A Vision for FCIPT

Emerging Opportunities in Plasma Processing

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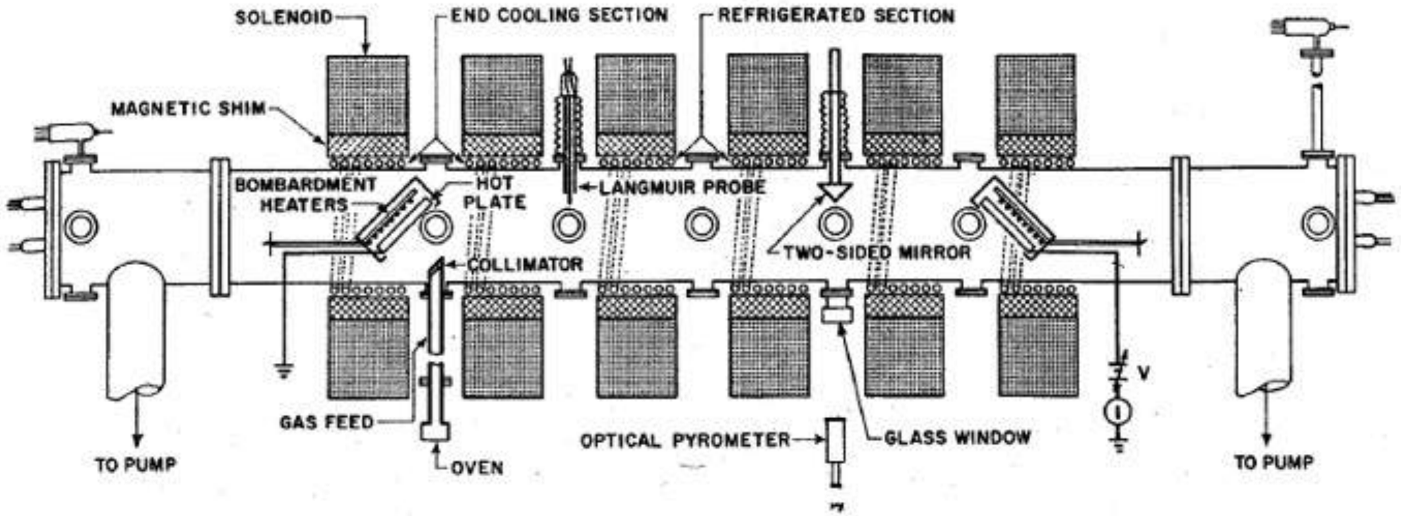
First observation of drift waves in the lab

Hendel, Chu, Politzer, Phys. Fluids **11**, 2426 (1968)
Hendel, Coppi, Perkins, Politzer, PRL **18**, p. 439 (1967)
<u>Q-machines</u>, Motley (1975)

Q-1 Device "Q-Machine" (Princeton)

