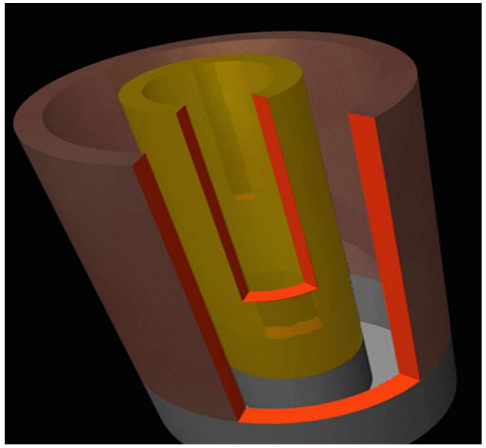

1st RCM on CRP F43024: Atomic Data for Vapour Shielding in Fusion Devices:

Effects of radiation, ion and electron beams emitted from the dense plasma focus on Tin and its alloys

M. Akel, M. Ahmad and Sh. Al-Hawat

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Outline

- **Introduction**

- **Experimental work**
  - ✓Plasma treatment of the Tin targets under different experimental conditions (power, pressure, gas, number of shots and distances)
  - ✓Characterization (SEM, EDX, XPS, PIXE, X-ray, OES)

- **Simulation work**
  - ➢Simulation of the ion and electron beam properties emitted from the plasma focus using Lee model;
  - ➢Calculation of the stepping power using SRIM code.
- **Conclusion**

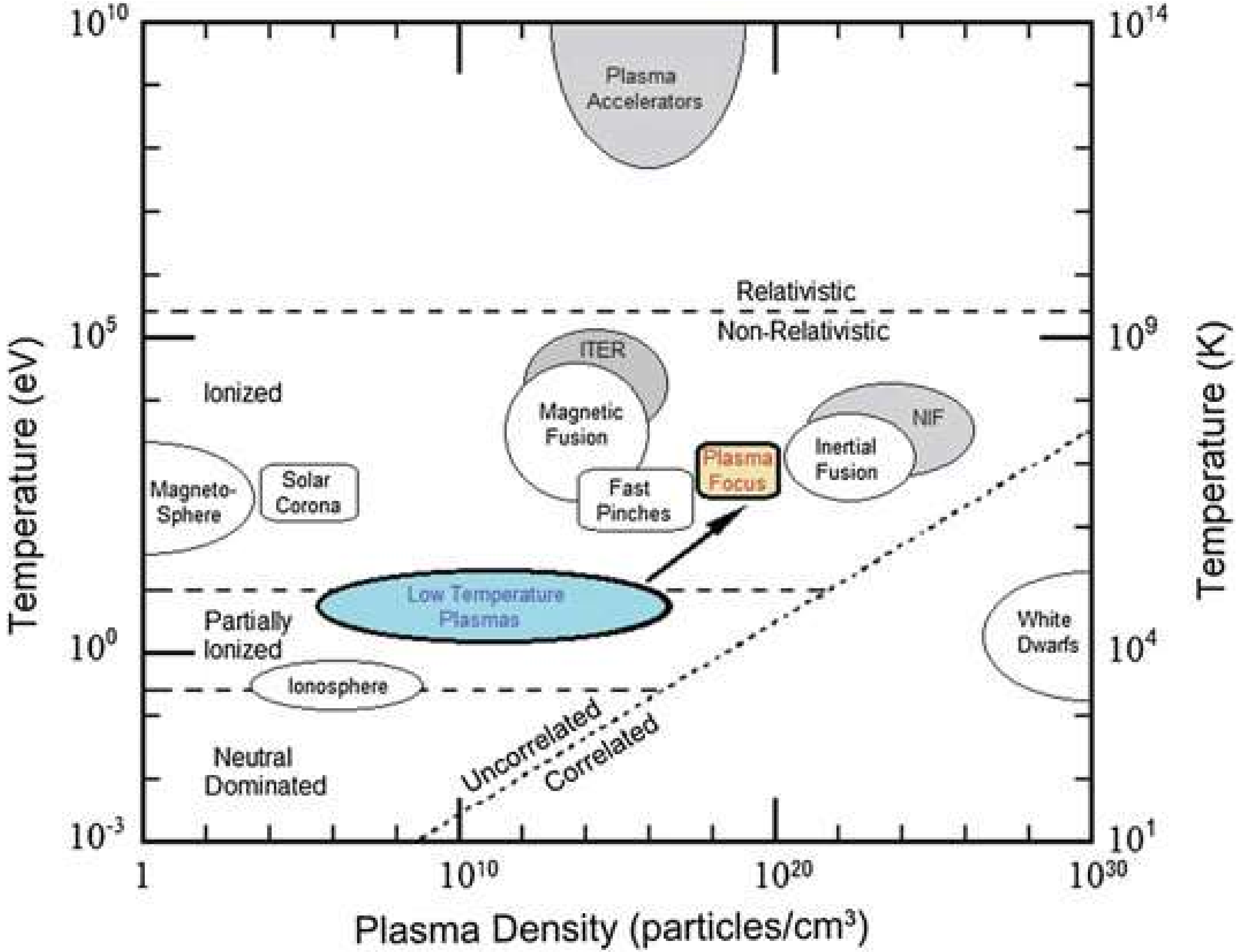
outline

- Introduction

Introduction

Plasma focus pinches produce radiation pulses (neutrons and X-rays), shock waves, ions and electron beams, plasma filaments, plasma jets, and plasma bursts, being an interesting plasma to study the effects of fusion-relevant pulses on materials.

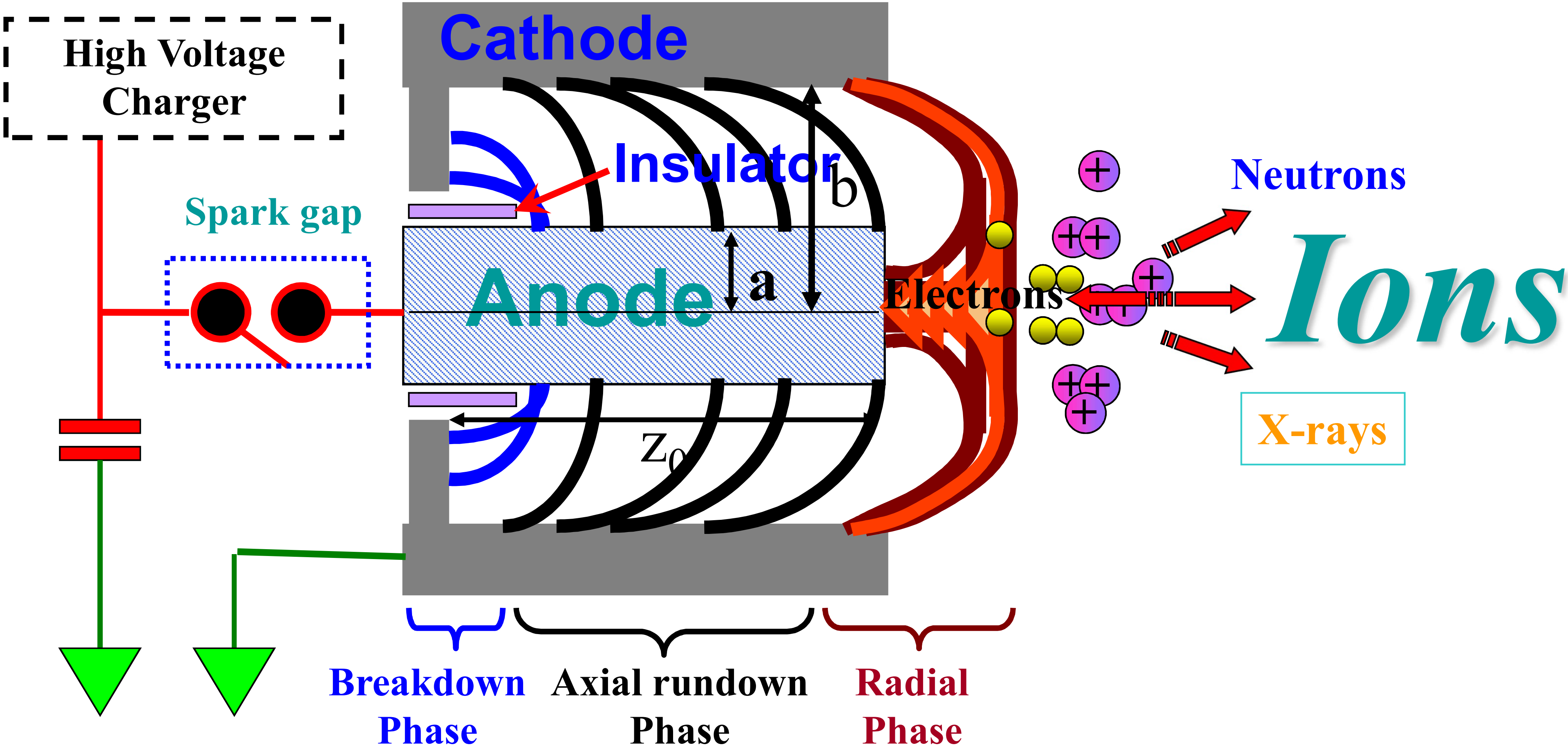
Targets of different materials relevant to fusion reactors can be characterized using the plasma focus environment (using single pulses, or several cumulative pulses), which can simulate conditions similar to those that will be encountered in larger fusion facilities.



Plasma Science and Technology for Emerging Economies, DOI 10.1007/978-981-10-4217-1_2

The Dense Plasma Focus

high temperature*, *high density*, *short lived plasma



AECS Mather type Plasma Focus Device

Bank parameters:

L_0=1430 nH, C_0= 25 µF, r_0 = 50 mOhm

Tube parameters:

Outer radius b = 3.2 cm,

Inner radius a = 0.95 cm

Anode length z_0= 16 cm

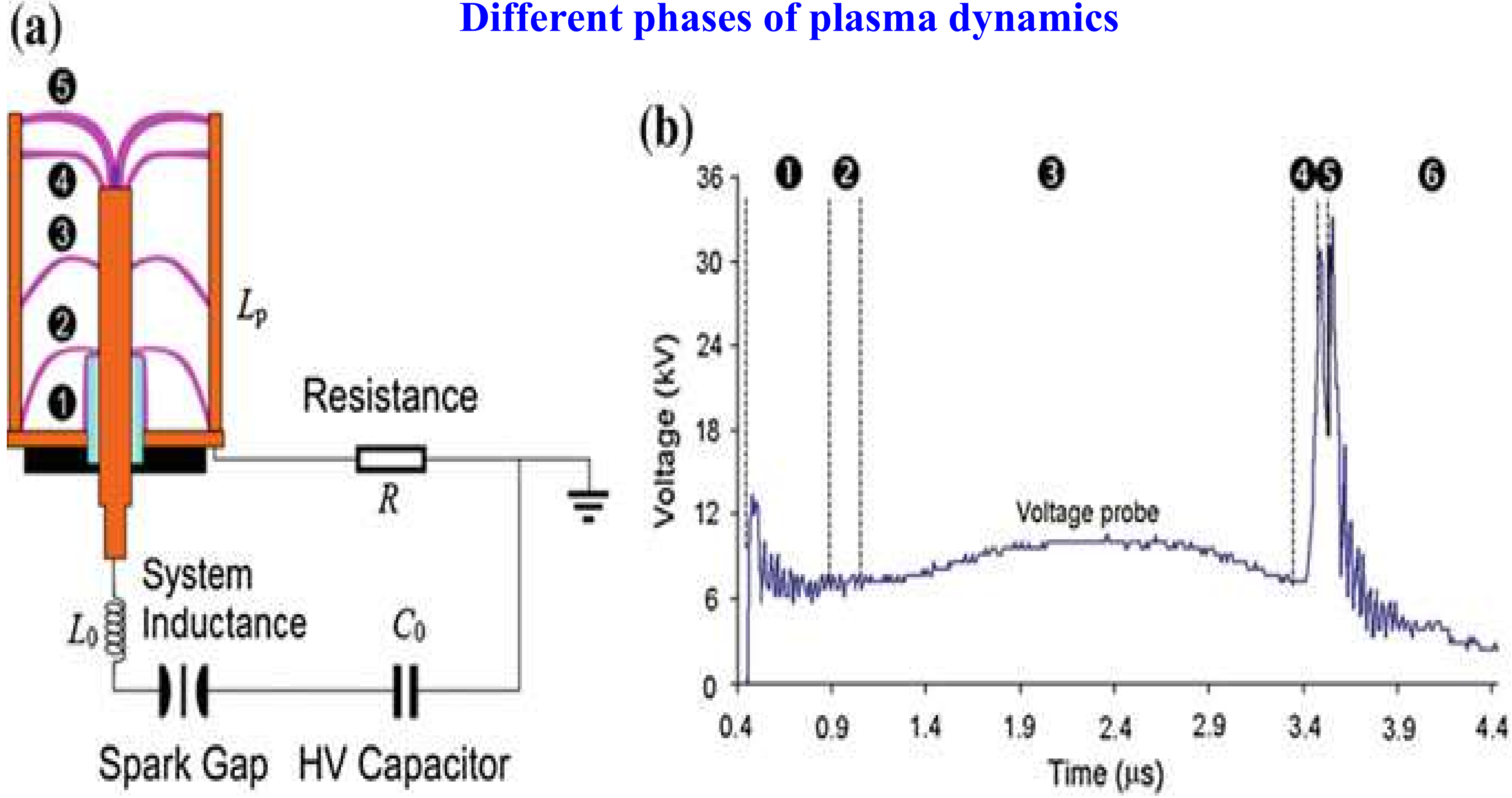
Operating parameters:

V_0 = 12-16 kV,

Helium, Nitrogen, Neon, Argon, etc...

