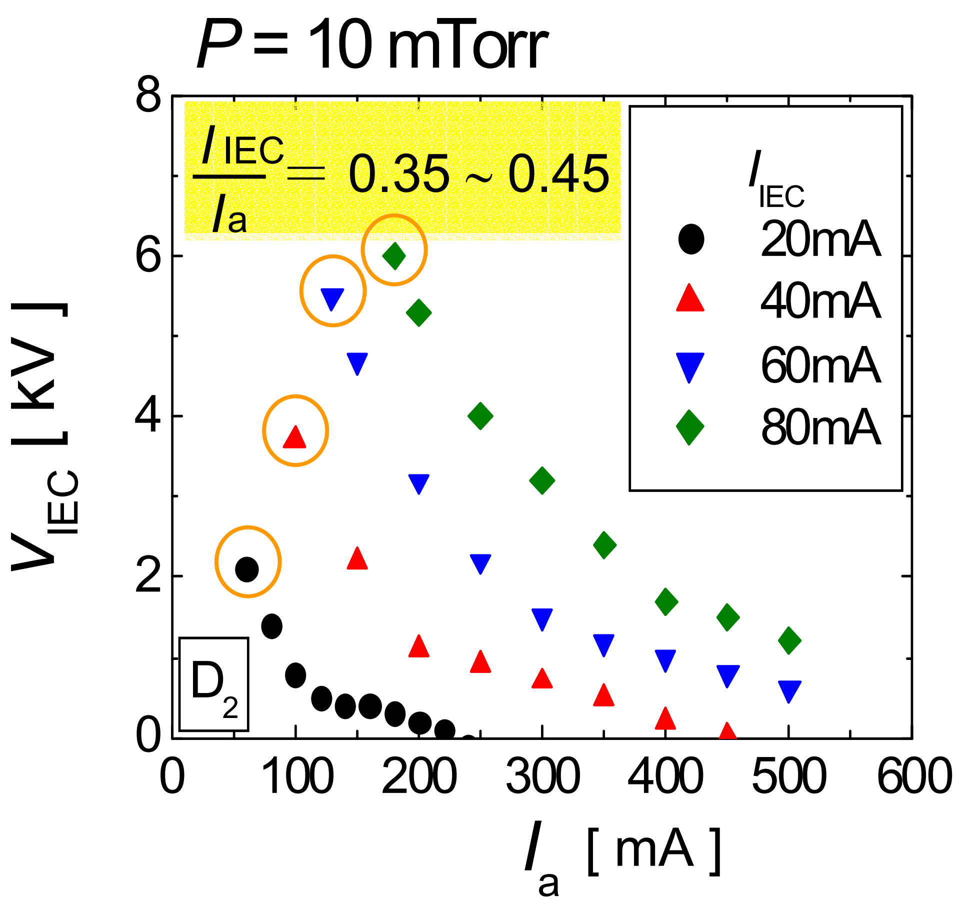
Magnetron discharge was maintained at lower *P* with glow discharge.

Electrons from glow discharge relate to the magnetron discharge.

IEC discharge was maintained at lower pressure than that only glow discharge. High voltage couldn't be applied to the IEC cathode.

Major part of ions is provided from magnetron discharge.

Glow/Magnetron hybrid discharge with an anode



V_{IEC} increases as I_a decreases.

The number of ions provided to the IEC cathode decreases.