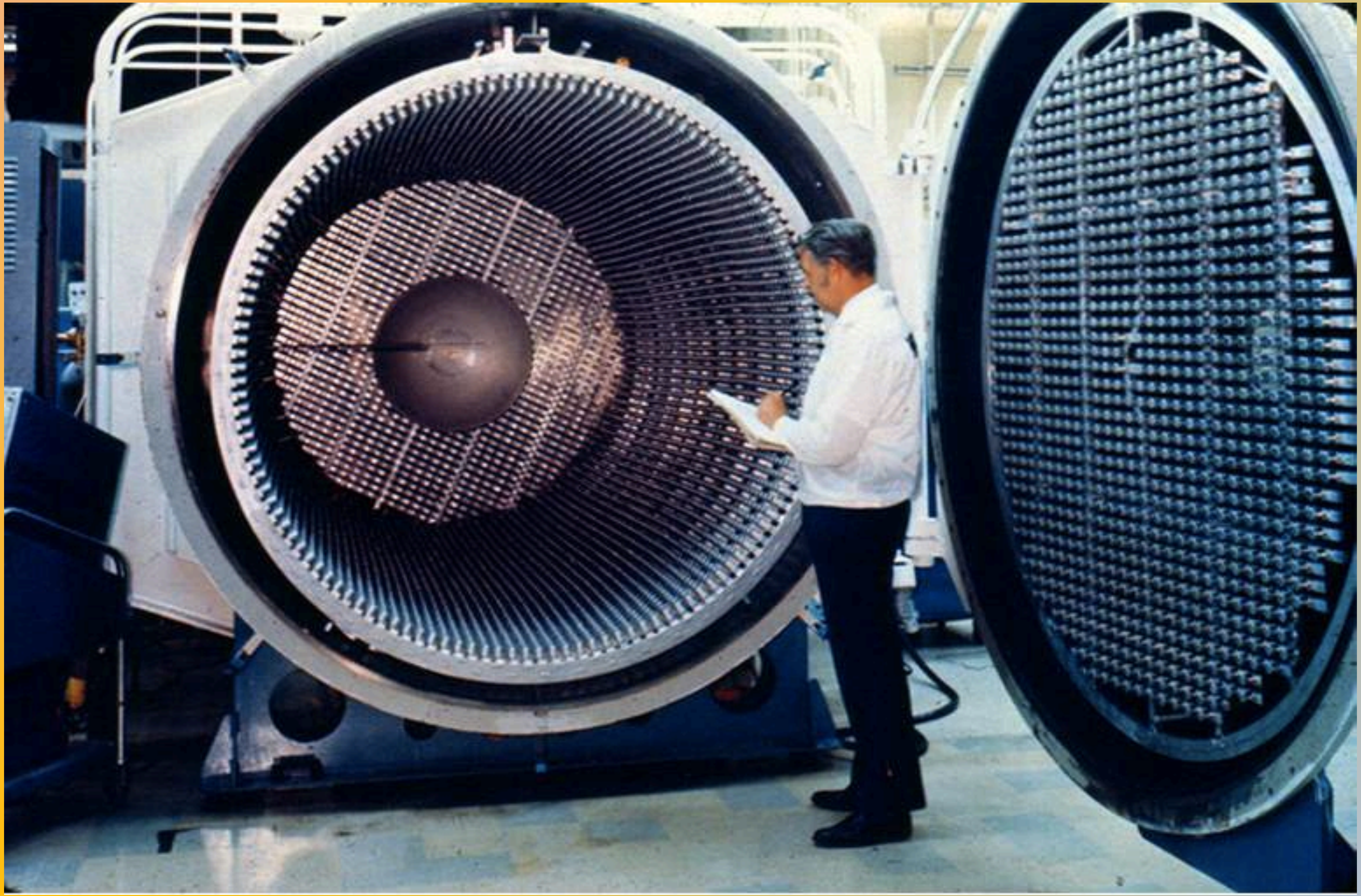


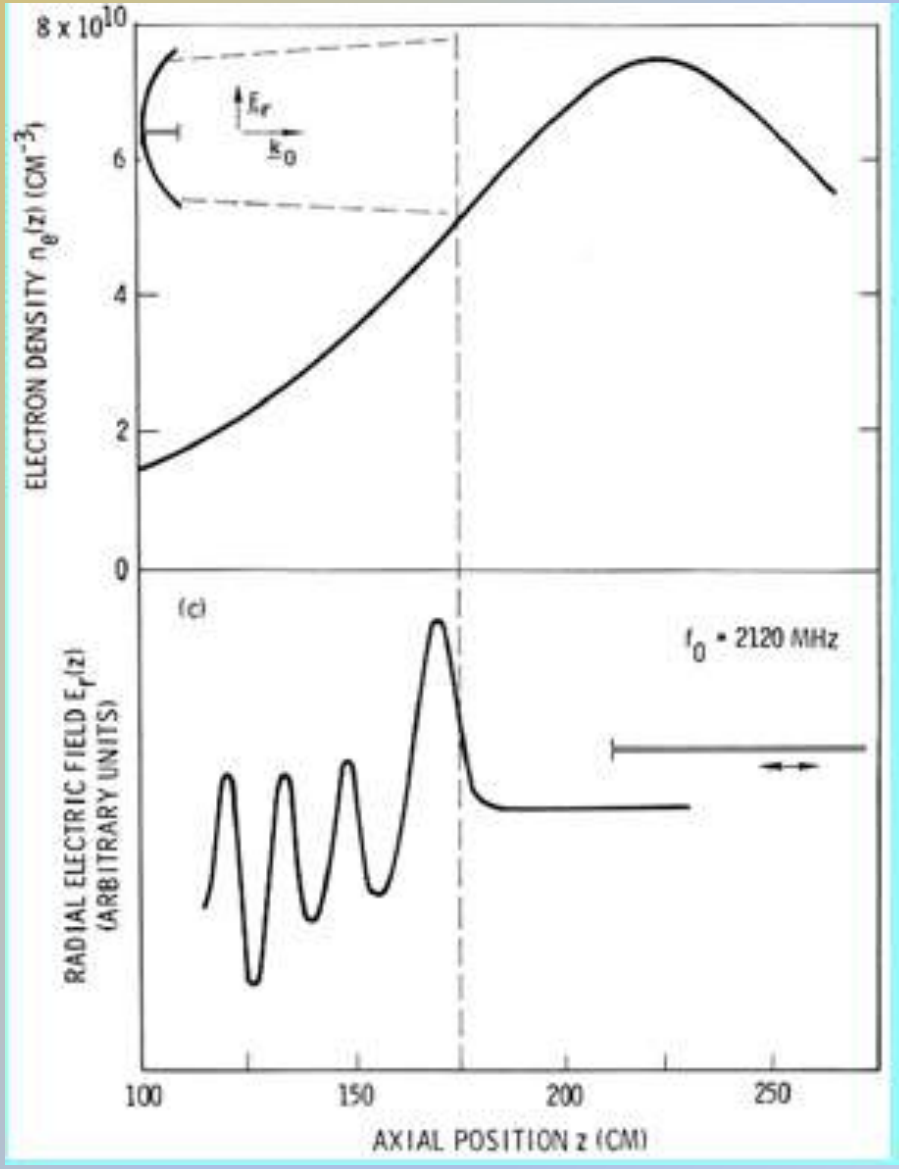
Steady state ion beam source, no currents or flows

$n_e = 5\text{x}10^{10} - 5\text{x}10^{12}$ cm^{-3} (fully ionized K^+ or Cs^+ plasma)

$L \approx 128$ cm, $a \approx 1.5$ cm, $B \approx 2\text{-}7$ kG, $\rho_i \approx 0.1$ cm, $\beta \leq 10^{-6}$

$T_e \approx T_i \approx 0.25$ eV (2800° K $\approx$ W plate temperature)

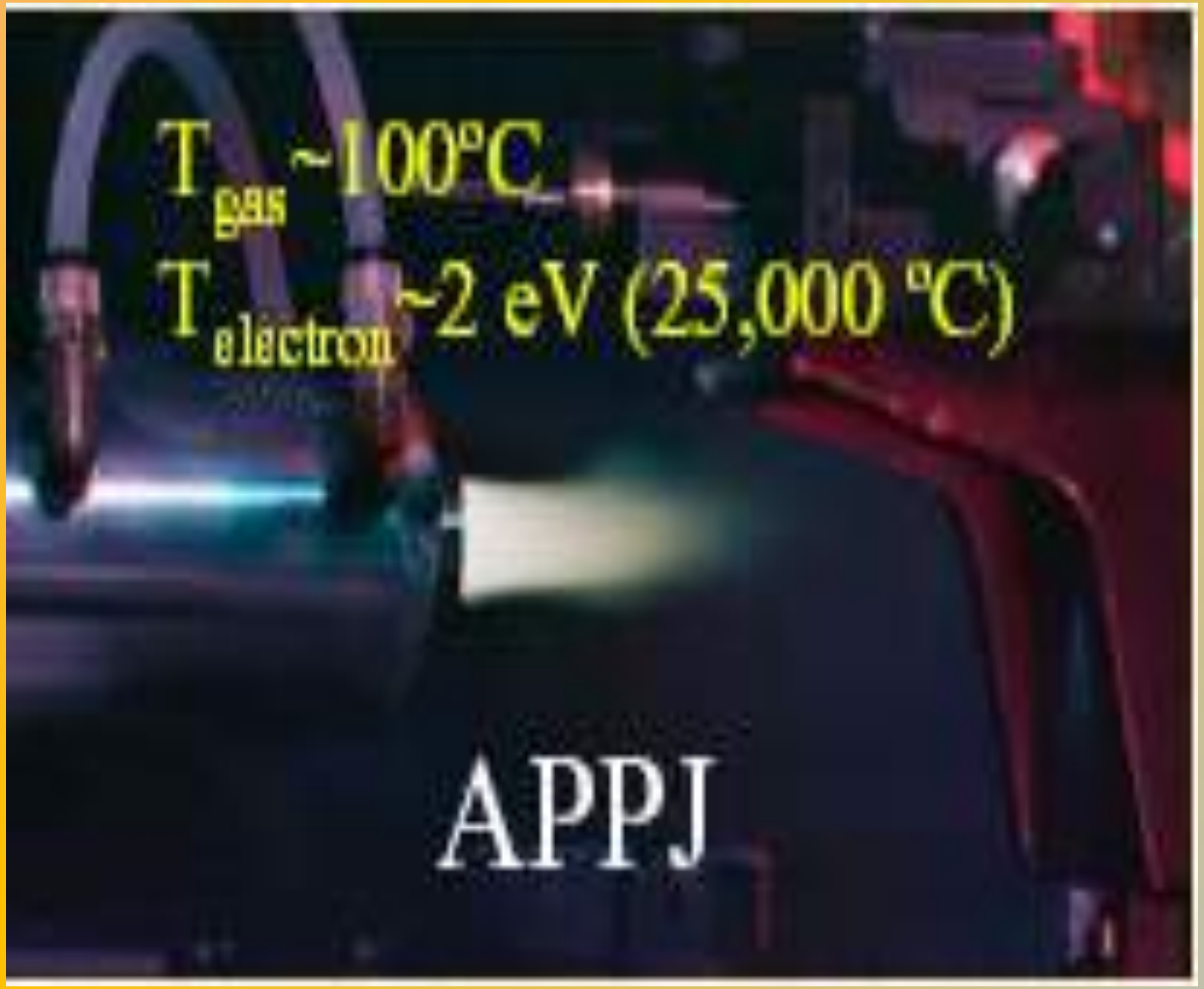




The QUIPS (QUIescent Plasma Source) machine: UCLA

Nonlinear effects at the critical layer. The radiation pressure creates a density cavity which produces energetic electrons and ions

Plasma physicists have invented many schemes for producing cold plasma at atmospheric pressure



- For electron energy > 3 eV, energy transfer through inelastic collisions is very efficient.
- Transfer of energy from electrons to neutrals can be switched off by switching off the electric field after the plasma is formed.
- A repetitive train of pulses will create fresh bursts of short-lived plasma, with energetic electrons and cold neutrals.