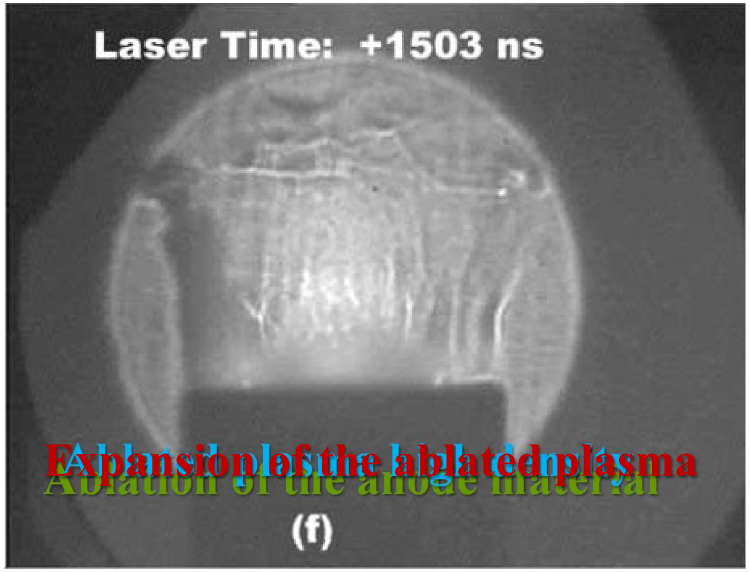
Peak current = 50-60 kA

Different phases of plasma dynamics

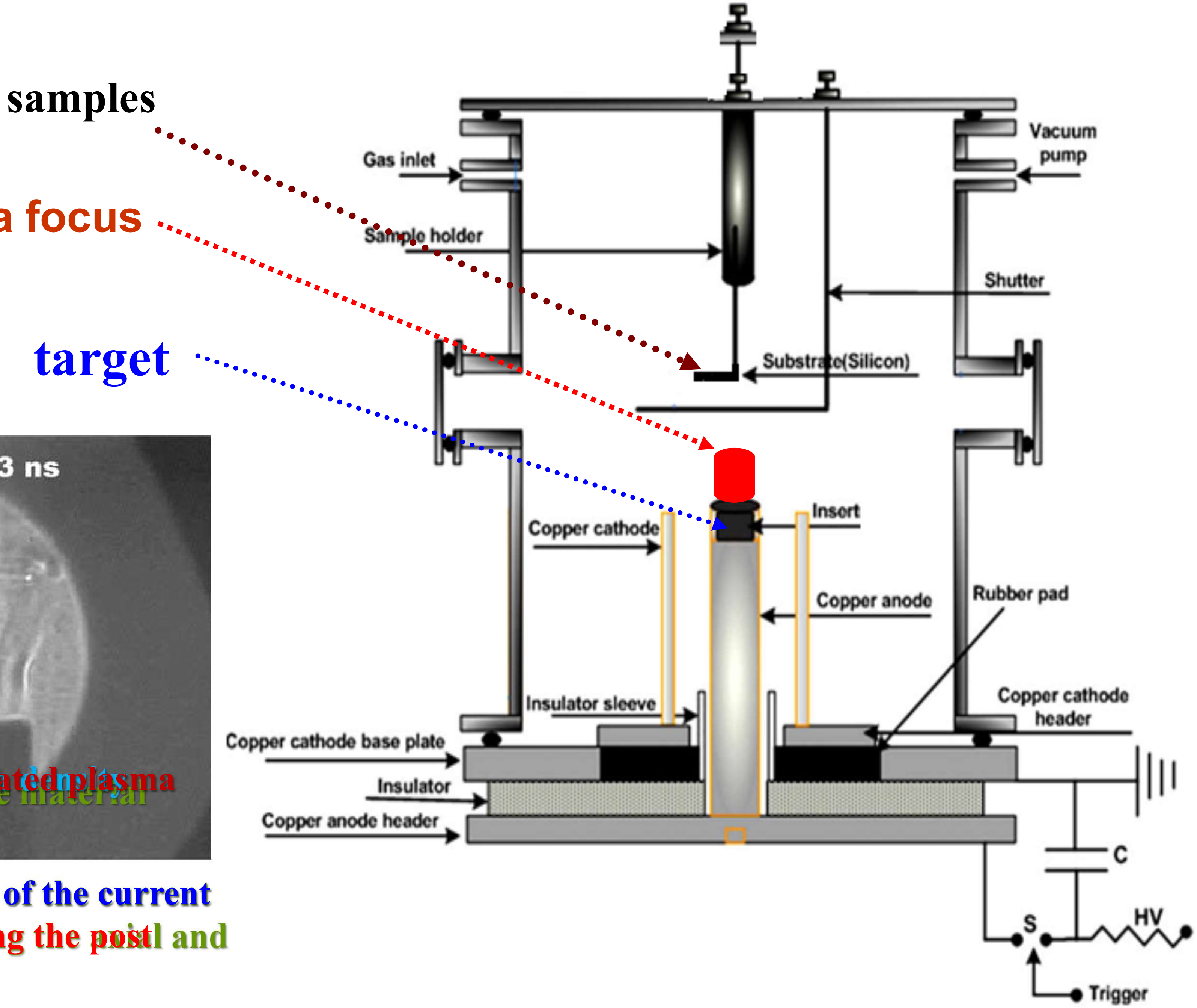


(a) Different phases of plasma dynamics from (i) breakdown and current sheath formation ❶, (ii) inverse pinch ❷, (iii) axial acceleration ❸, (iv) radial compression ❹, and (v) pinch ❺ phase. (b) The oscilloscope trace of the typical voltage probe signal with approximate timing duration marked on it.

Evaporation and deposition by relativistic electron beams

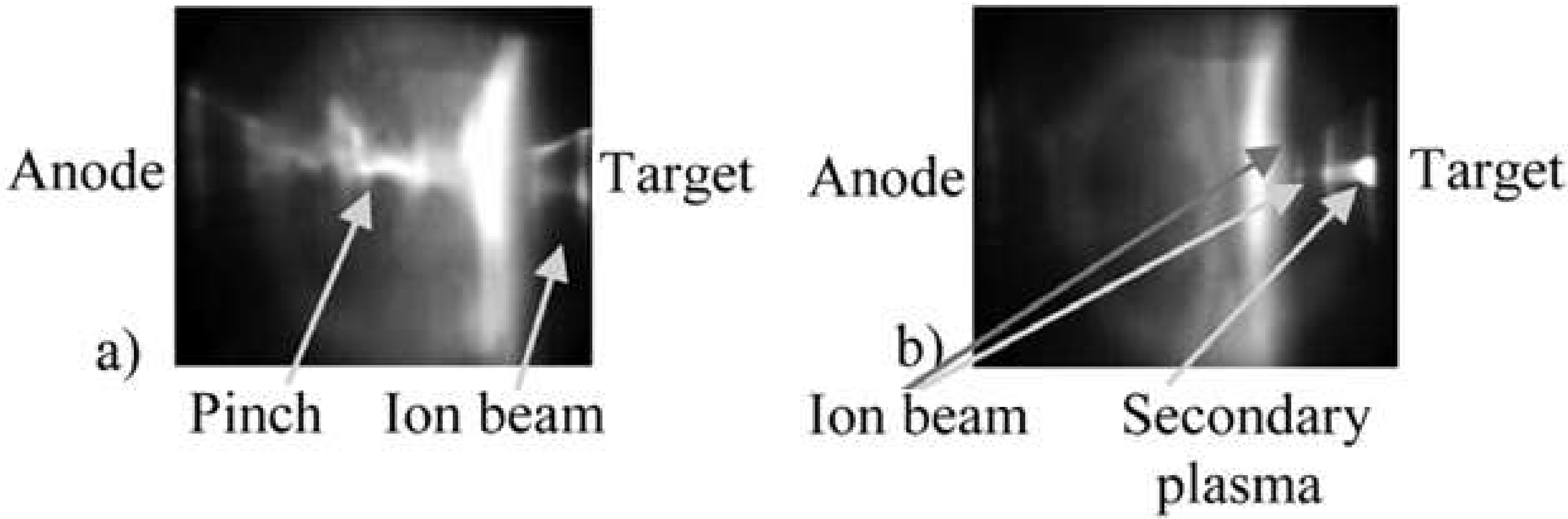


Shadowgraph images of the current sheath captured during the post axial and radial collapse phase.



L.Y. Soh, et. al., IEEE Trans. Plasma Sci. 32, 448–455 (2004).

Evaporation and deposition by energetic ion beams

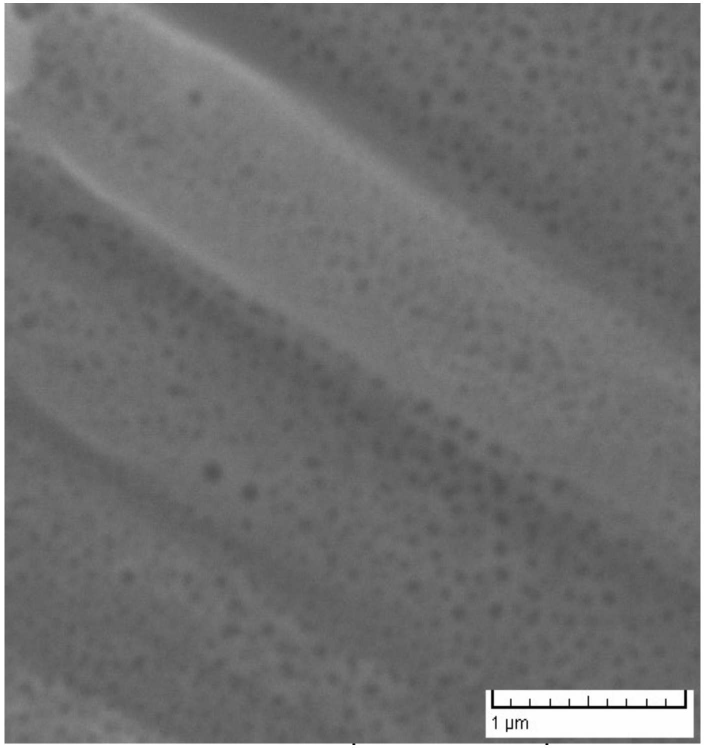


Two frame photos of plasma in its self-luminescence produced by the action of the ion beam and interaction of the fast ions with a solid target (production of the secondary plasma cloud or target vapour)

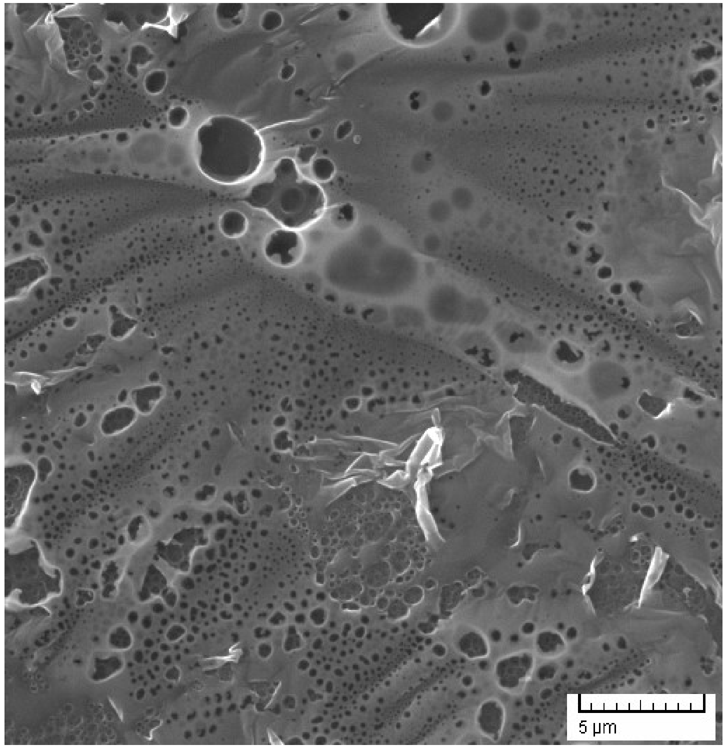
V A Gribkov, Plasma Phys. Control. Fusion 57 (2015) 065010 (8pp)

Previous experimental works at AECS PF Lab.:

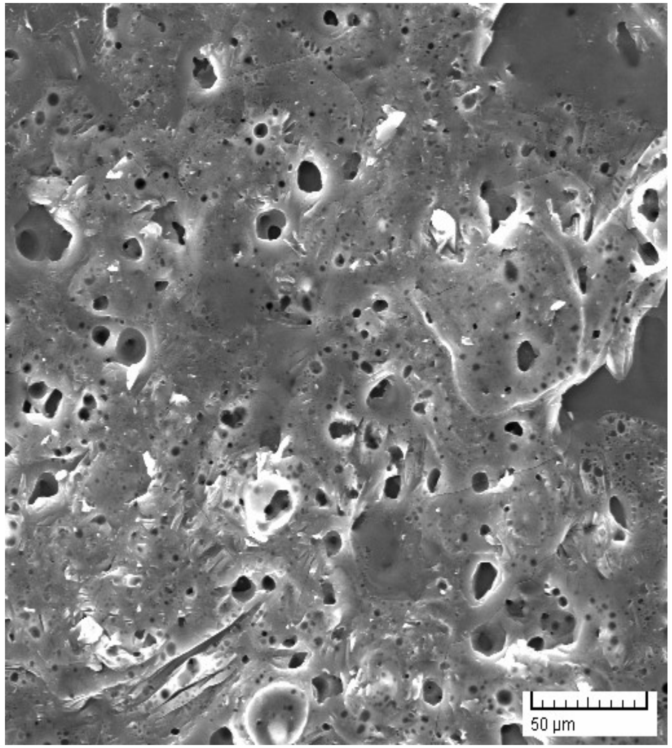
✓Characterization of porous and nano-structures deposited by PF on Silicon substrate:



1 shot, 6.5 cm



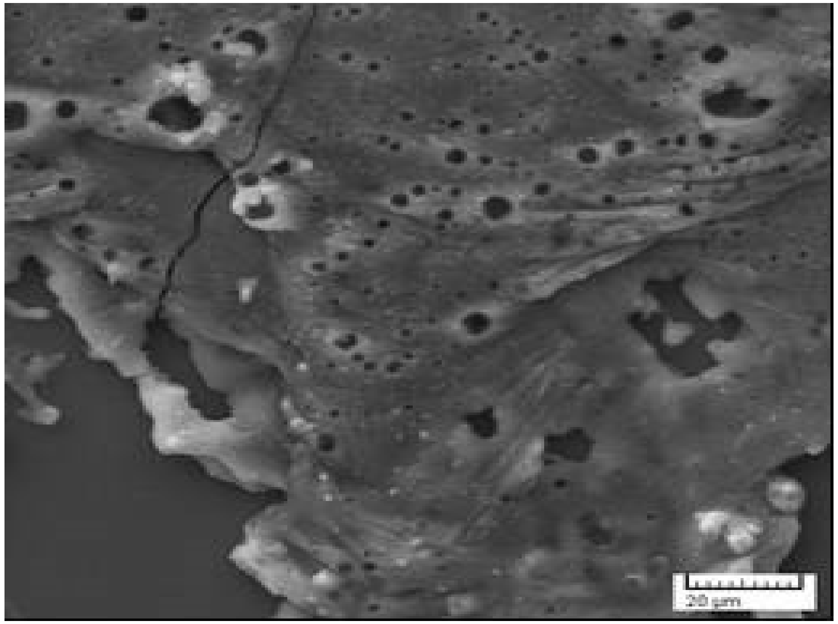
1 shot, 3.5 cm

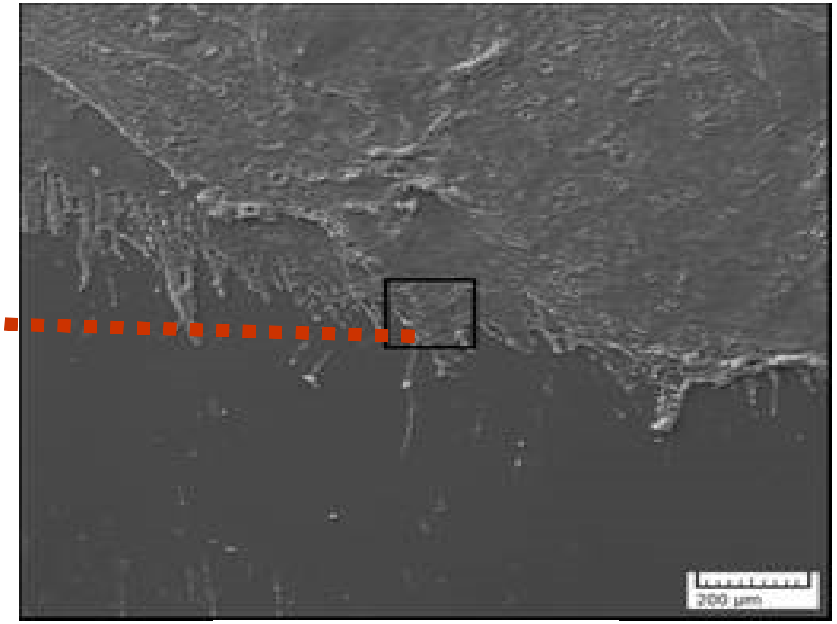


1 shot, 1.5 cm

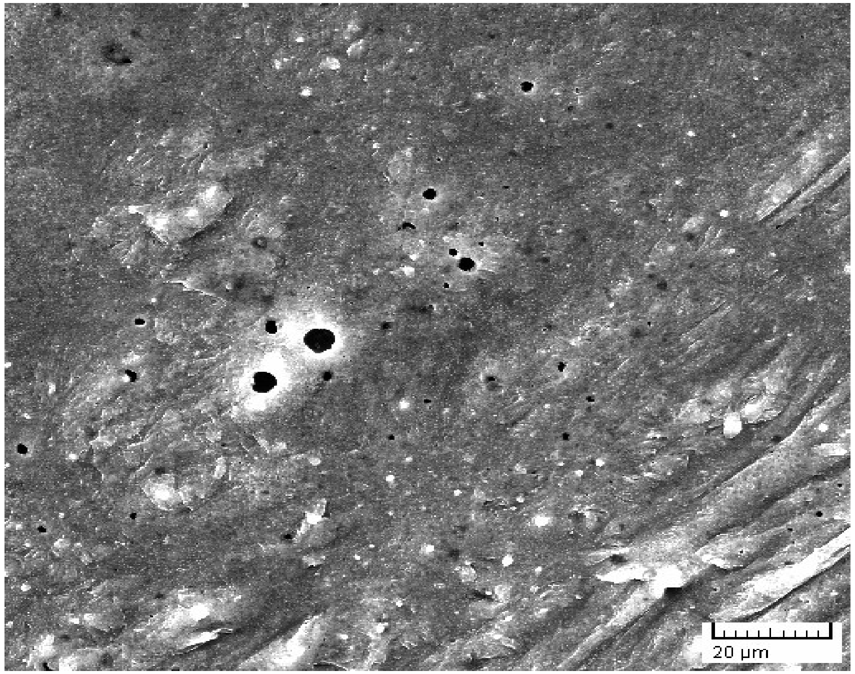
(Effect of the distance between the top of the anode and the target)