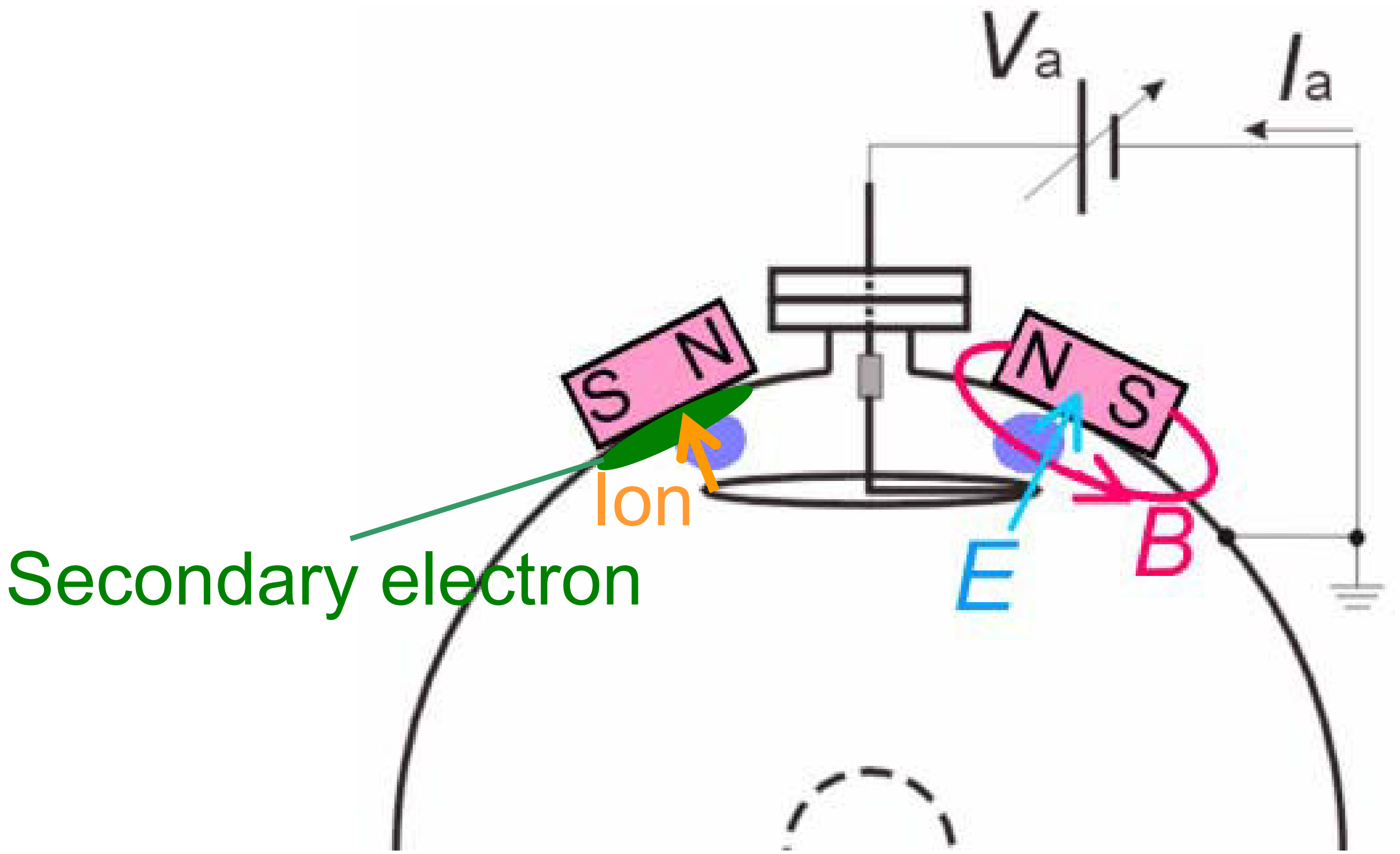
Assumption

I_{IEC} is provided only from magnetron discharge.

$\frac{I_{IEC}}{I_a}$ means ion extraction efficiency.