Problem: Low Degree of Ionization in Non-equilibrium plasmas

RF plasmoids: Wood Phys. Rev. 1930

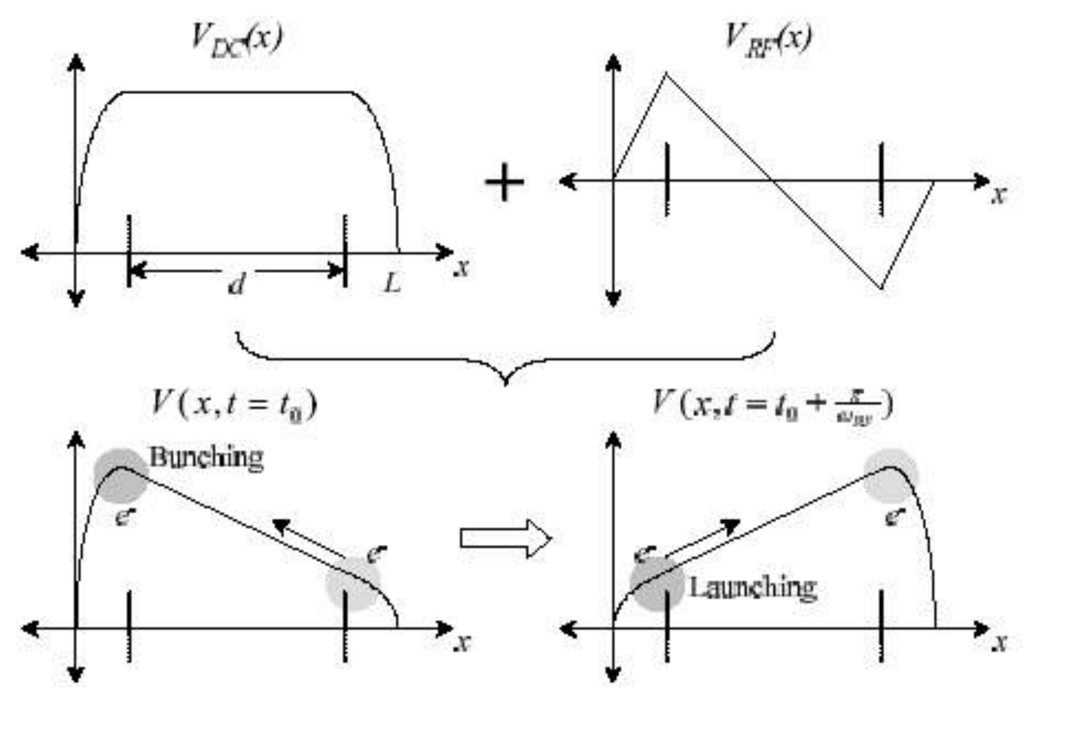
Series Resonance at $w_r = w_p [L_s/L_s+L_p]^{1/2}$

Electron bunching and beam formation. Cool bulk electrons

Plasma impedance approaches pure resistance

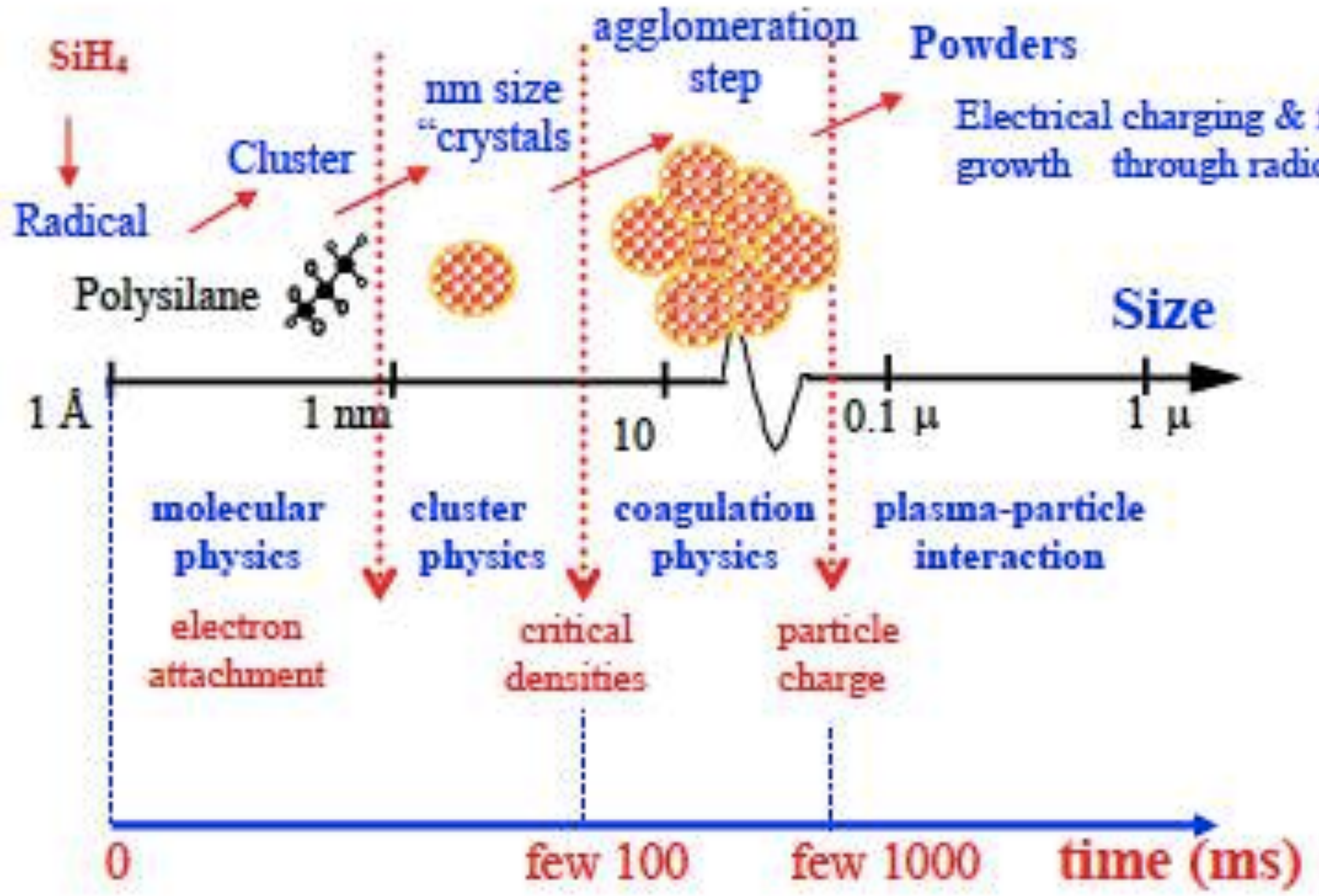
Internal electric field enhanced at resonance

Phase of E-field reverses in bulk



Series resonant discharge

N_e scales as w^3


SiH4
Radical
Cluster
nm size
"crystals
agglomeration
step
Powders
Electrical charging & further
growth through radical sticking
Polysilane
Size
1 Å
1 nm
10
0.1 µ
1 µ
molecular
physics
electron
attachment
cluster
physics
critical
densities
coagulation
physics
particle
charge
plasma-particle
interaction
0
few 100
few 1000
time (ms)