M. Ahmad, Sh. Al-Hawat, M. Akel , Journal of Fusion Energy 32 (4), 471 - 478 (2013)

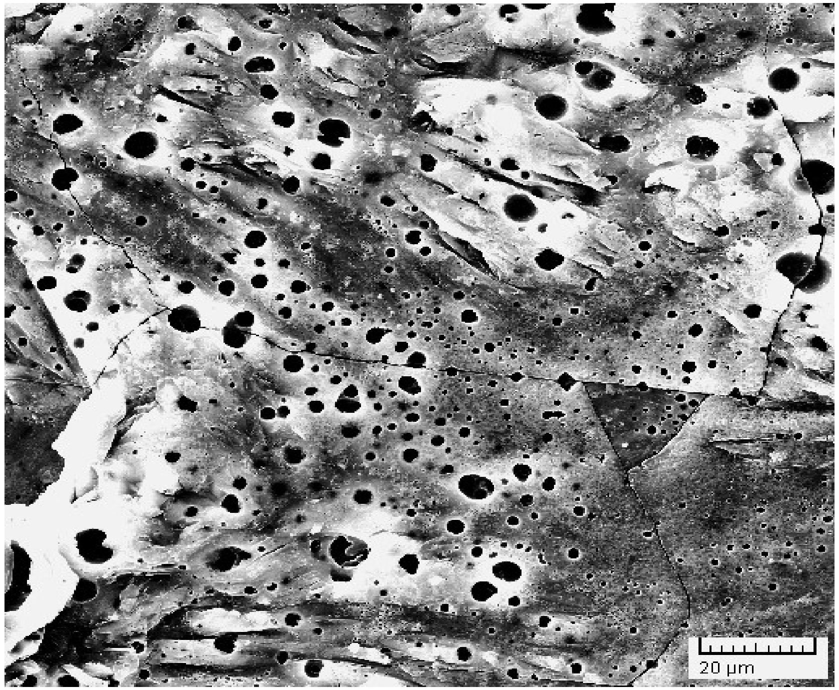




15 shot, 3.5 cm



12 Shots, 3.5 cm

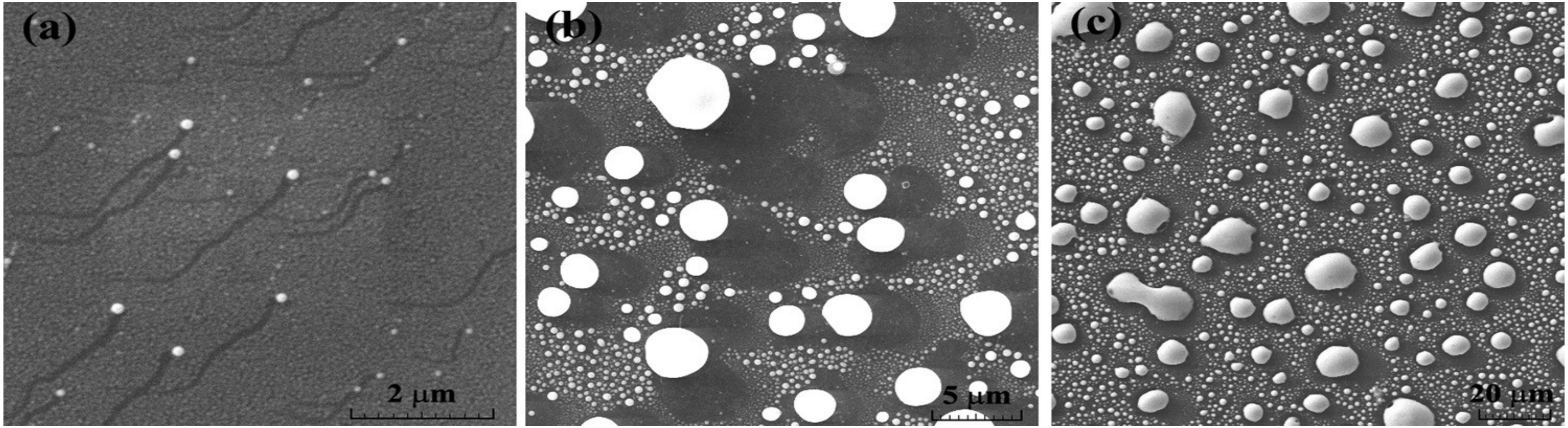


9 Shots, 3.5 cm

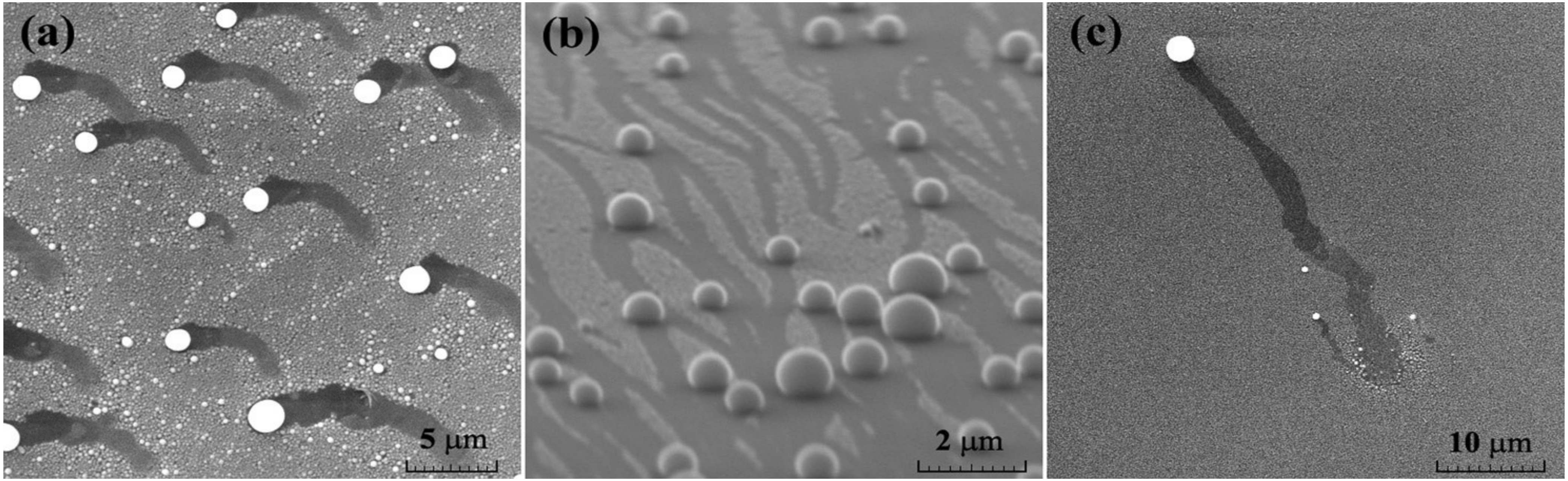
M. Ahmad, Sh. Al-Hawat, ***M. Akel*** *, Journal of Fusion Energy 32 (4), 471 - 478 (2013)*

(Effect of the shot number)

✓Characterization of bismuth nano-spheres deposited by PF on Si:

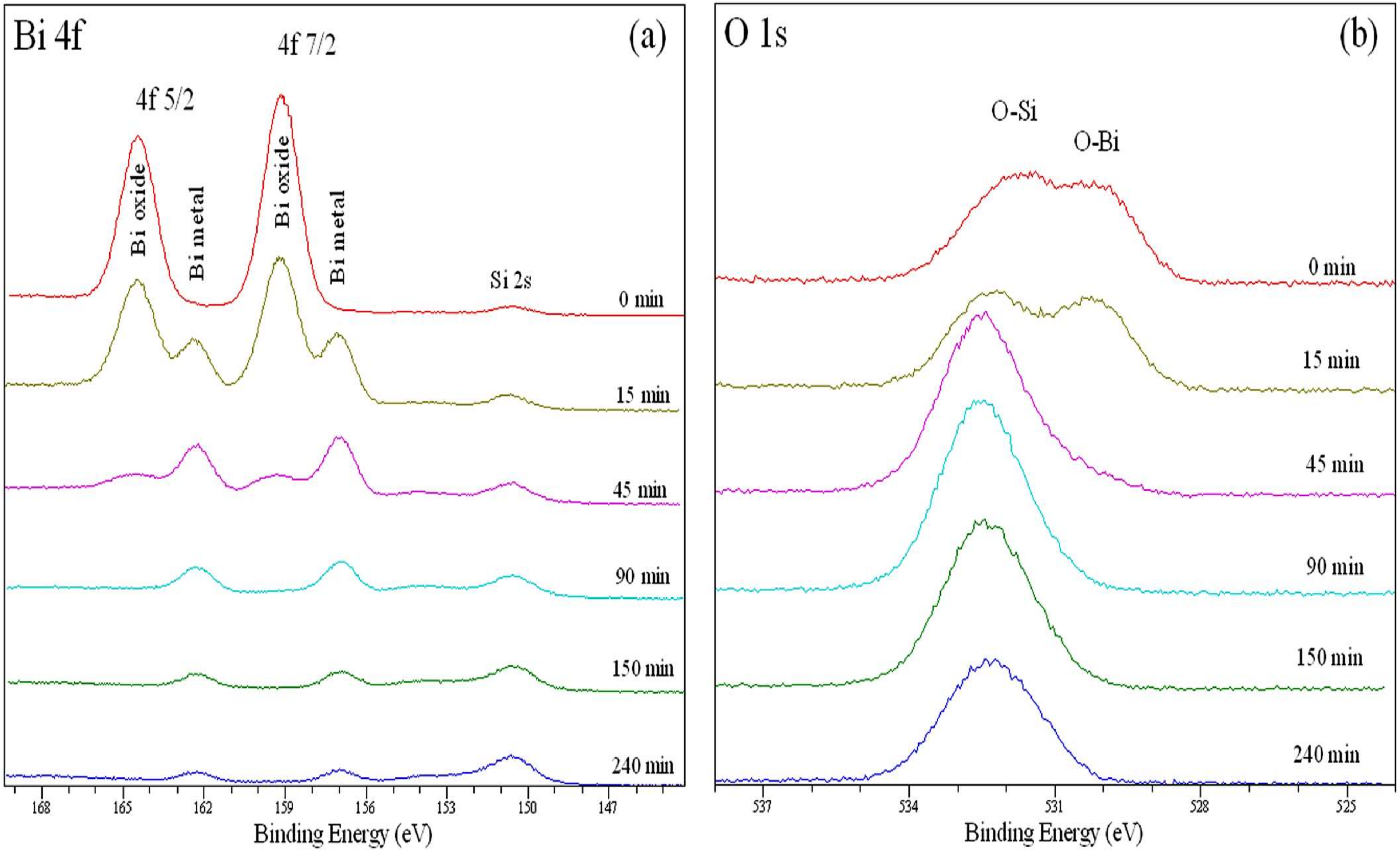


SEM images of samples treated by PF with 1 Sh at 6 cm (a), 15 Sh at 6 cm (b), and 40 Sh at 6 cm (c).



SEM images of samples treated by PF with 1Sh at 3 cm in the axis of anode (a), out of the axis of anode (b), and with 5 Sh at 6 cm out of the axis of anode (c).

Chemical composition of the deposited material

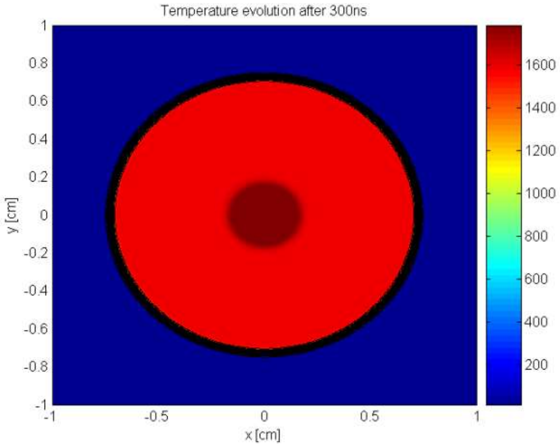


High resolution XPS spectra of Bi 4f (a) and O1s (b) realized at different etching times.

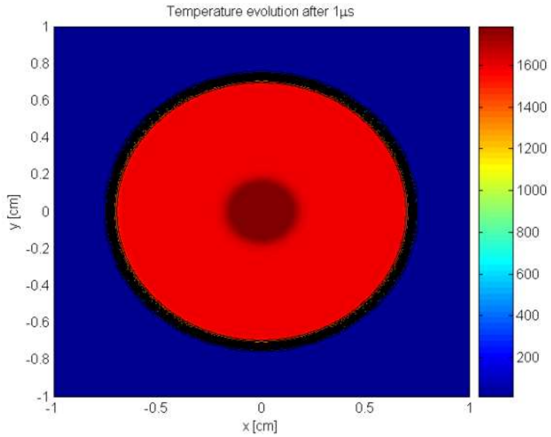
M. Ahmad, Sh. Al-Hawat, M. Akel and O. Mrad, JOURNAL OF APPLIED PHYSICS 117, 063301 (2015)

✓Thermal effect on silicon surface induced by ion beams in plasma focus

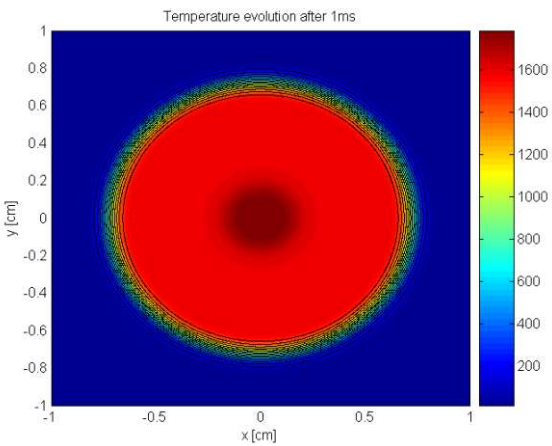
MATLAB program is used in the calculation, results are returned in a two-dimensional matrix, which contain data necessary to determine temperature profile within the target after each time interval, the melt duration, and the maximum melt depth.