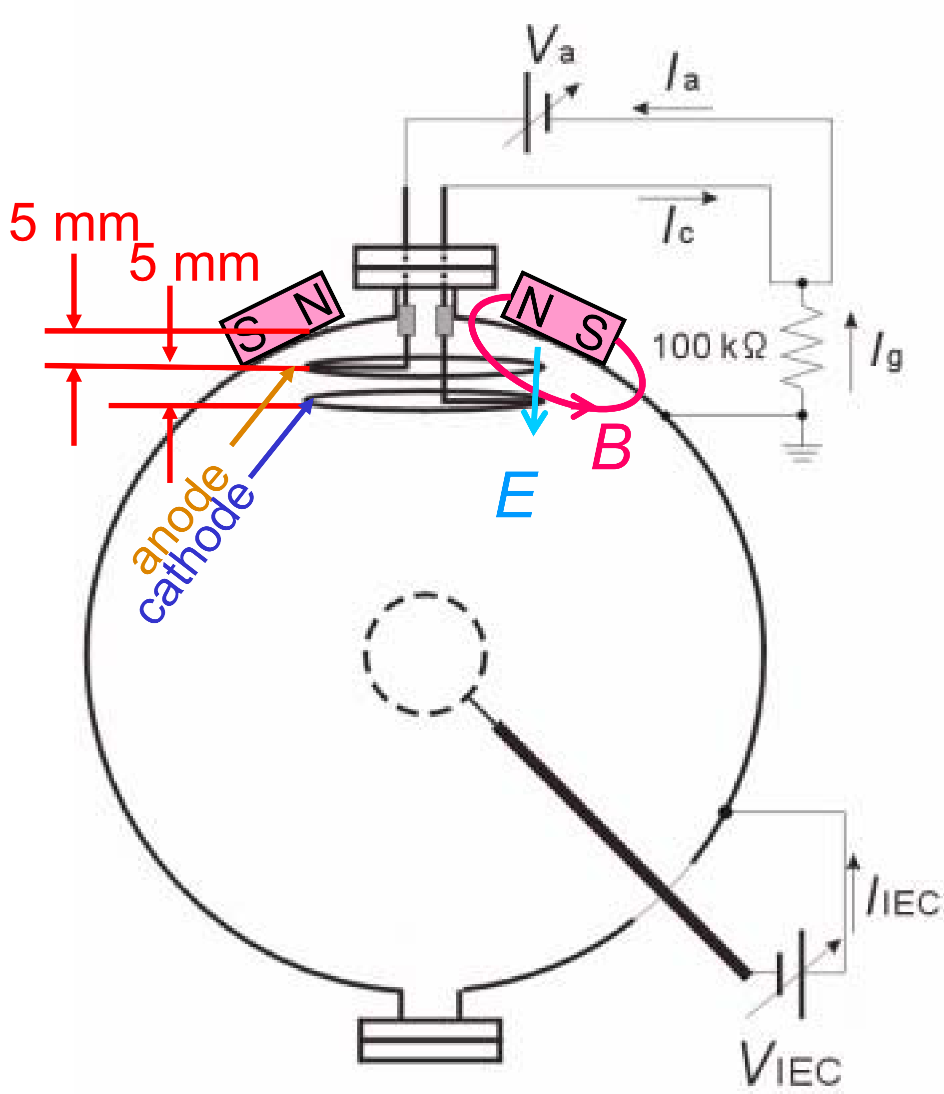
When about 40 % of magnetron discharge current is extracted to the IEC cathode, it can't be maintained.