Nanowire Synthesis & Shape Control

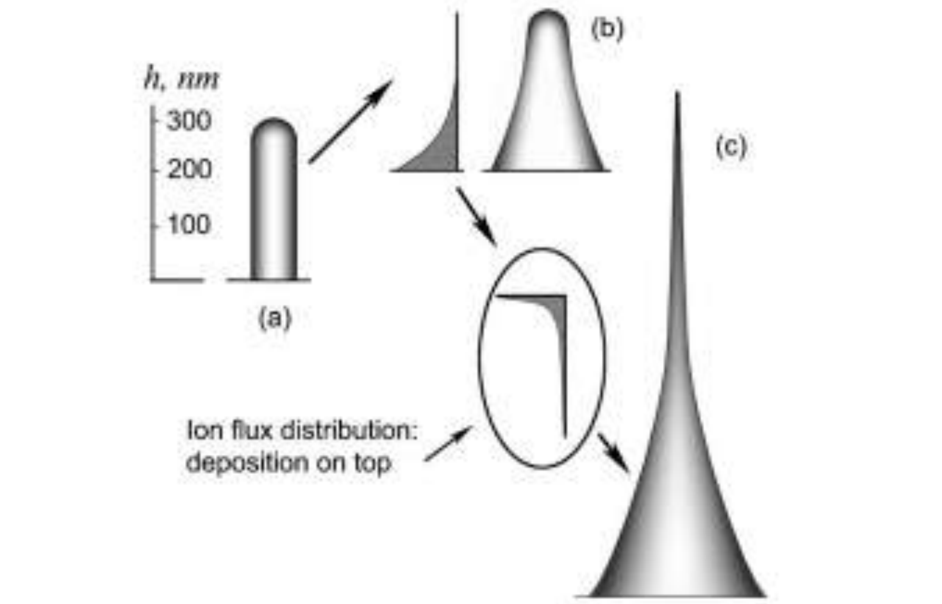
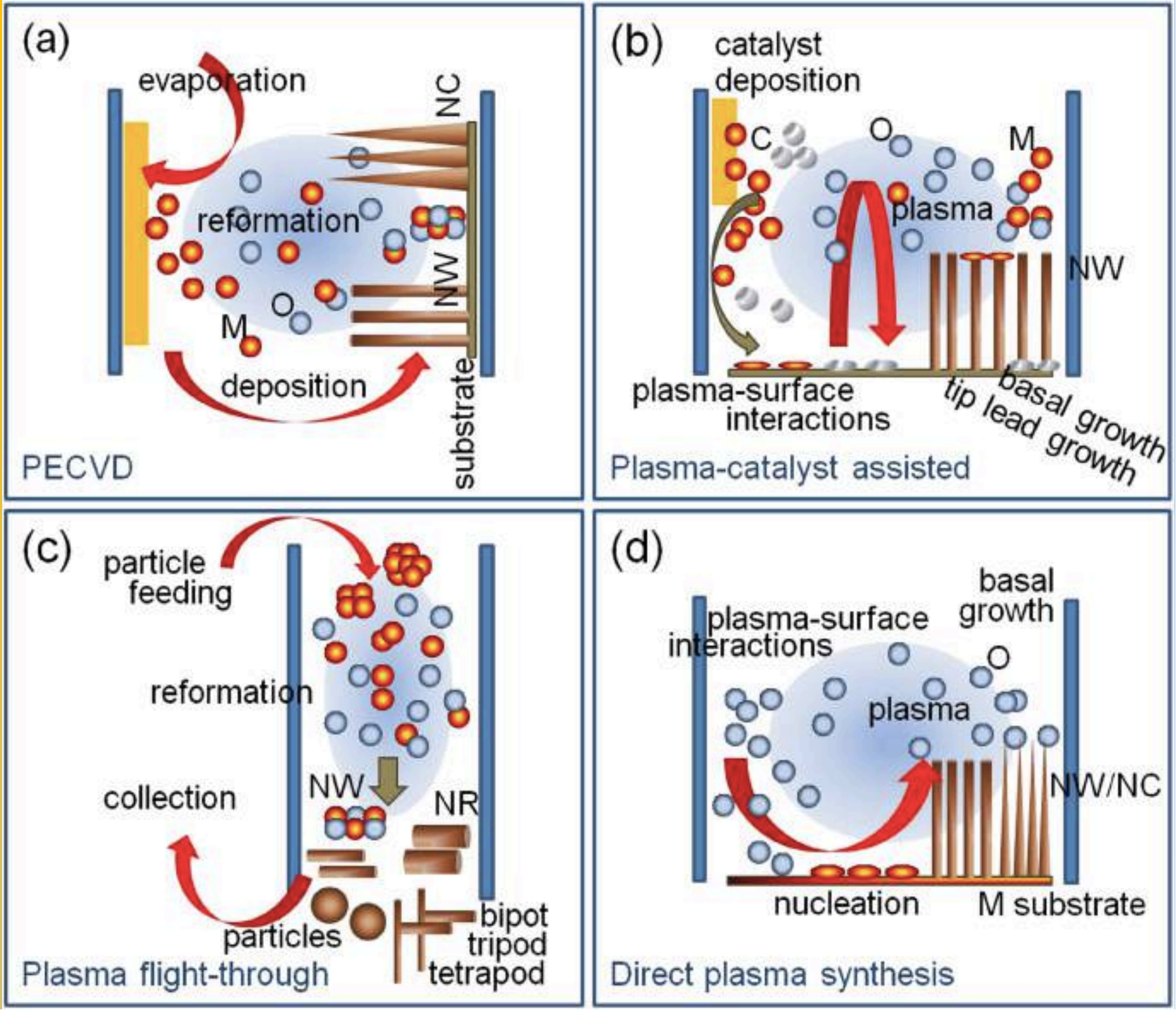
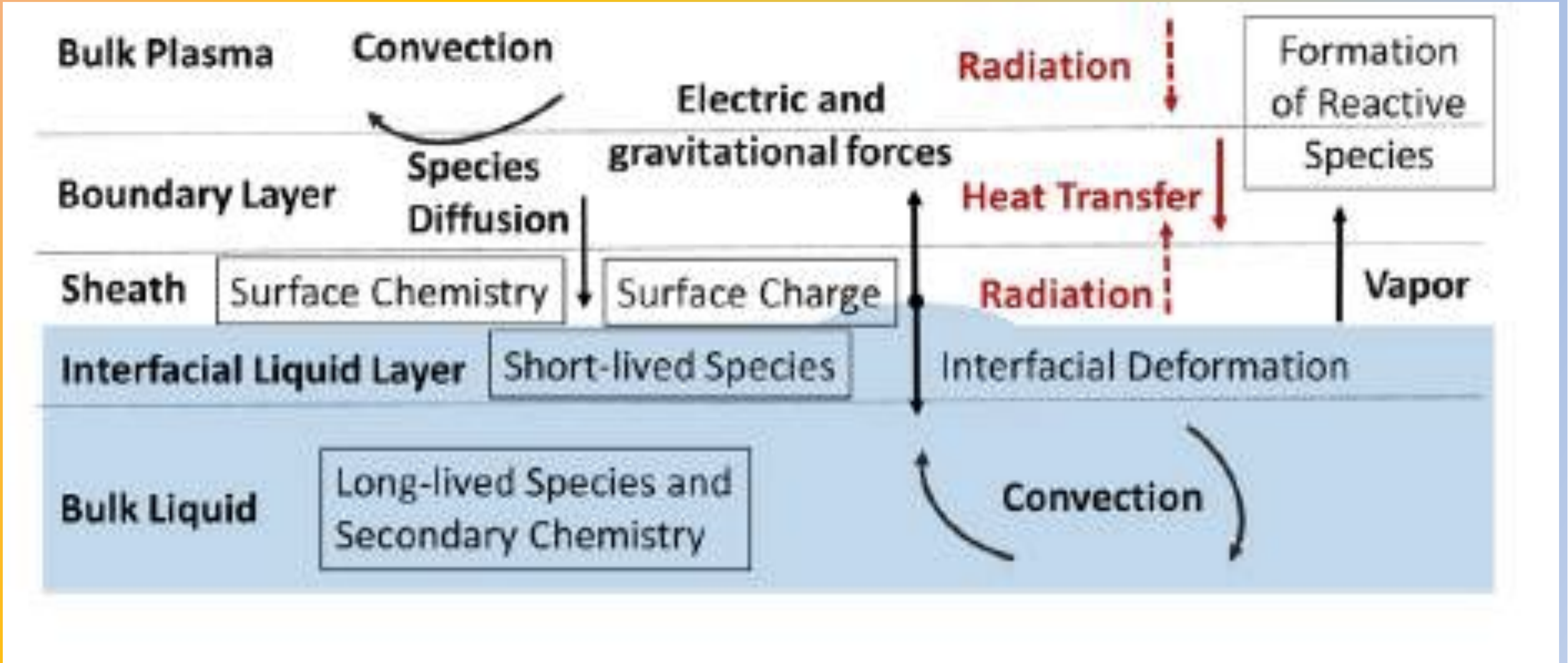