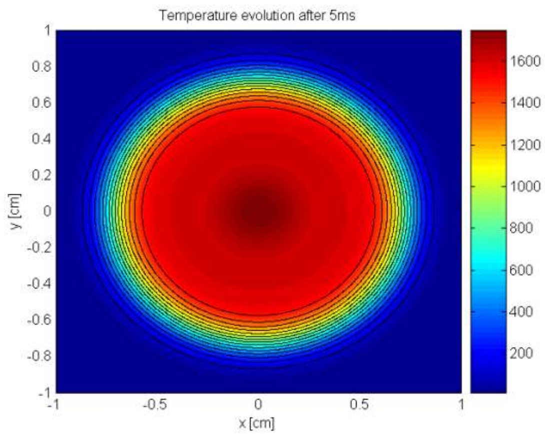
(a)



(b)



(c)



(d)

2D surface temperature evolution at various times, for a target at distance 2 cm from the anode. (a) at 300 ns, (b) at 1µs, (c) at 1ms and (d) at 5ms.

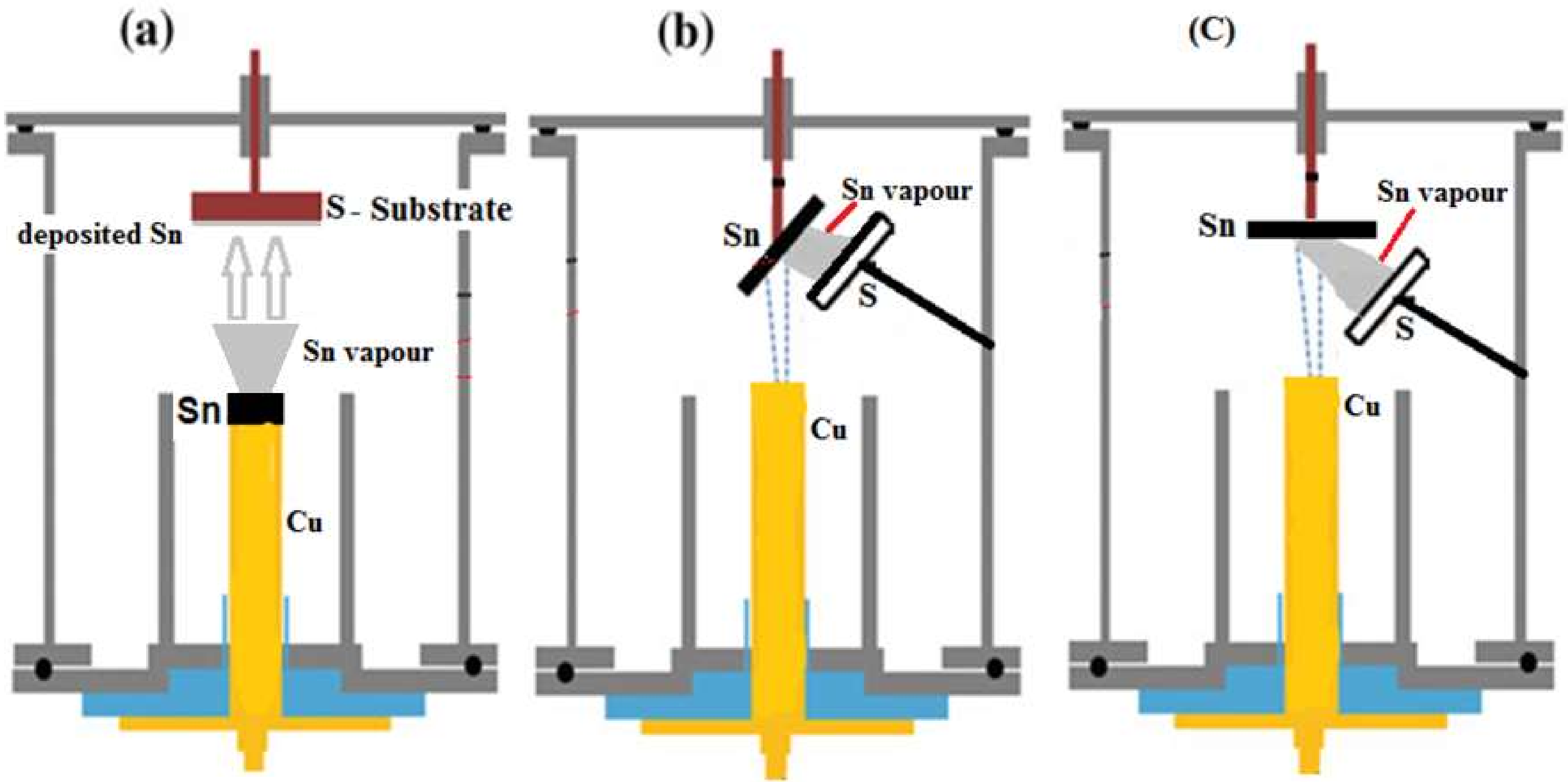
Z. Ahmad, M. Ahmad , Sh. Al-Hawat, M. Akel, Nuclear Instruments and Methods in Physics Research B 396 (2017) 61–67

outline

- **Experimental work**

Plan for the first year (experimental work):

Preparation and treatment of Tin targets:



Tin electron beams interaction **Tin ion beams interaction**

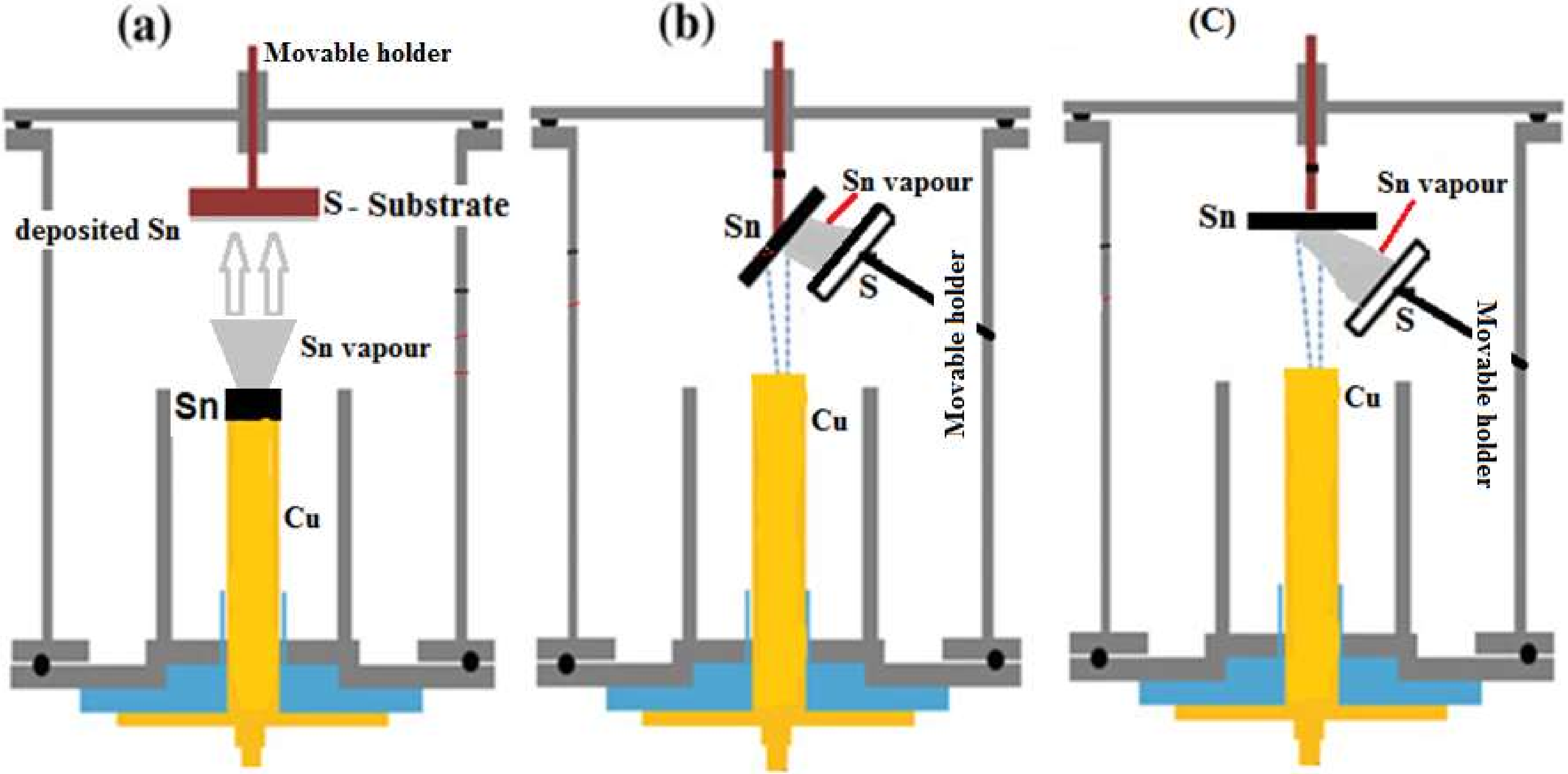
Electron and ion beams of different filling gases (He, N_2, Ne, Ar, etc..)

Plan for the first year (experimental work):

Treatment of the targets under different experimental conditions: Effect of **shot number and distances**:

✓**between the anode and targets (electron beam case)**

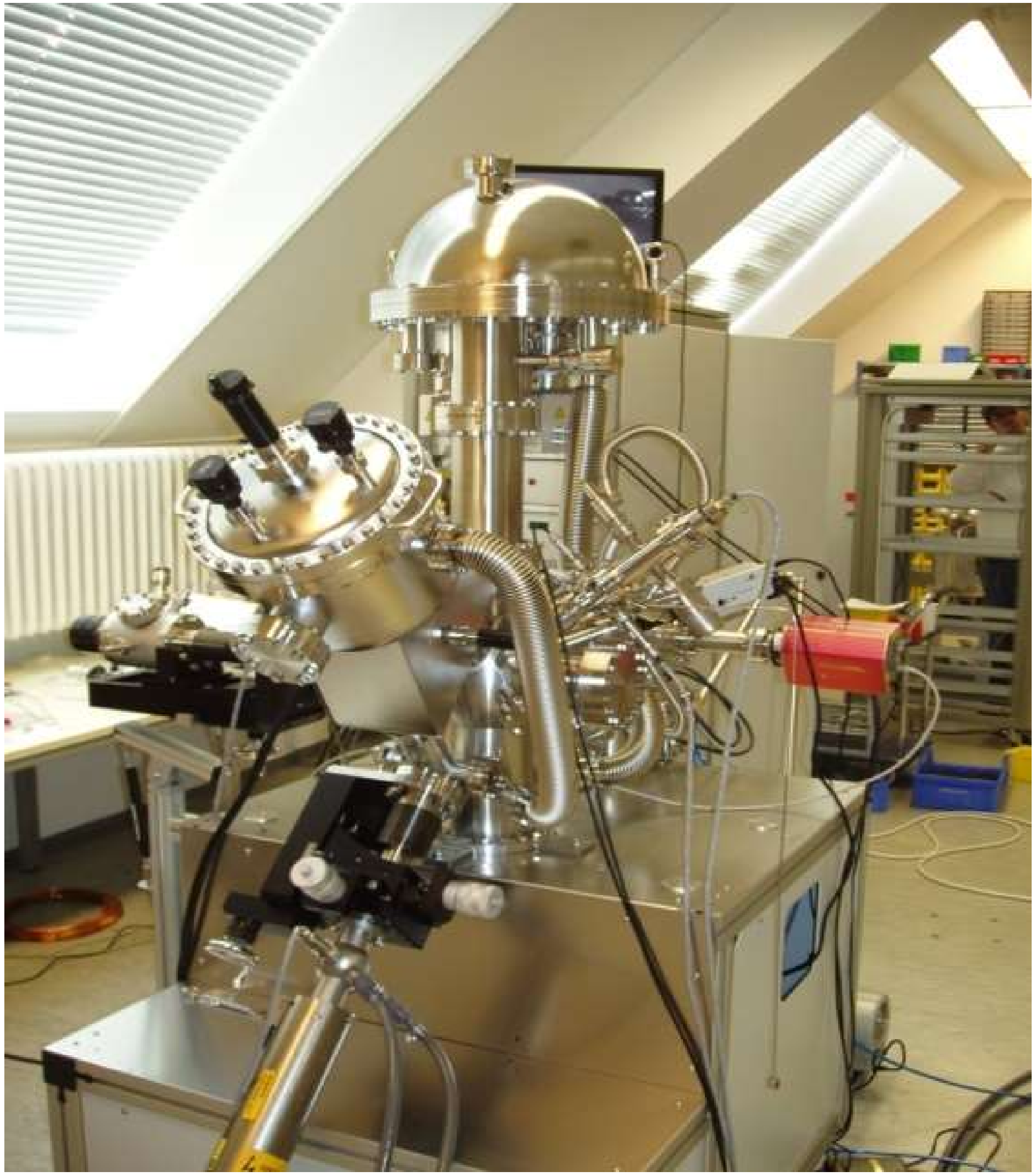
✓**between the primary and secondary targets (ion beam case).**



Tin electron beams interaction **Tin ion beams interaction**

Plan for the first year (characterization work):

✓Characterization of the treated secondary samples using various techniques like X-ray photoelectron spectroscopy technique (XPS).