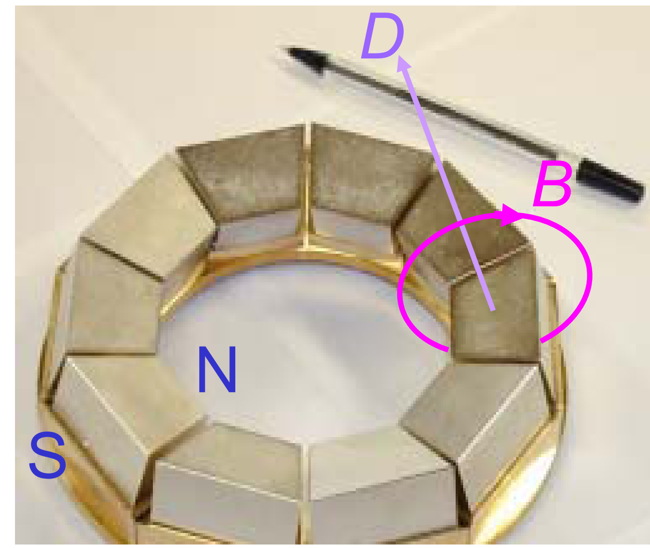
Magnetron discharge with an anode



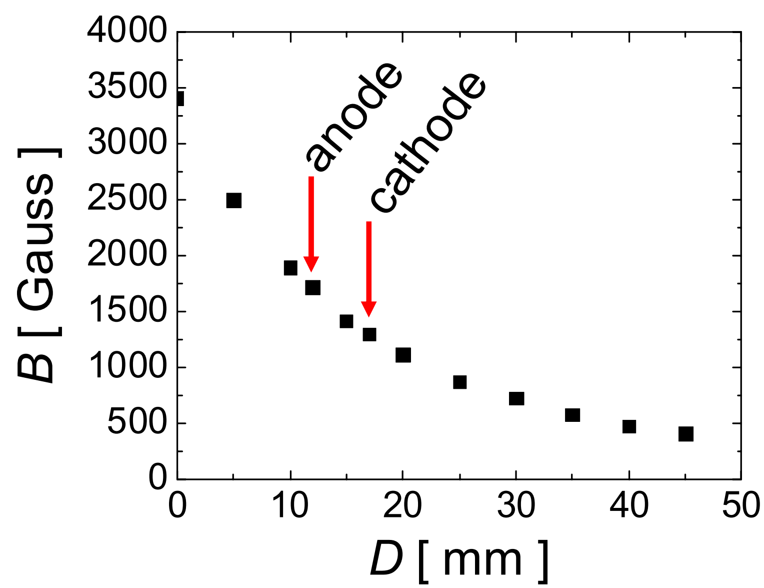
Secondary electrons are needed to maintain magnetron discharge.
A part of ions have to go to the chamber.
It’s difficult to extract major part of ions to the IEC cathode.