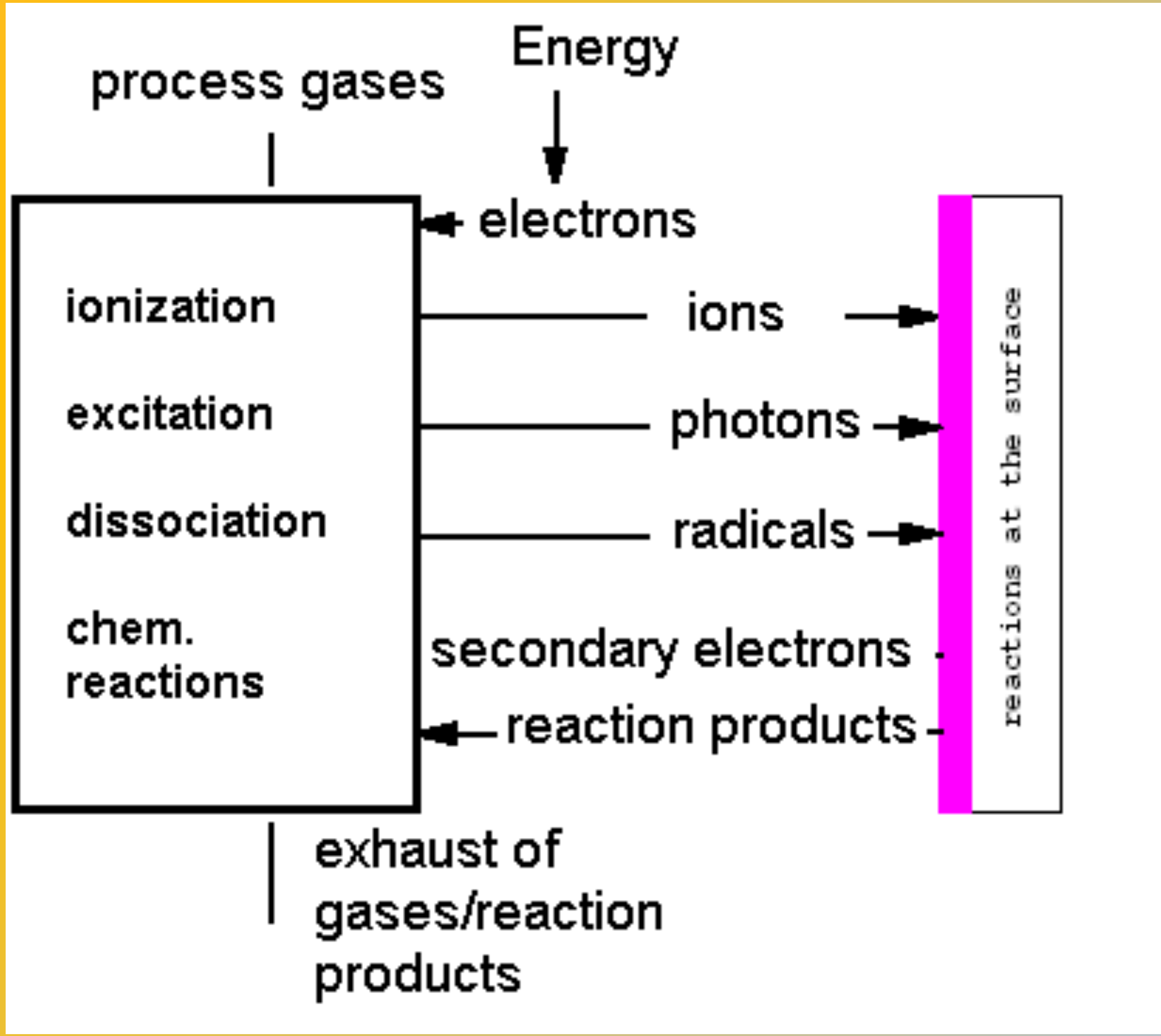
FIG. 5. Reshaping nanotips in a two-stage process: (a) original nanotip, (b) formation of the nanotip base (T_e=2 eV, U_s=50 V, and n_p=4.5×10^{17} m^{-3}), and (c) formation of the emissive spike (T_e=2 eV, U_s=20 V, and n_p=10^{17} m^{-3}).





PLASMA-LIQUID INTERPHASE

Conventional plasma processing



Internal parameters

Electron/ion density

Electron temperature (EEDF)