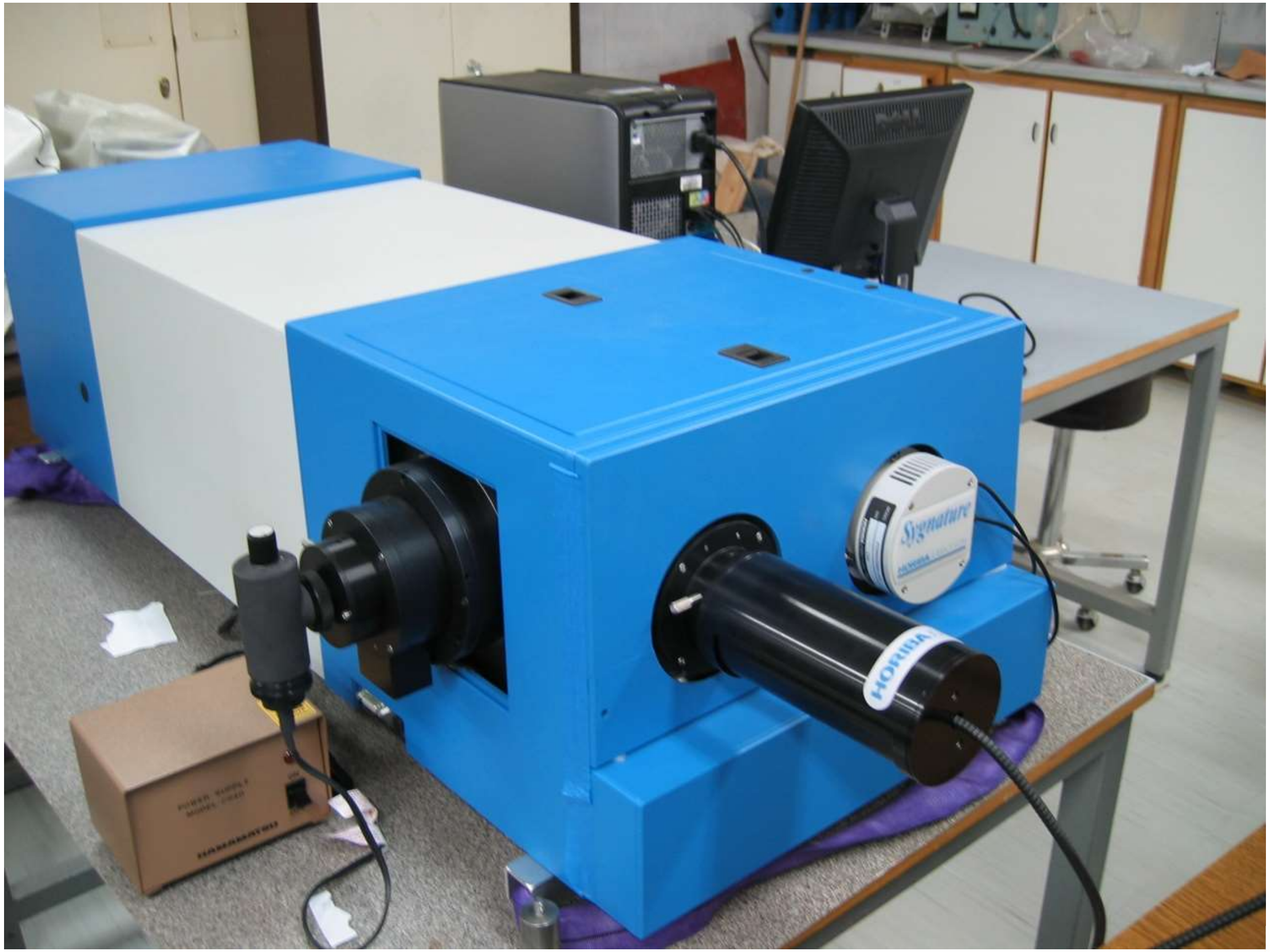


Plan for the first year (characterization work):

✓Characterization of the treated secondary samples using various techniques like XPS and Proton Induced X-ray Emission (PIXE).

Plan for the first year (characterization work):

Optical emission spectroscopy (OES) measurements of the formed Tin vapour using the FHR1000 spectrometer;



Resolution: 0.008 nm

Grating Turret:
(3٦٠٠ g/mm & 1200 g/mm)

Accuracy: ±0.03 nm

Repeatability: ±0.015 nm

Slits (0-7 mm): automated variable dual entrance and exit ports.

Lens-Based Fiber Optic Interface at the entrance of the monochromator.

SYGNATURE-CCD

Spectral Range:
300 nm to 1100 nm

Spectral Acquisition Time
20 ms per spectrum

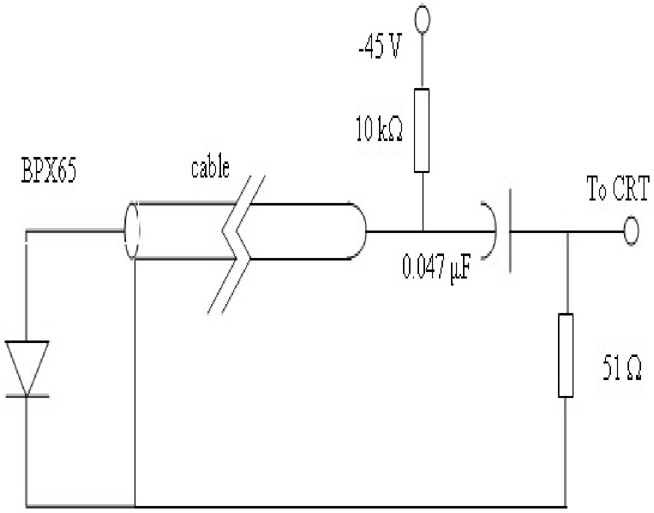
Integration Time
10 ms to 65 s

Light sources for calibration

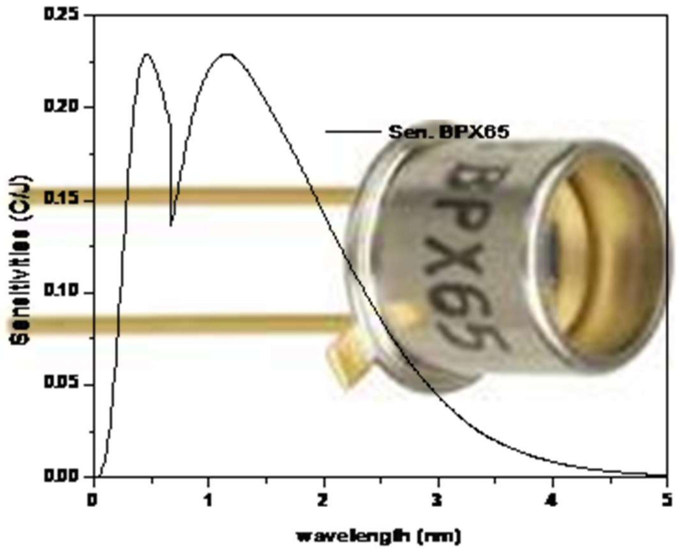
SynerJY software

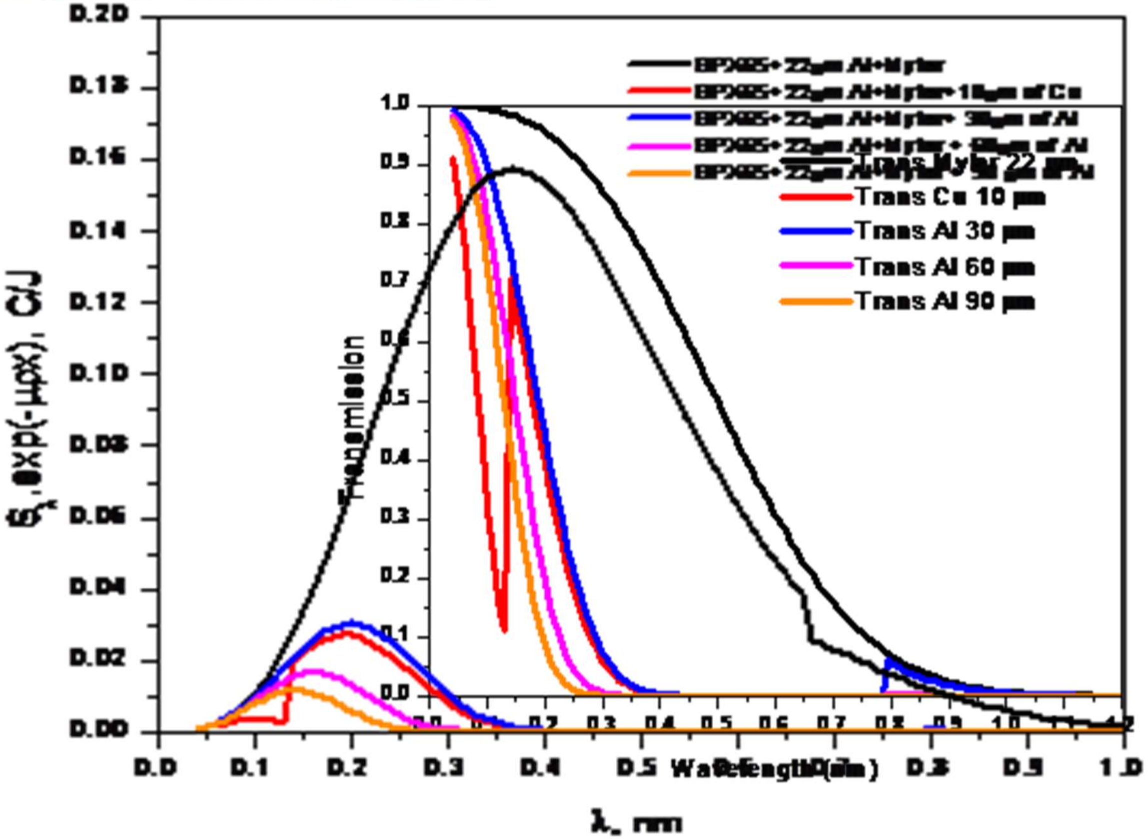
Getting and installation of the ICCD and synchronization circuit..?????.