Magnetron discharge with an anode and cathode

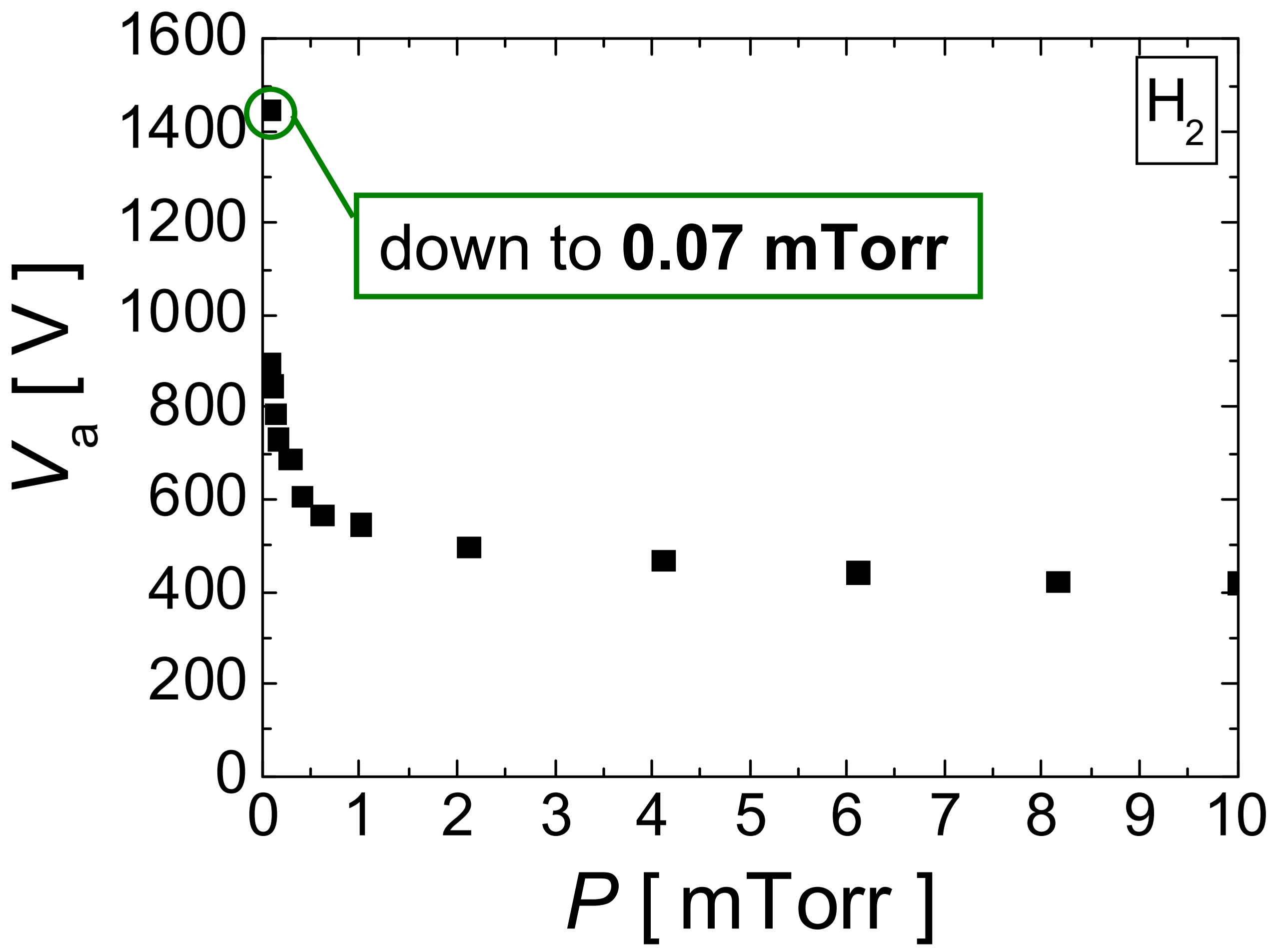




Max 7000 Gauss (Nd-Fe-B)