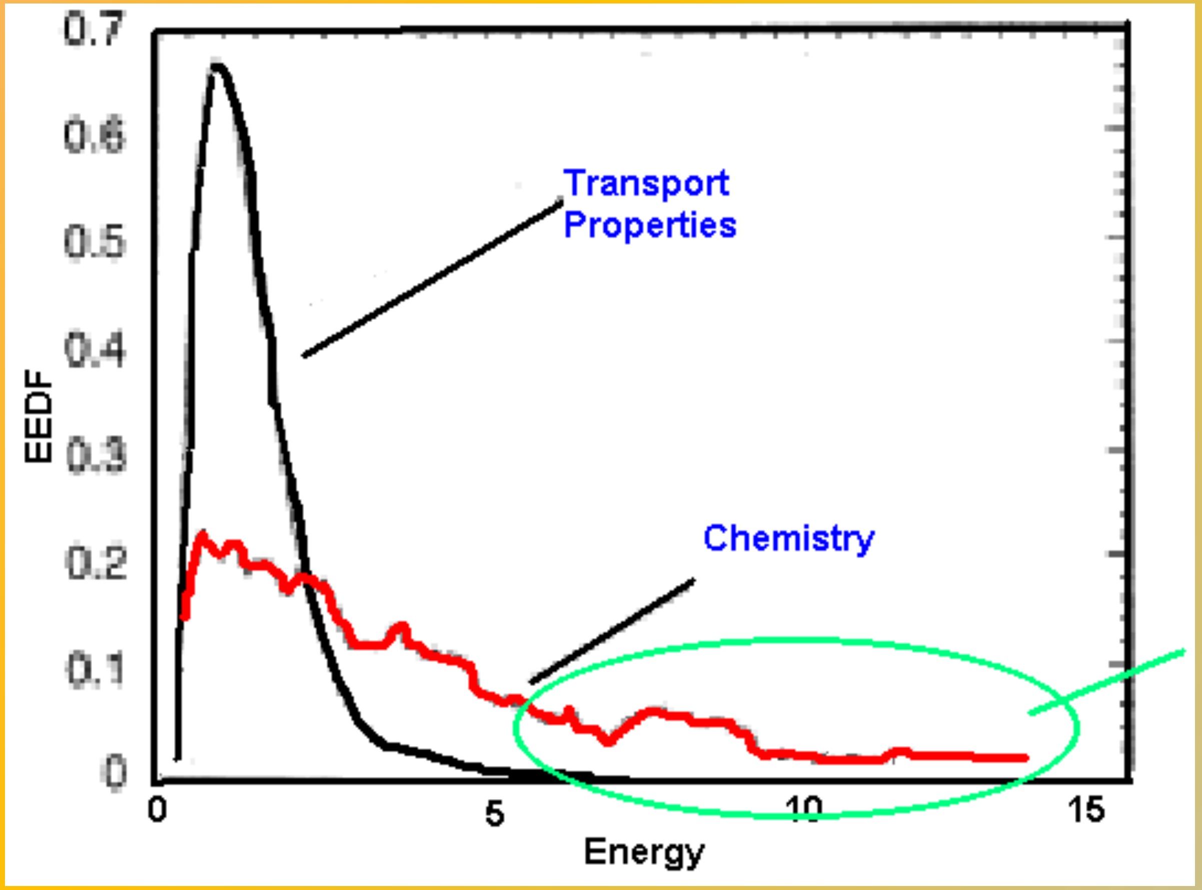
Radical density/flux

Ion flux

Ion energy

Active control of processing plasmas

The role of electron temperature in plasma processing



Threshold energy for chemistry

Increased breeding of SiH3 precursor

Enhanced CF_2/F ratio increases SiO_2 etching selectivity

More CH_3 in methane plasma improves diamond film

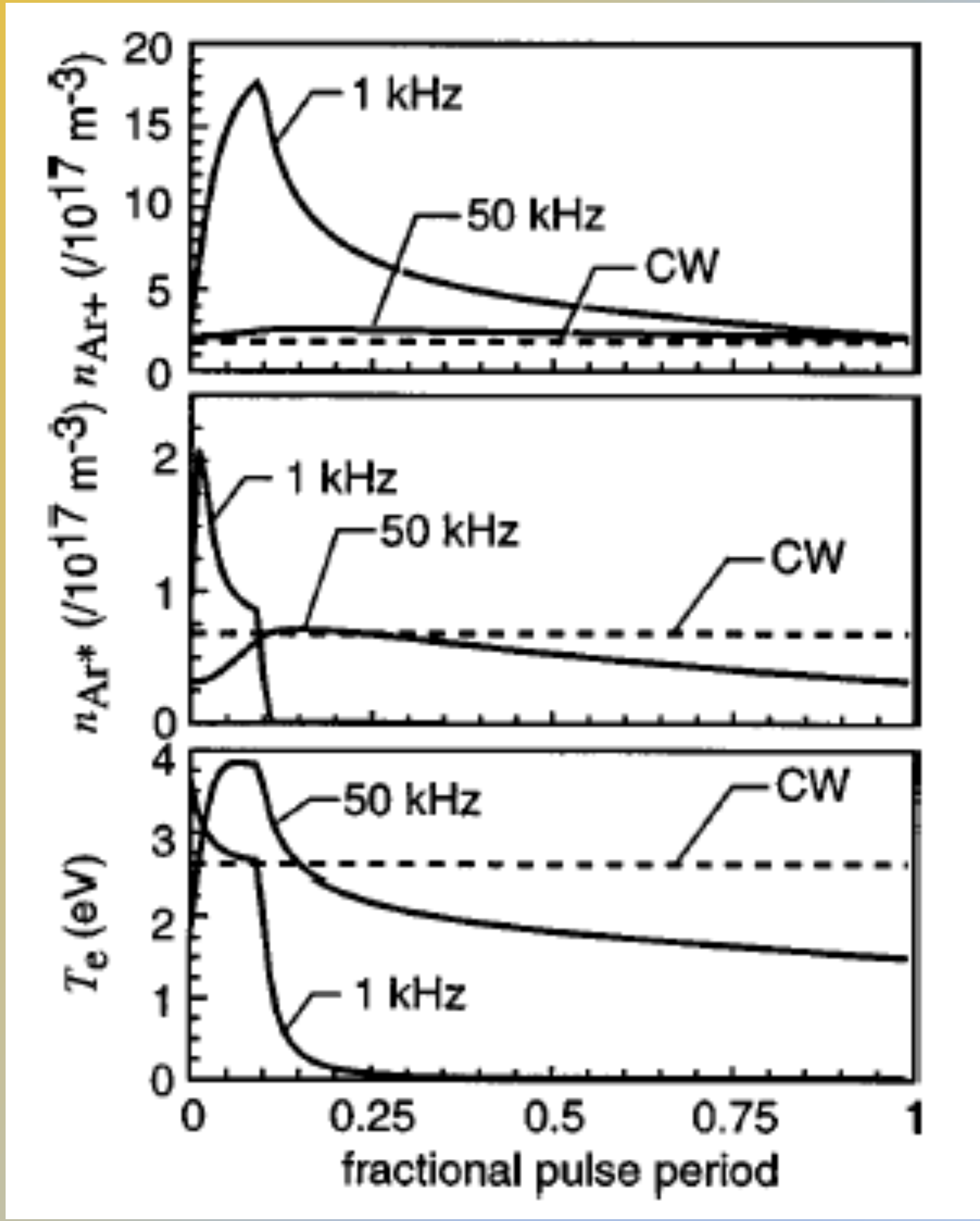
Low electron temperature is good!

Active control by pulsing

N_i reaches many times steady value.

Ions trapped in off period due to low Bohm speed

N* and T_e increase at initiation and drop sharply at off period



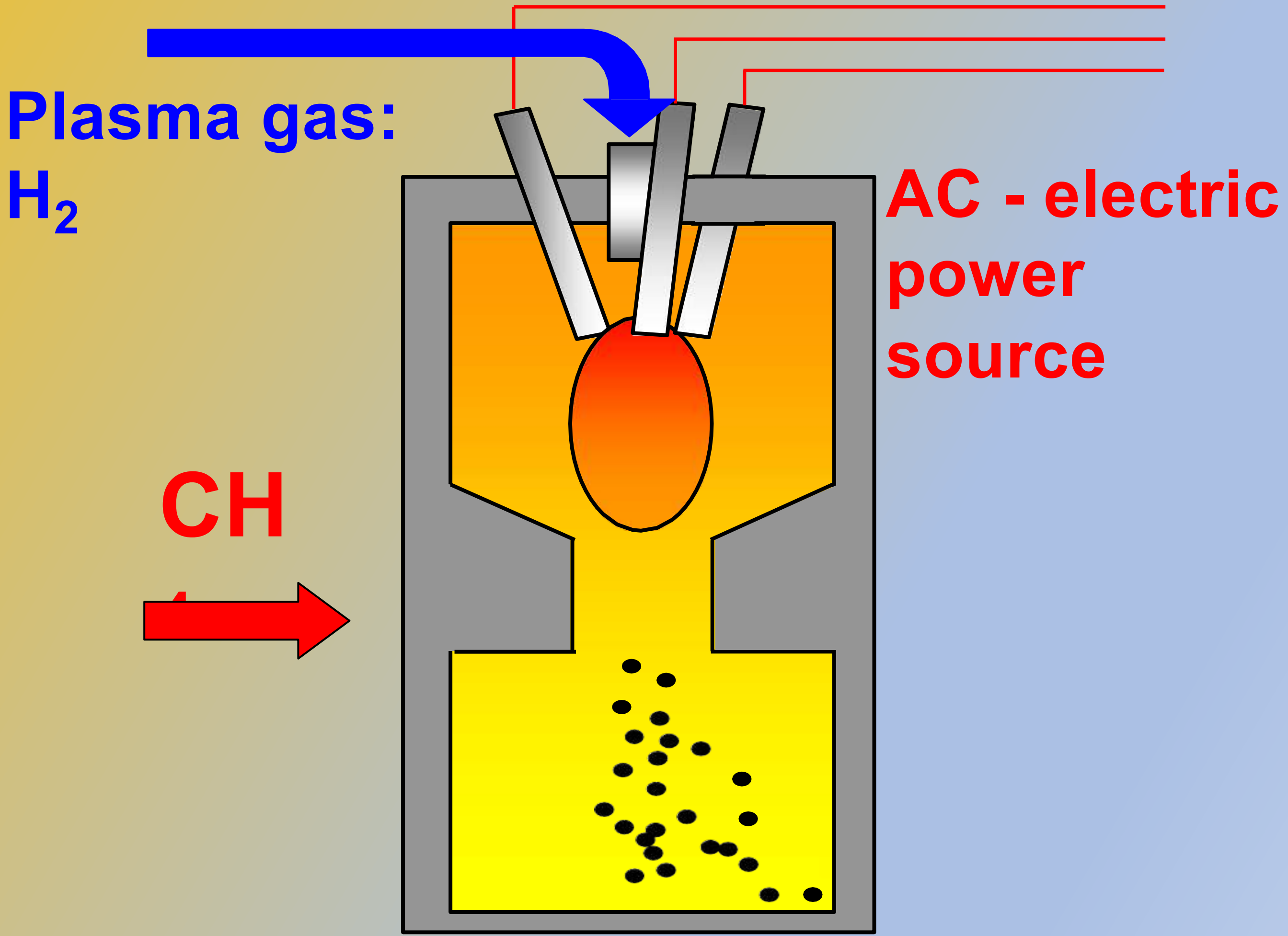
Technical and economic analysis of Plasma-assisted Waste-to-Energy processes