Tin vapour characterization using X-ray emission

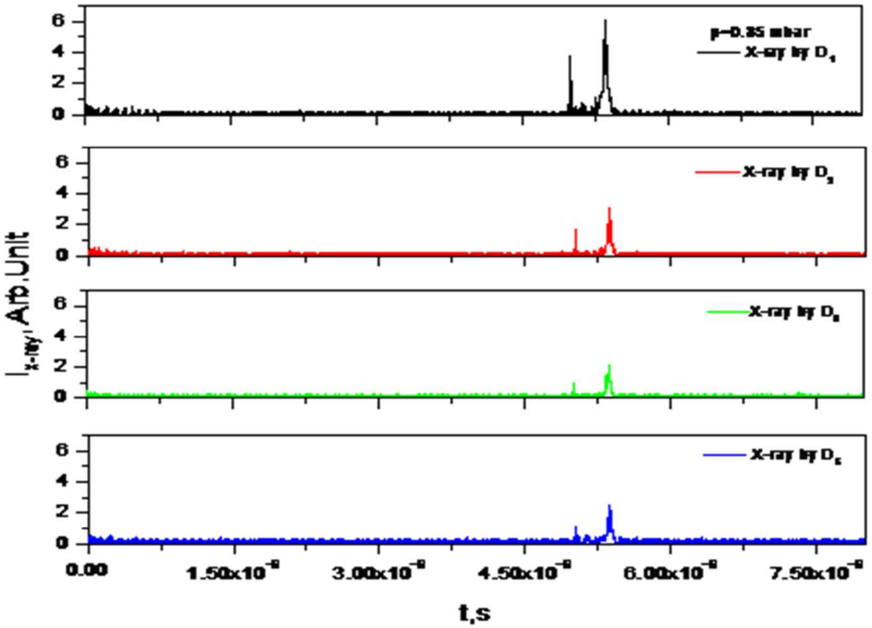


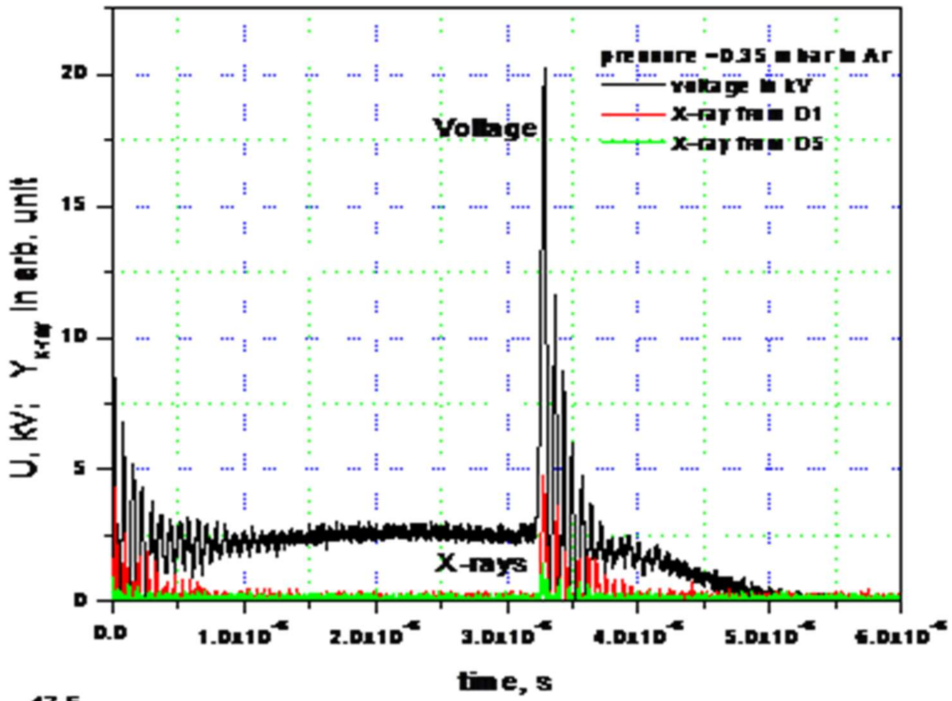
The biasing circuit for BPX-65 diodes

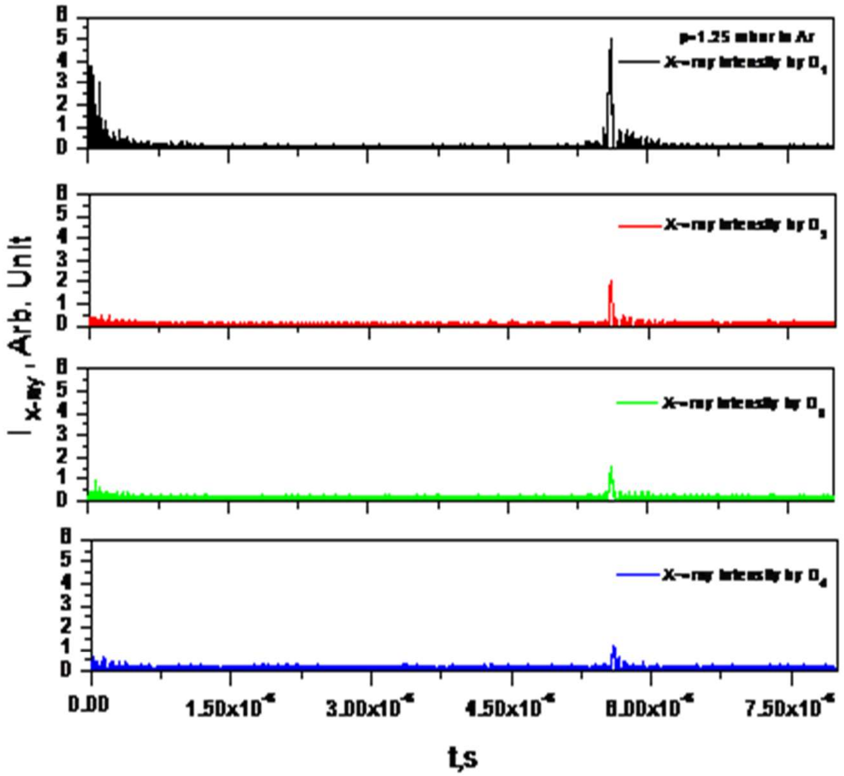


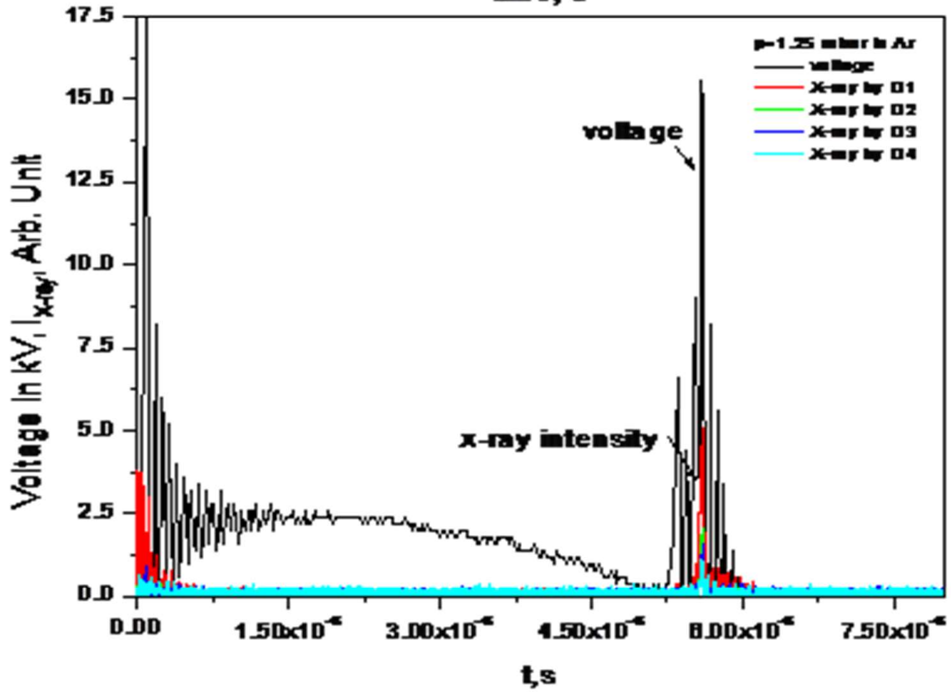


X-ray ratio method for Te determination









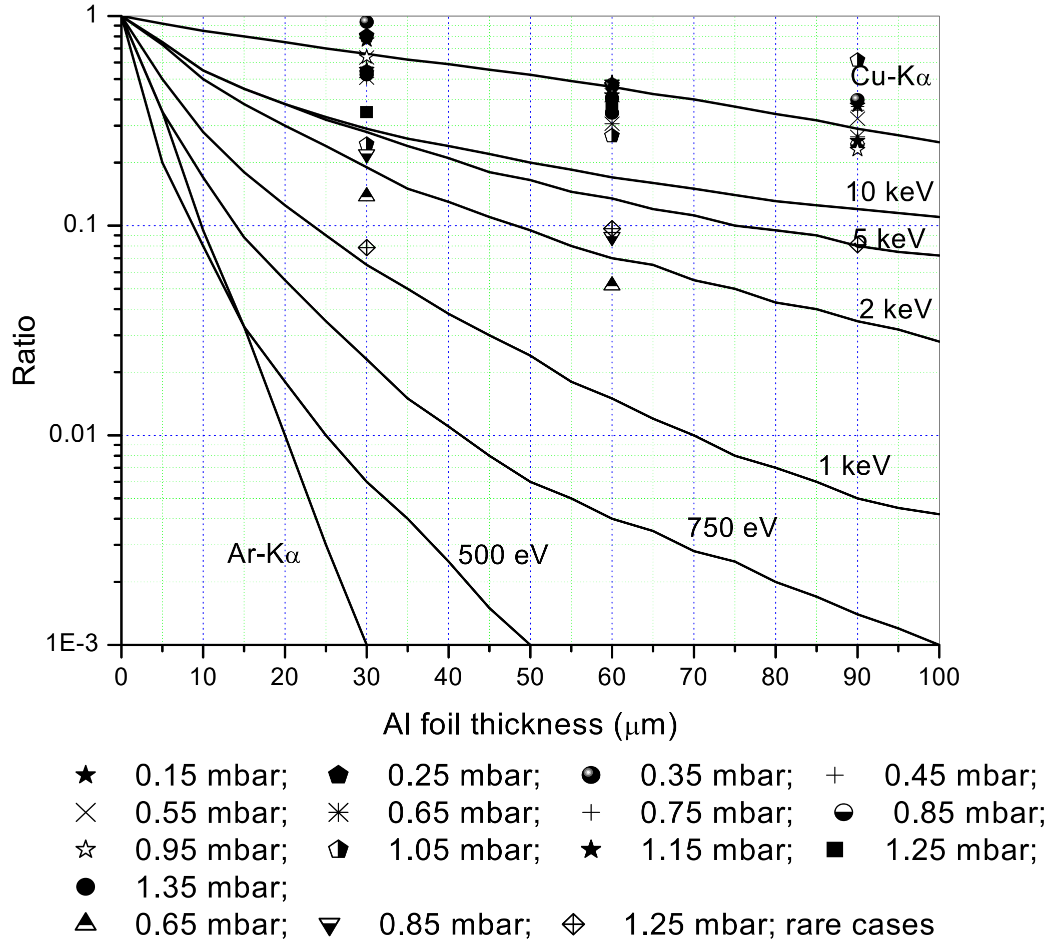
Sh. Al-Hawat, M. Akel , C. S. Wong,   Journal of Fusion Energy 30 (6), 503 - 508 (2011)

X-ray ratio method for Te determination

The radiation emission spectra of hot plasma at various plasma parameters have been computed using the

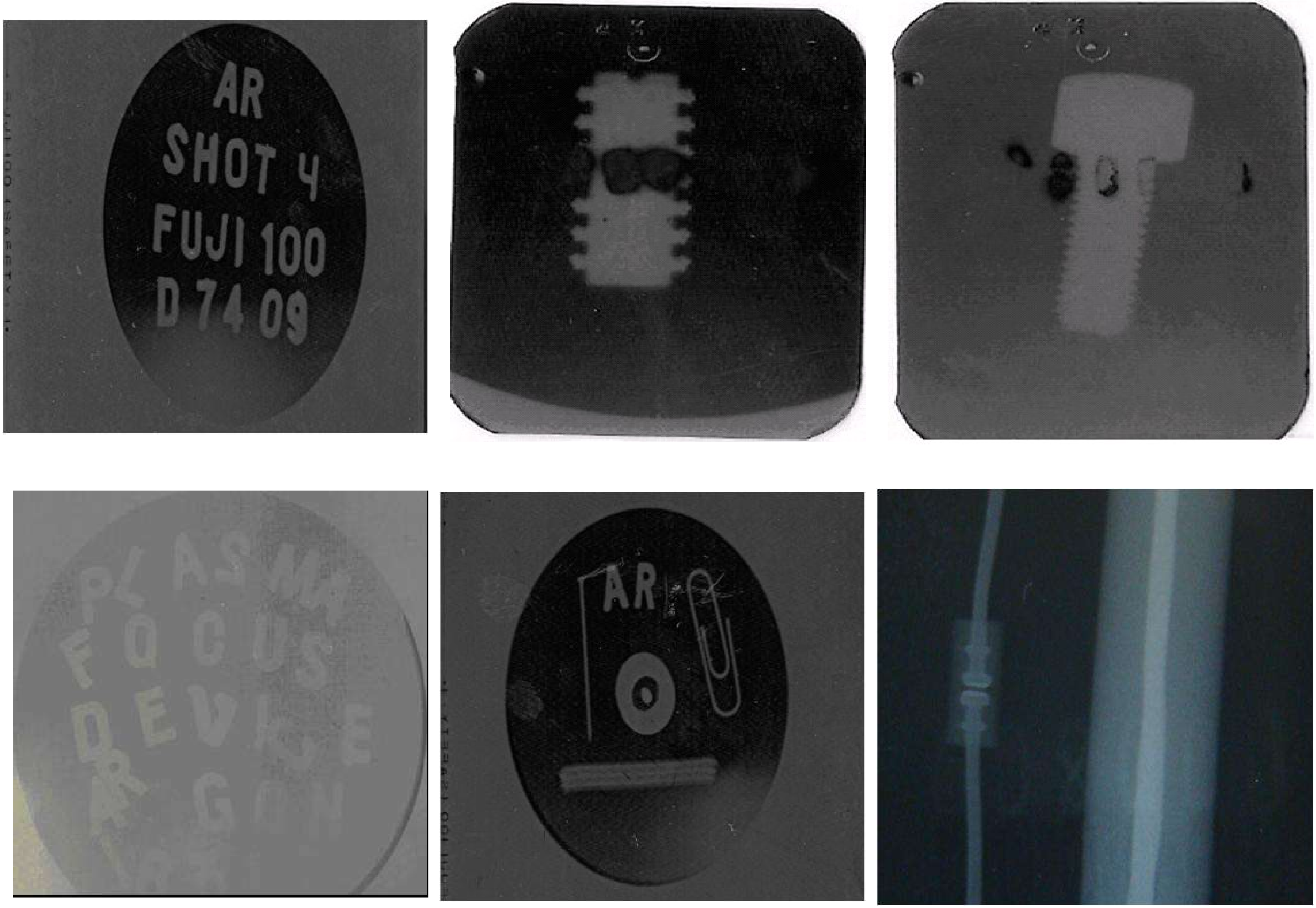
POPULATE , XRAYFIL , FLYCHK codes.

The X-ray ratio curves for various electron temperatures with probable electron and ion densities of the plasma produced have been computed with the assumption of the NLTE model for the distribution of the ionic species.



Sh. Al-Hawat, M. Akel , C. S. Wong, Journal of Fusion Energy 30 (6), 503 - 508 (2011)

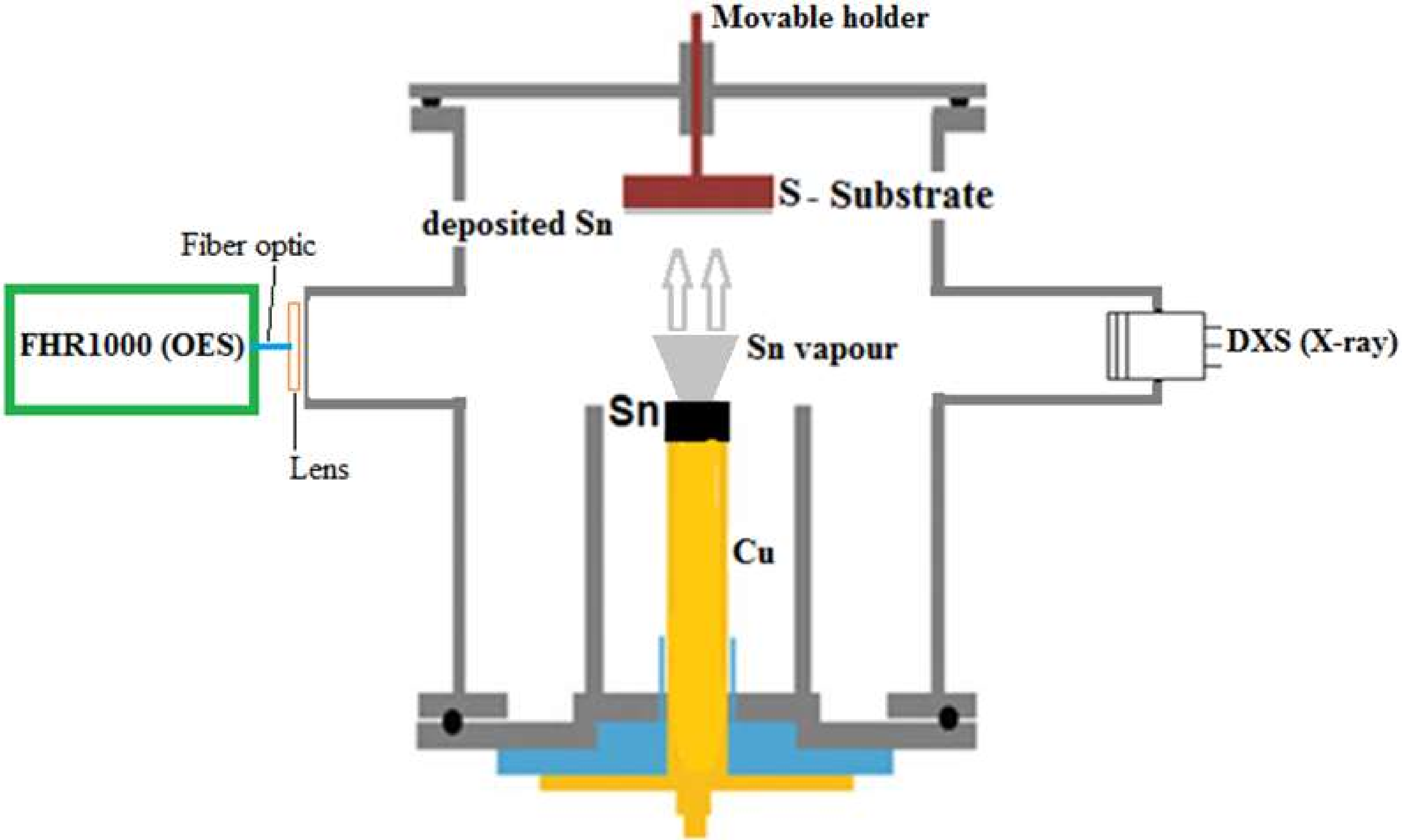
X-Ray Radiography by AECS-PF



Sh. Al-Hawat, M. Akel , S. Shaaban, Journal of Fusion Energy, 34 (1), 163-171 (2015)

Plan for the first year (characterization work):

Optical emission spectroscopy (OES) and X-ray:

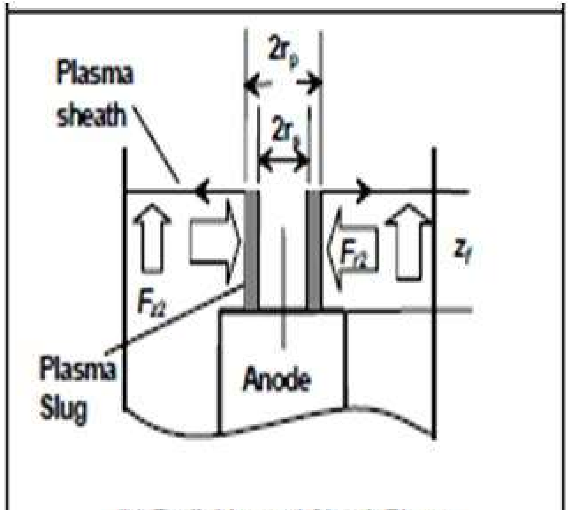


Schematic of OES and DXS spectrometers positions

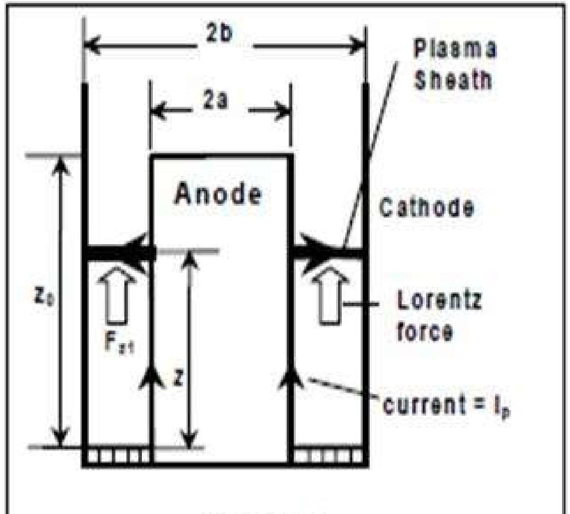
outline

•Simulation work

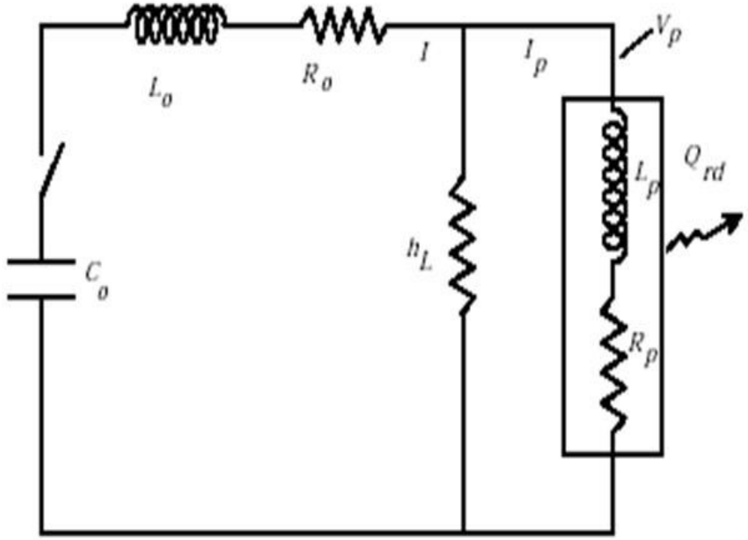
Simulation of ion and electron beam properties using Lee model