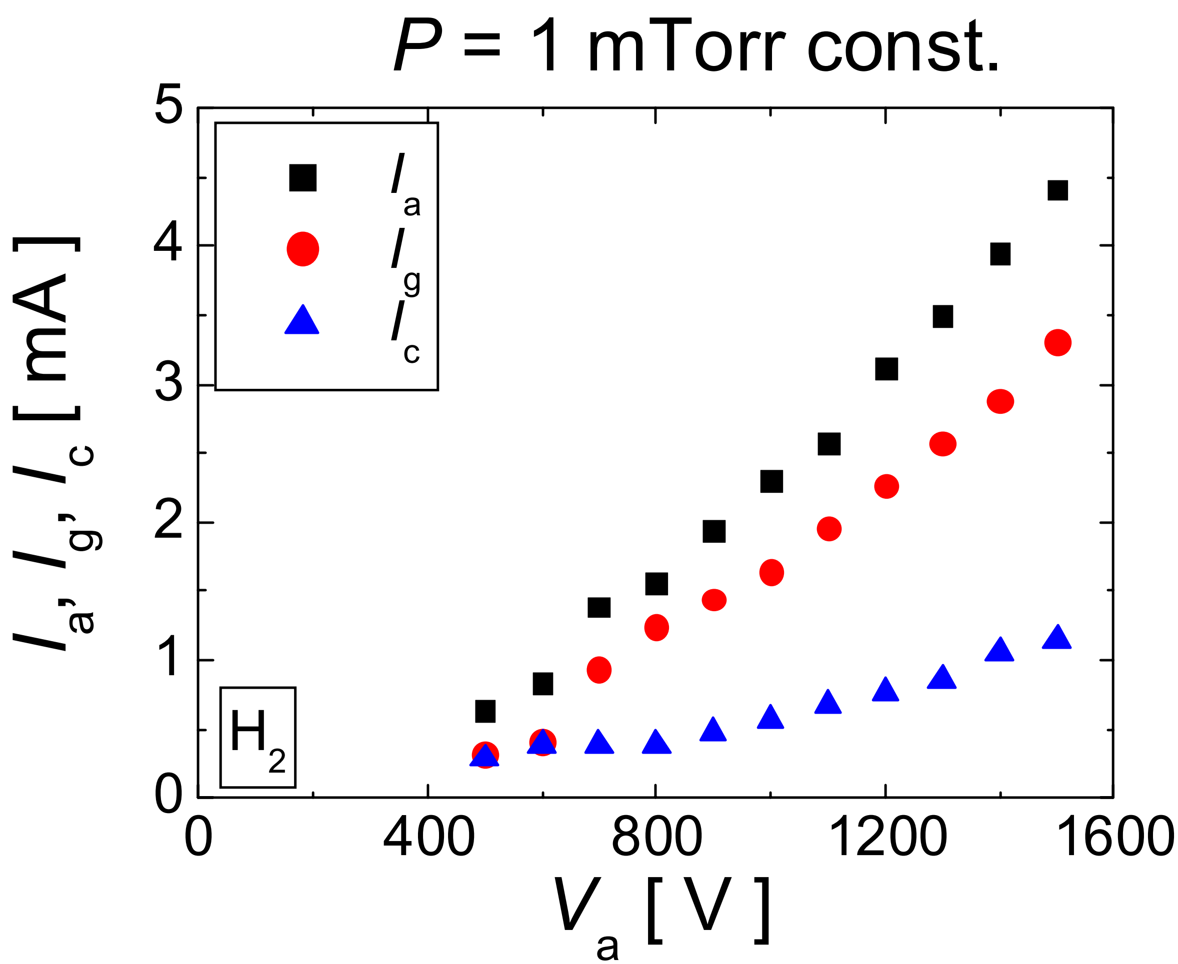


Magnetron discharge with an anode and a cathode (V_{IEC} = 0 V)