By

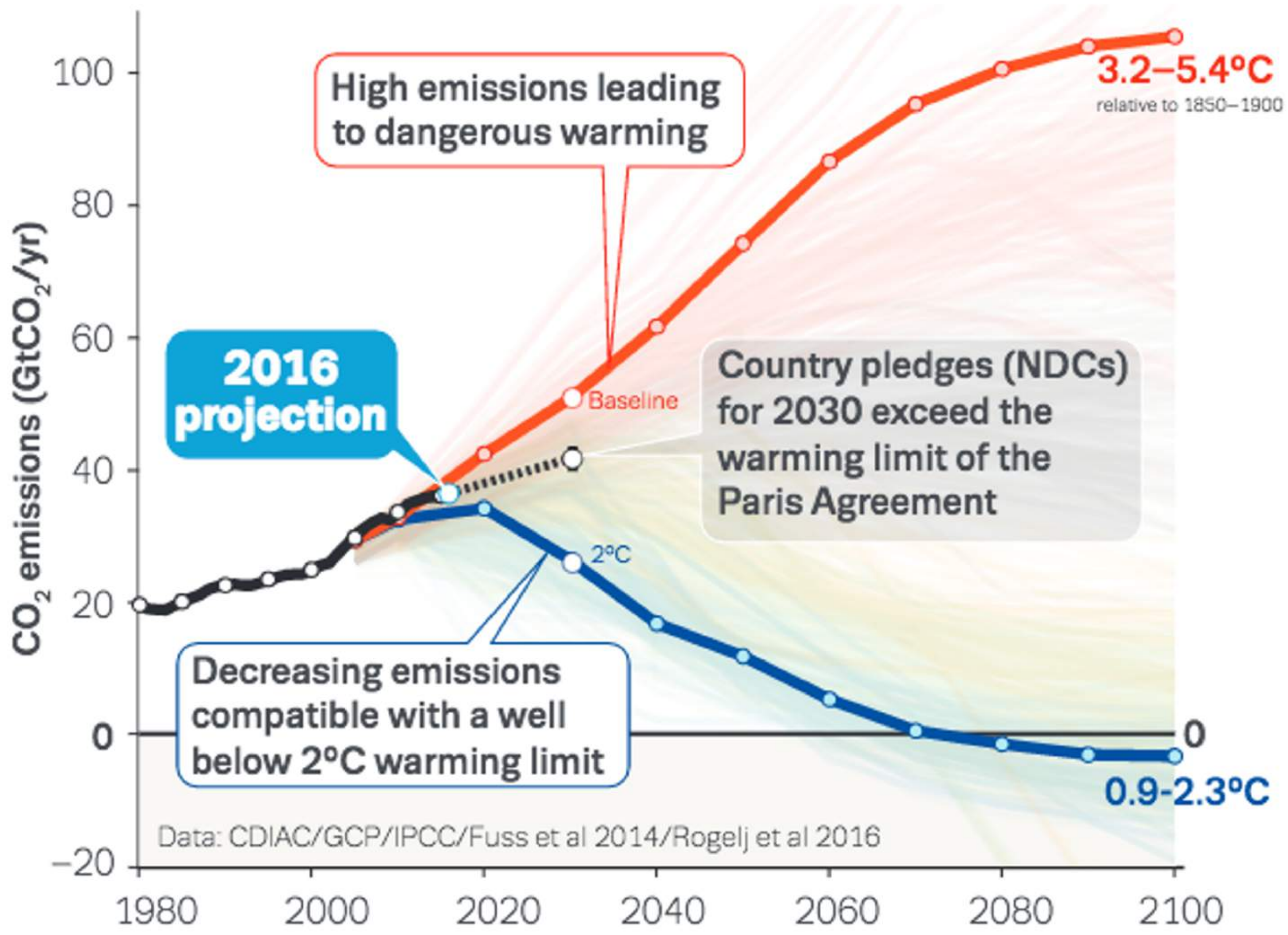
Caroline Ducharme

Capital Cost		
Unit cost of mass burn plant, $/TPD	$	220,000
Cost of mass burn plant	$	66,000,000
Ratio cost of stoker and boiler		25%
Cost of stoker and boiler	$<16,500,000>	
Cost of exhaust stack	$	<1,200,000>
Cost of plant without stoker/boiler/stack	$	48,300,000
Cost of Scalehouse	$	500,000
Cost of Utility Interconnect	$	1,500,000
Cost of waste pre-processing	$	5,000,000
Cost of plasma arc	$	27,400,000
Cost of heat exchanger	$	6,800,000
O_2 injection	$	-
Gas scrubbing	$	-
Cost of Plasma Arc Facility	**$**	**89,500,000**

Plasma Reactor



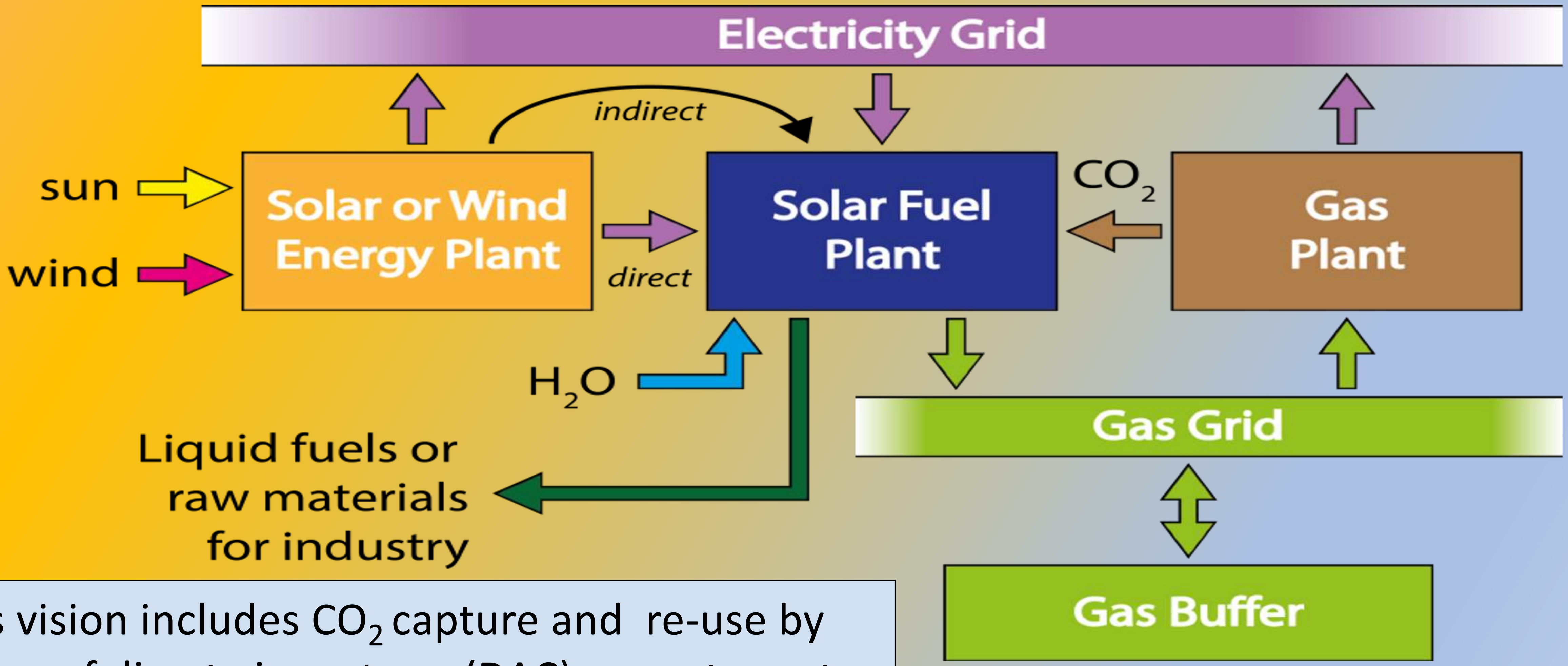
Laurent Fulcheri
Mines ParisTech, France