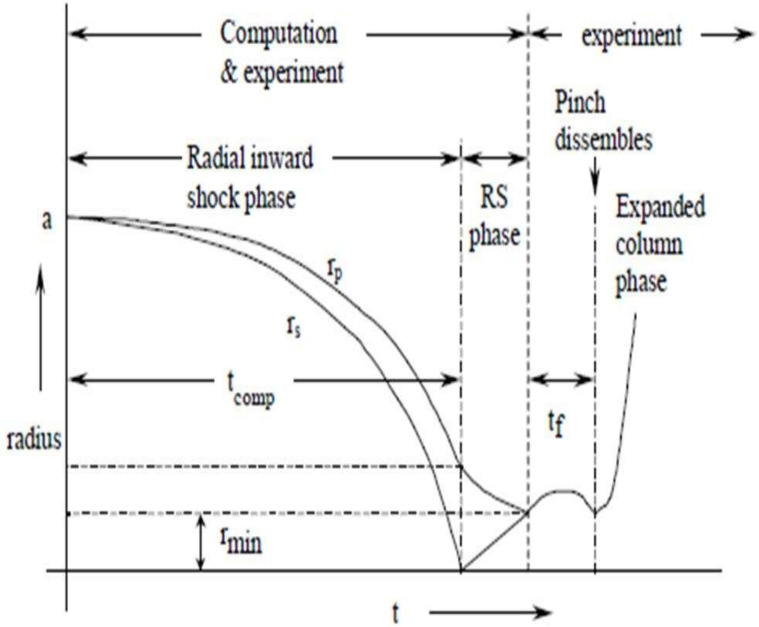


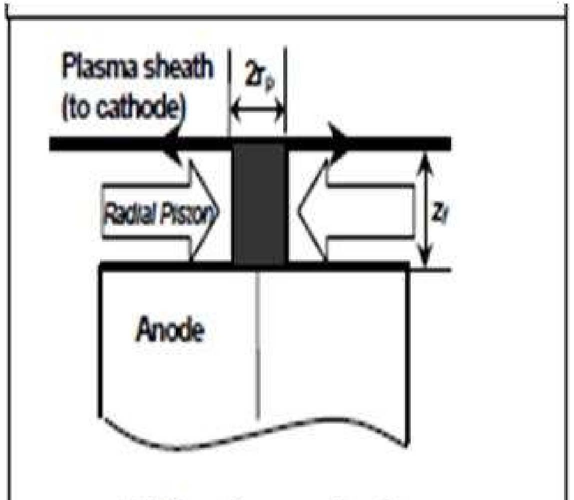
(b) Radial Inward Shock Phase



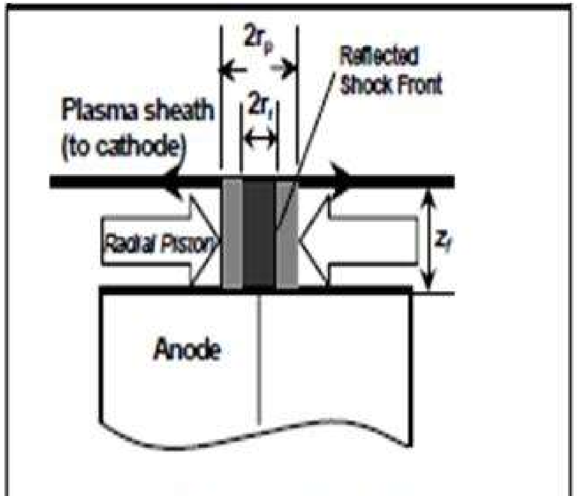
(a) Axial Phase





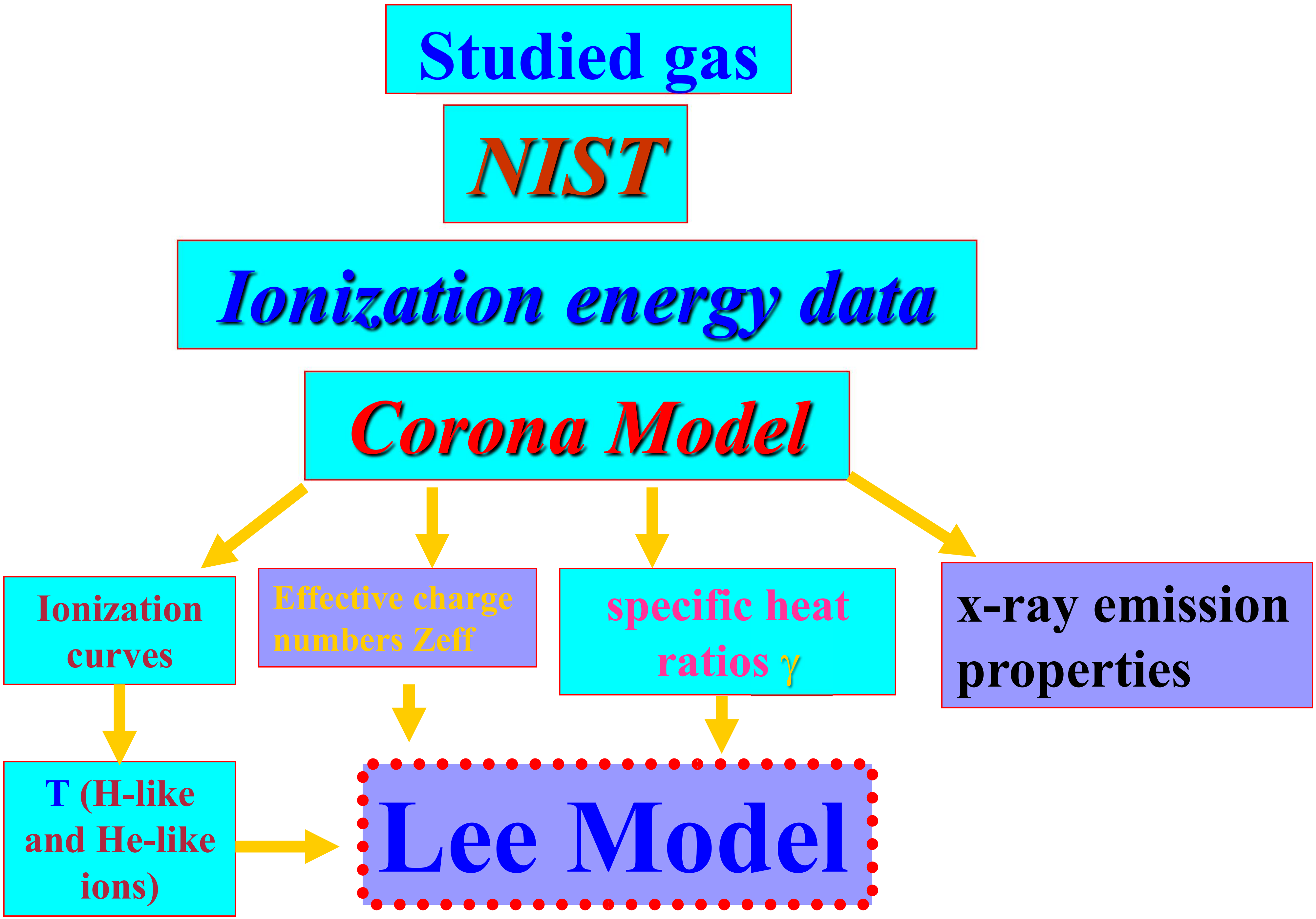


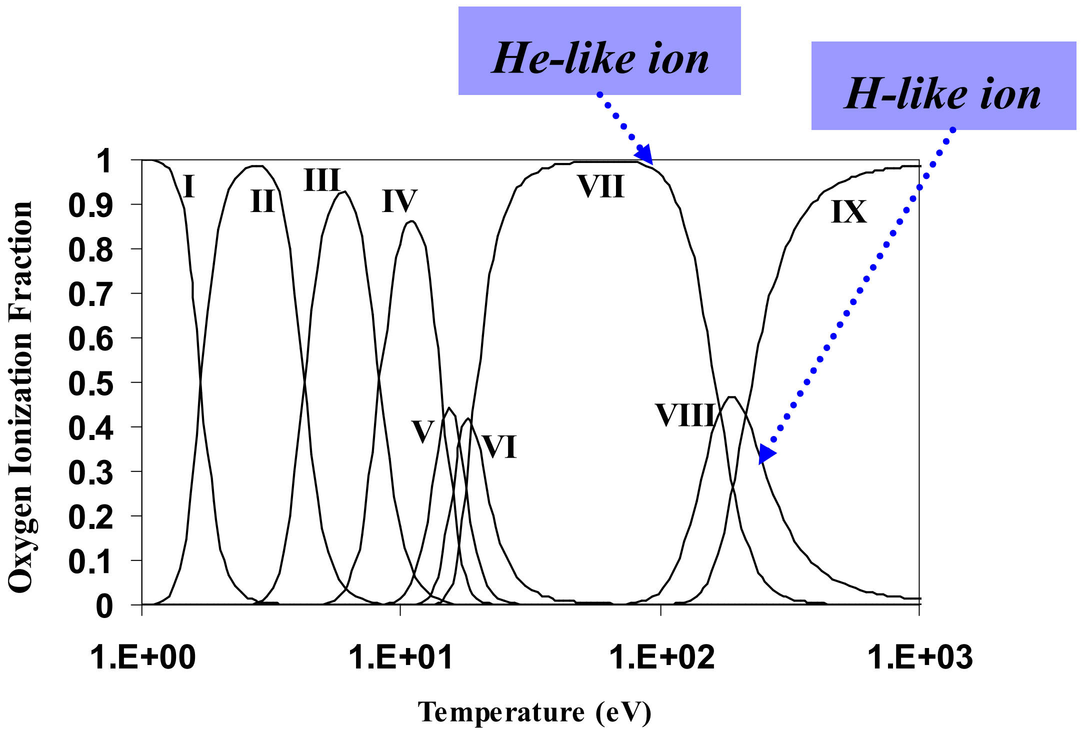
(d) Slow Compression Phase

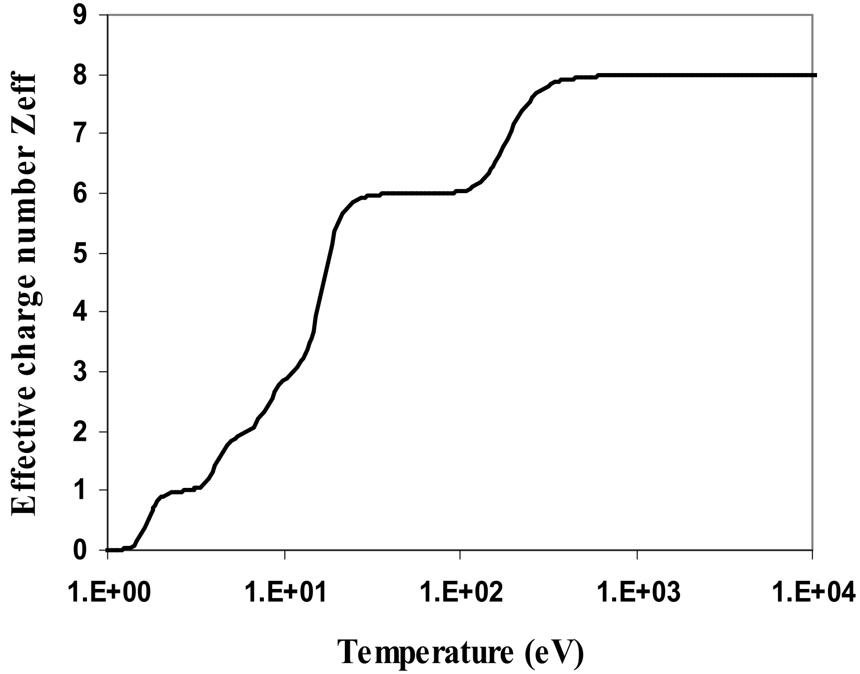


(c) Reflected Shock Phase

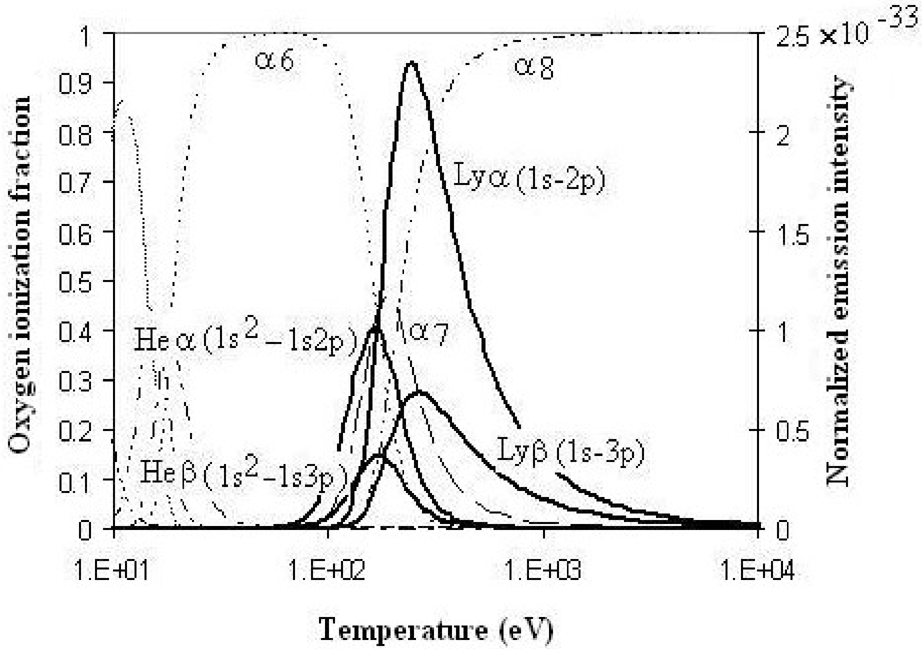
Corona model:



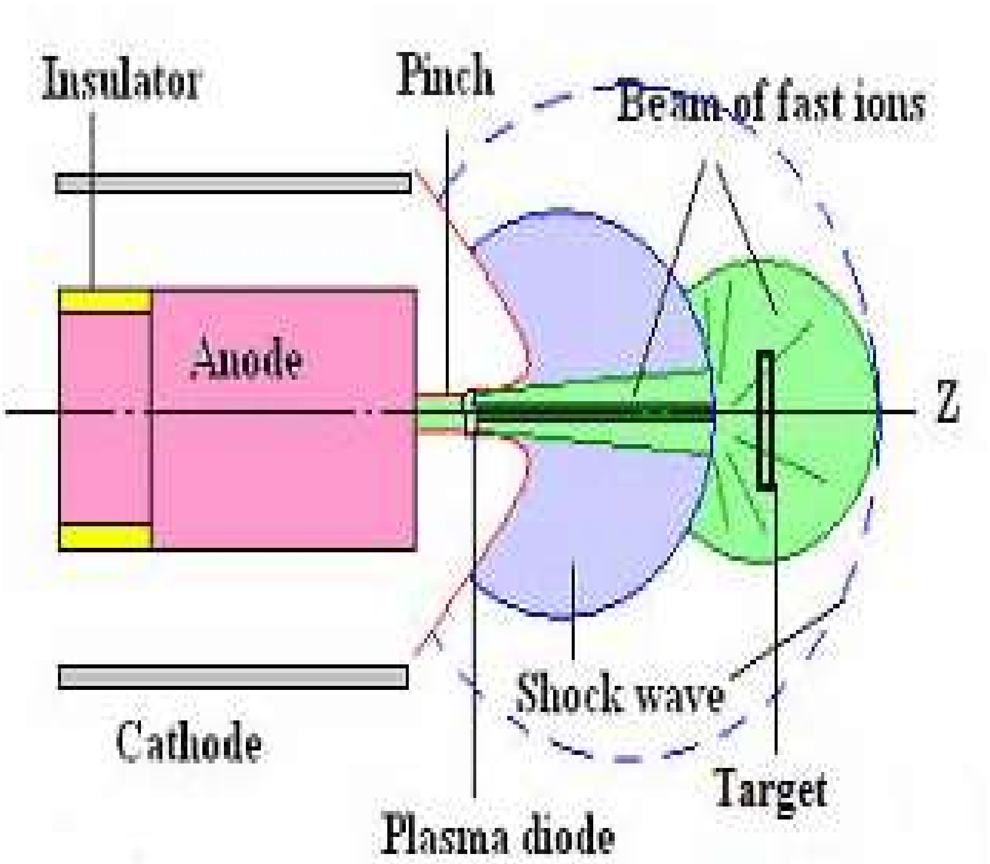


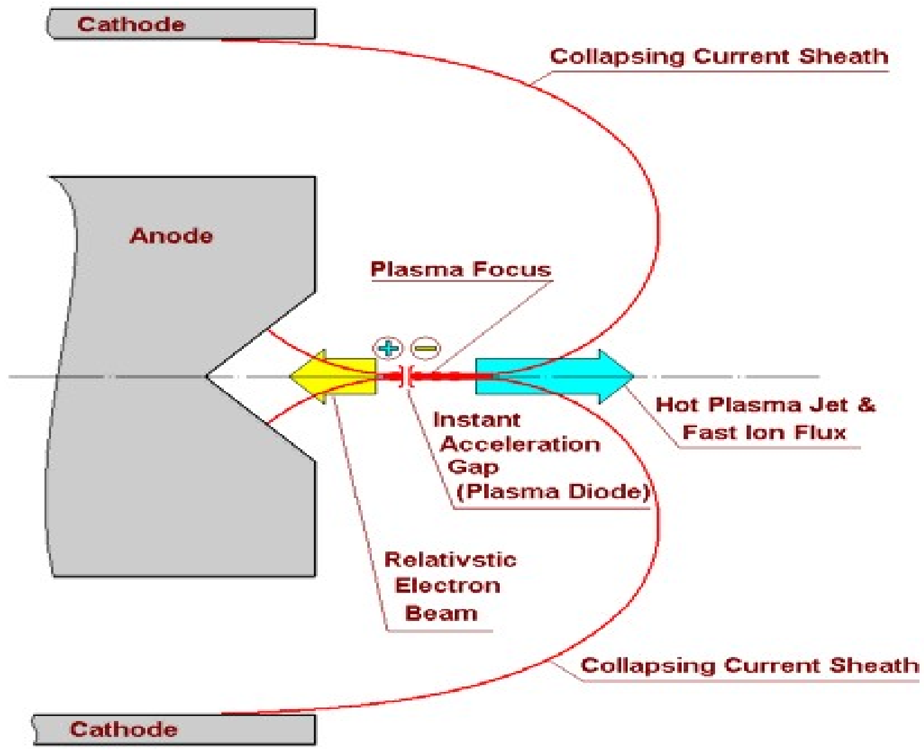


Gas	Temp.	Zeff	$E_{ion}=E_i+(3/2)(1+Z_{eff})kT$
Nitrogen	~160 eV	6.48	1.16+1.79 keV
Oxygen	~225 eV	7.38	1.59+2.82 keV
Neon	~420 eV	9.38	2.69+4.36 keV
Argon	~3 keV	17.00	11.03+54 keV



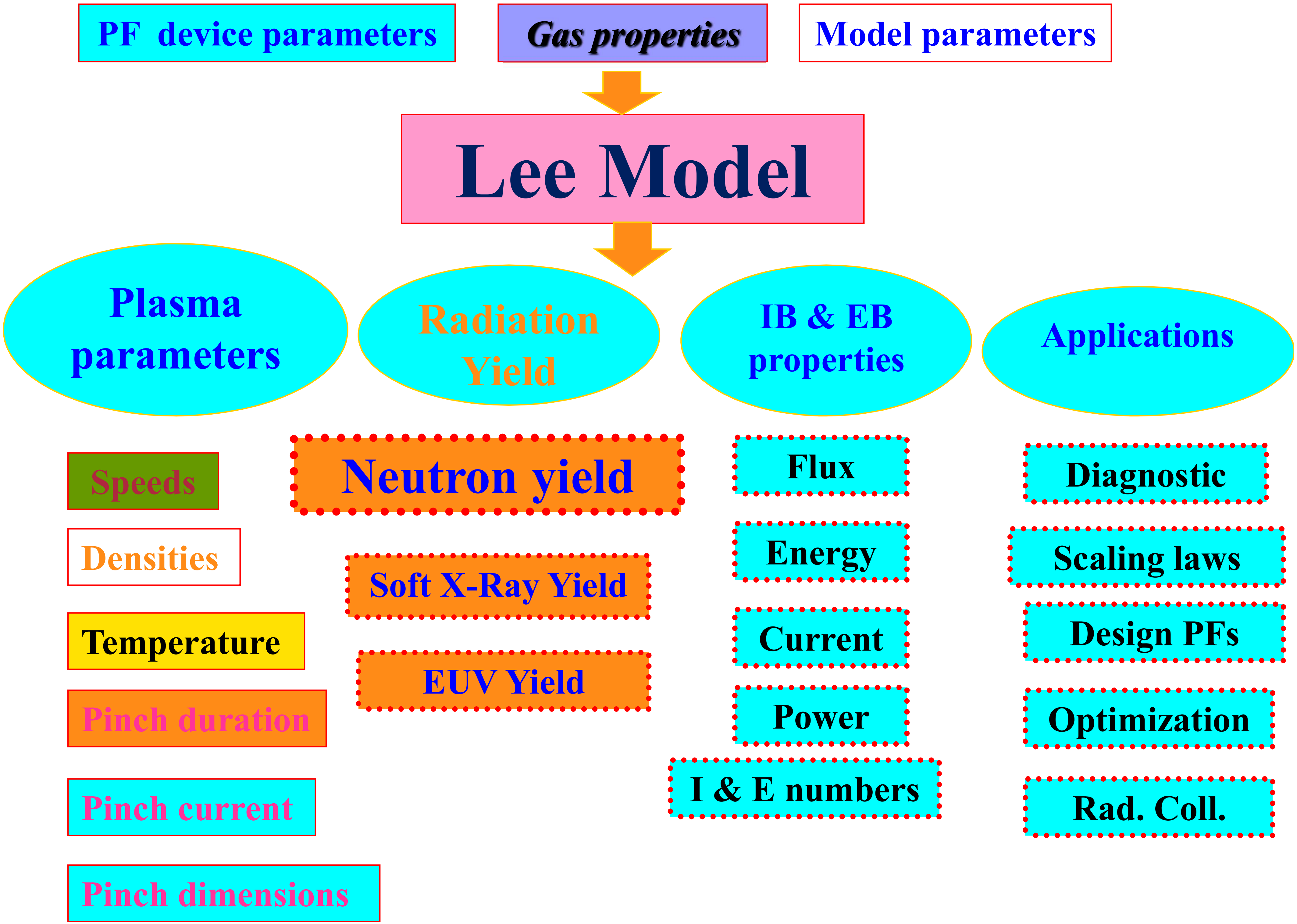
Dynamics of electron beams, plasma streams and fast ion beams in the plasma focus





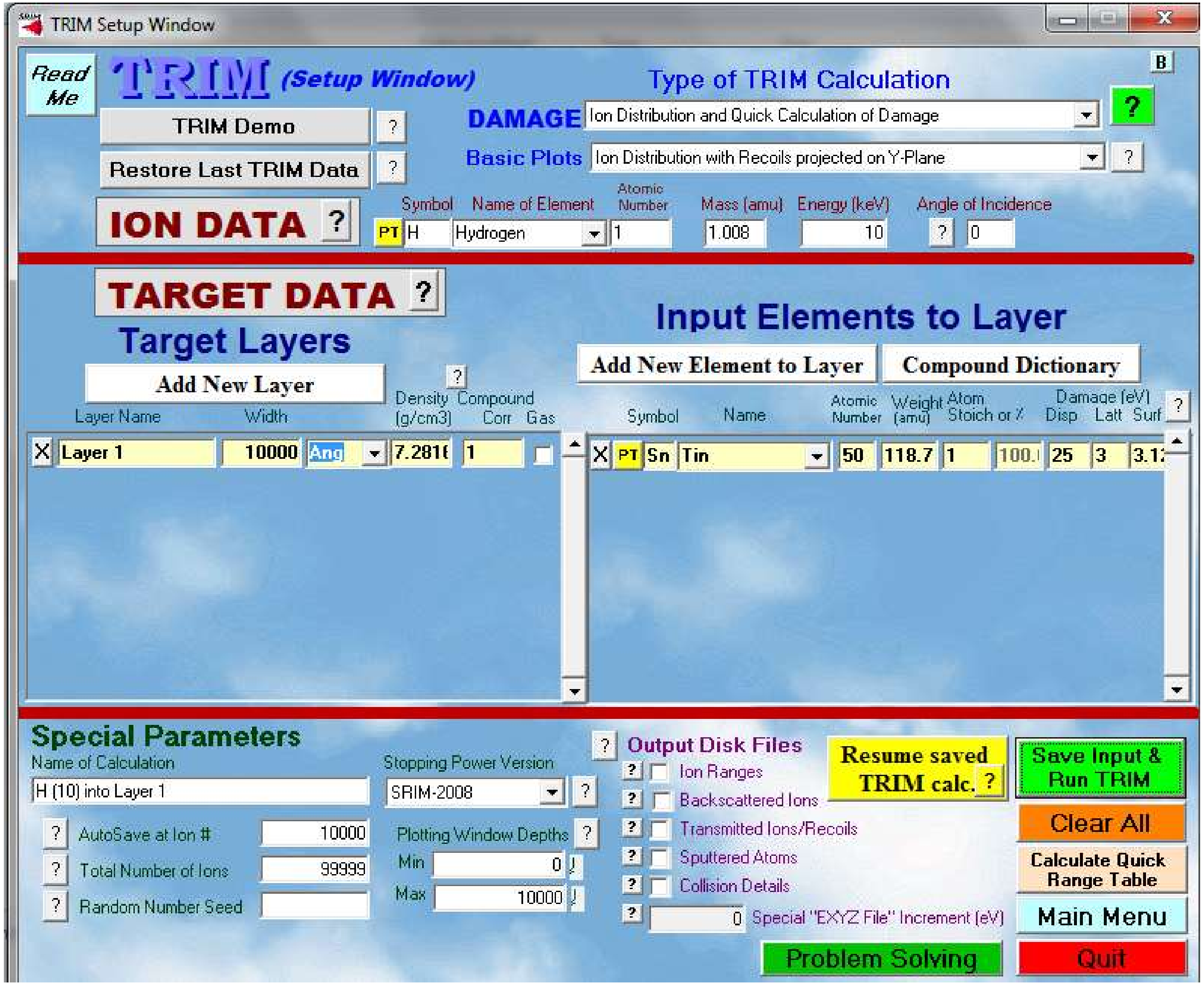
The Lee model has been modified based on the virtual plasma diode mechanism for studying of electron and ion beams from plasma focus.

S. Lee, S.H. Saw, Phys. Plasmas 20, 062702 (2013), S. Lee, http://www.plasmafocus.net (2013)
M. Akel, S. H. Saw and S. Lee, IEEE T. Plasma Sci. 45(8) (2017) 2303.


PF device parameters
Gas properties
Model parameters
Lee Model
Plasma parameters
Radiation Yield
IB & EB properties
Applications
Speeds
Densities
Temperature
Pinch duration
Pinch current
Pinch dimensions
Neutron yield
Soft X-Ray Yield
EUV Yield
Flux
Energy
Current
Power
I & E numbers
Diagnostic
Scaling laws
Design PFs
Optimization
Rad. Coll.

Interaction of the high energy ions with the Tin target using SRIM code

The SRIM code could be used for computation of the energy loss (stopping power) for energetic ions due to interactions with the background gas and the Tin target.



www.srim.org for the stopping and range of ions in matter,
M Akel, et., al. PHYSICS OF PLASMAS 21, 072507 (2014)

Conclusion

In our experiment we are planning to use Tin targets (pure and alloys) to simulate the TOKAMAK wall, and to study the efficiency of the sputtering of Tin. One plasma shot or multi-shots can be used to evaporate and sputter the surface of target.

The sputtered Tin particles (atoms and ions) will be deposited on secondary target (stainless steel substrate or silicon for example).

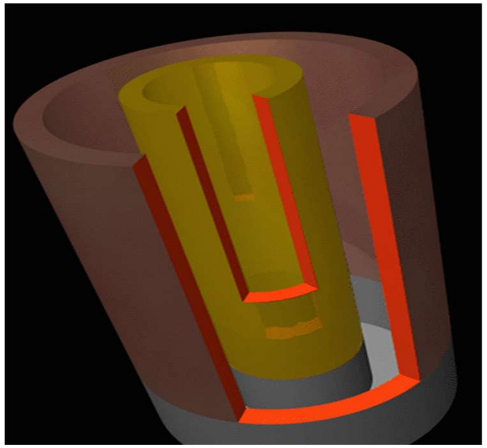
The analysis of this target will give information about the elemental composition of deposited material on the surface of this target according to different experimental conditions.

Conclusion (continued)

The change in the experimental conditions (such as working gas pressure, number of shots and distance from the anode) can play a huge role on the Tin sputtering amount. Also, in such experiments other metals could be mixed with the Tin in the target.

Numerical study of the ions beam properties (ion beam energy, ion beam flux, ion beam fluence, beam ion number, ion beam current, power flow density, and damage factor) emitted from the plasma focus short pulses.

Optical emission spectroscopy measurements of the formed Sn vapour due to interactions of plasma focus (electrons and ions) with the treated targets.



Thank You