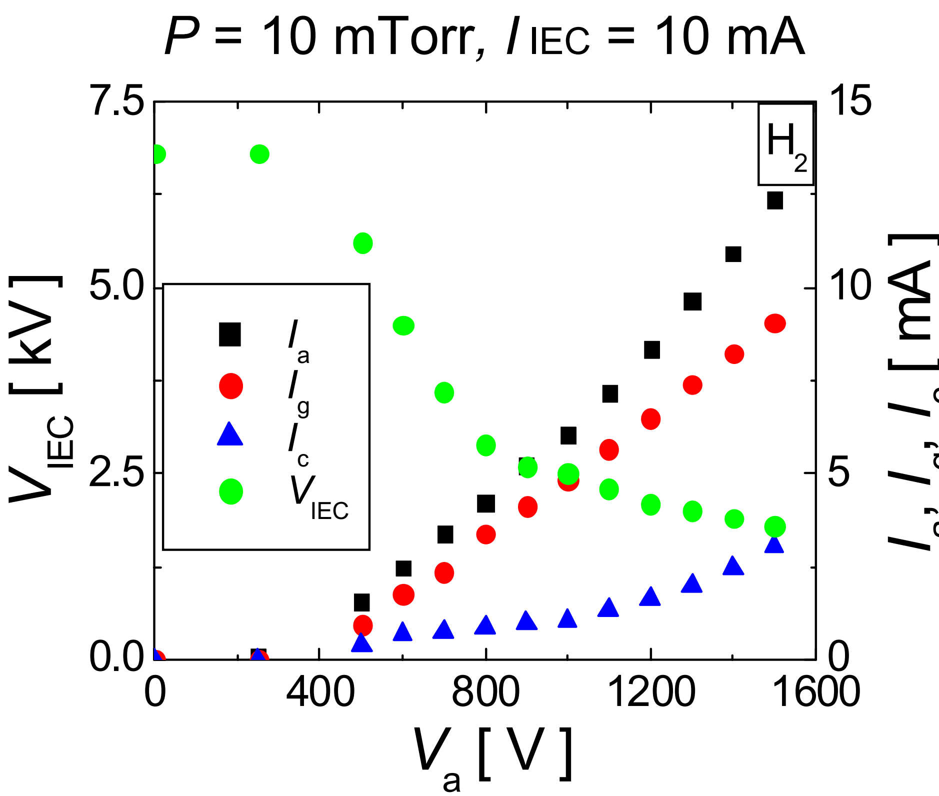
Magnetron discharge ignition

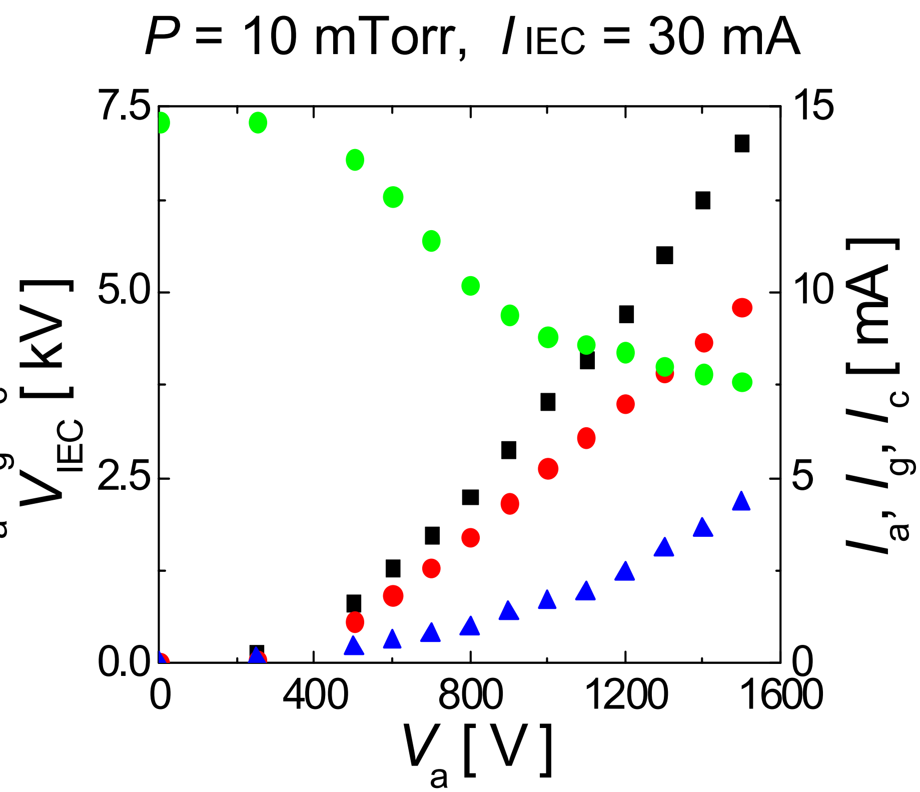
Magnetron discharge with an anode and a cathode (V_{IEC} = 0 V)



Magnetron discharge current increases as the anode voltage increases

Glow/Magnetron hybrid discharge with an anode and a cathode





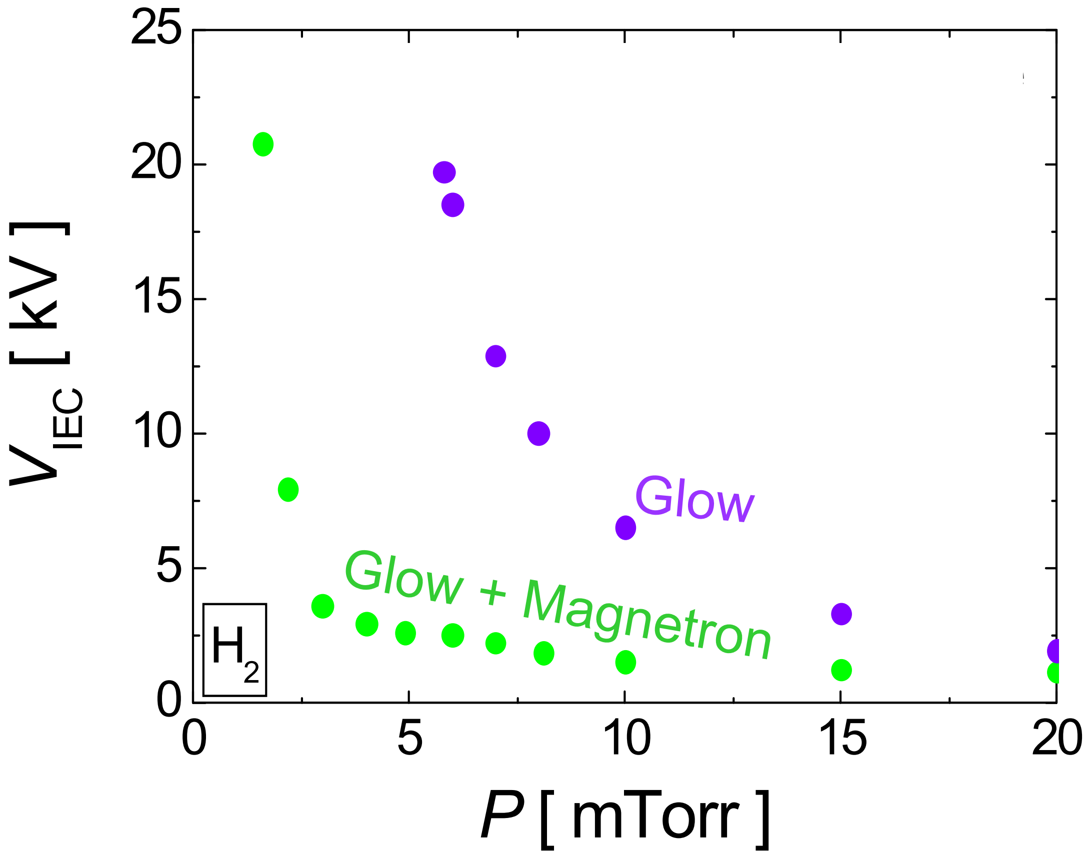
Magnetron discharge current increases as V_a increases, and V_{IEC} decreases.

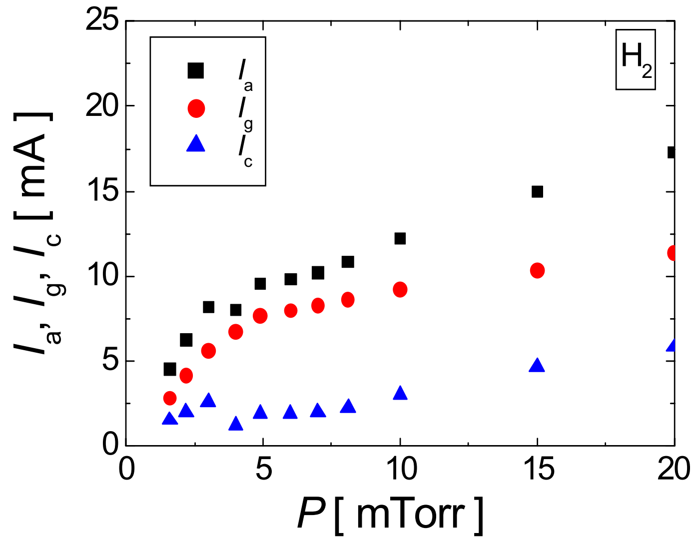
The number of ions provided to the IEC cathode increases.

This effect is more significant with lower I_{IEC} (Left side).

Glow/Magnetron hybrid discharge with an anode and a cathode

V_a = 1500 V, I_{IEC} = 10 mA const.





Magnetron current decrease as pressure decreases.
Then V_{IEC} increases.

The number of ions provided to the IEC cathode decreases.

Pressure was reduced by use of magnetron discharge at the same V_{IEC} and I_{IEC}.

Conclusions

Magnetron discharge plasma with an anode and a cathode is maintained at the pressure of 0.07 mTorr.

In the IEC/magnetron hybrid discharge, magnetron discharge plasma serves as an ion source.
As a result, lower pressure operation can be attained than glow discharge.

Future works

Evaluate an effect of magnetron discharge on the neutron production rate.

Optimize the configuration of the magnetron discharge system.