Can We Make Fossil Fuels Carbon Free?

- **Reform fossil fuels to enhance Hydrogen content**
- **Convert CO2 into Fuel**

Vision: CO_2 neutral energy infrastructure



This vision includes CO_2 capture and re-use by means of direct air capture (DAC) or capture at point sources

CO_2 assymetric vibrational excitation

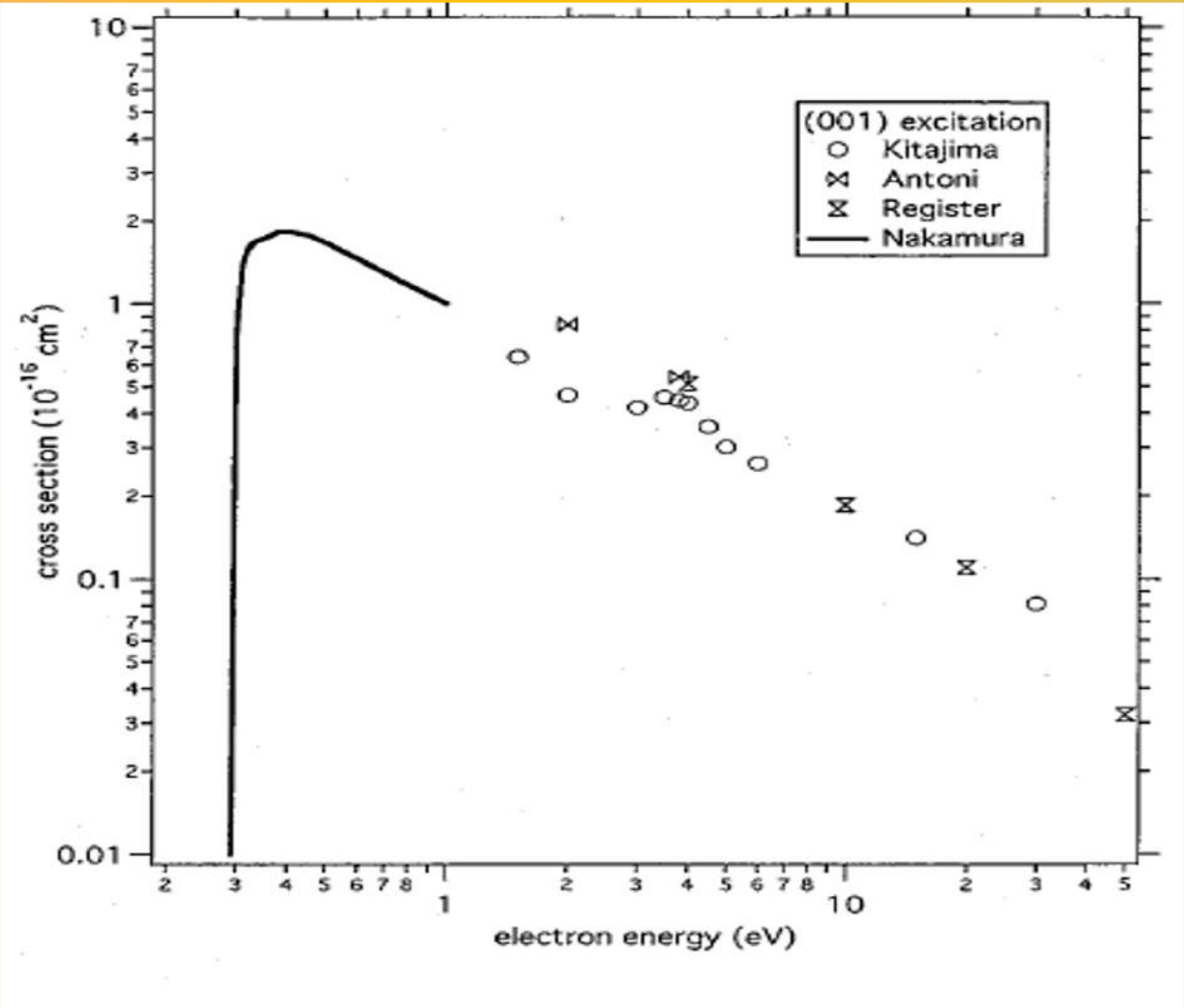
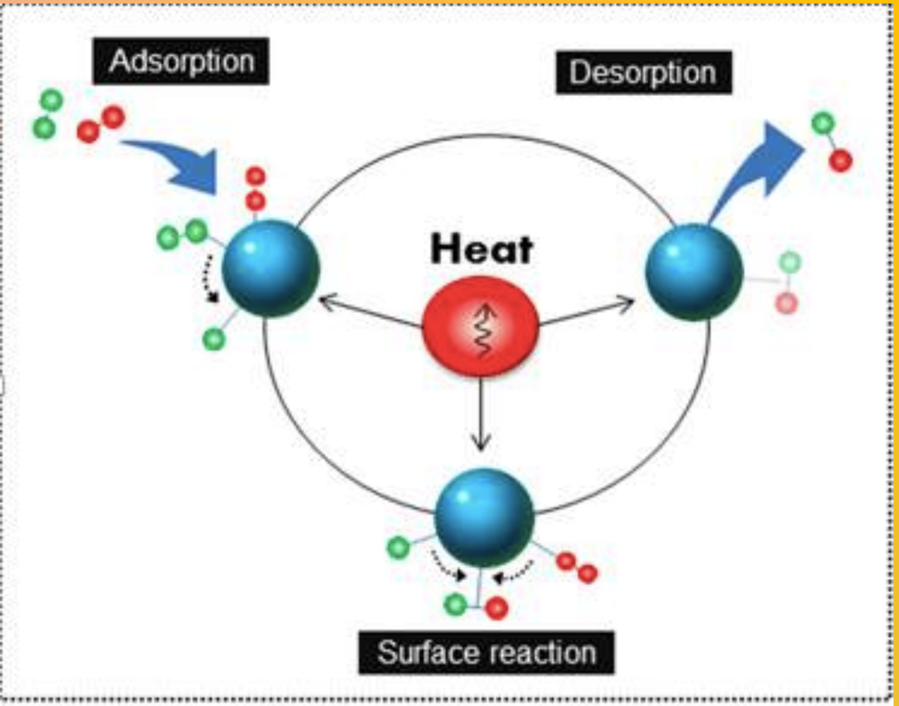
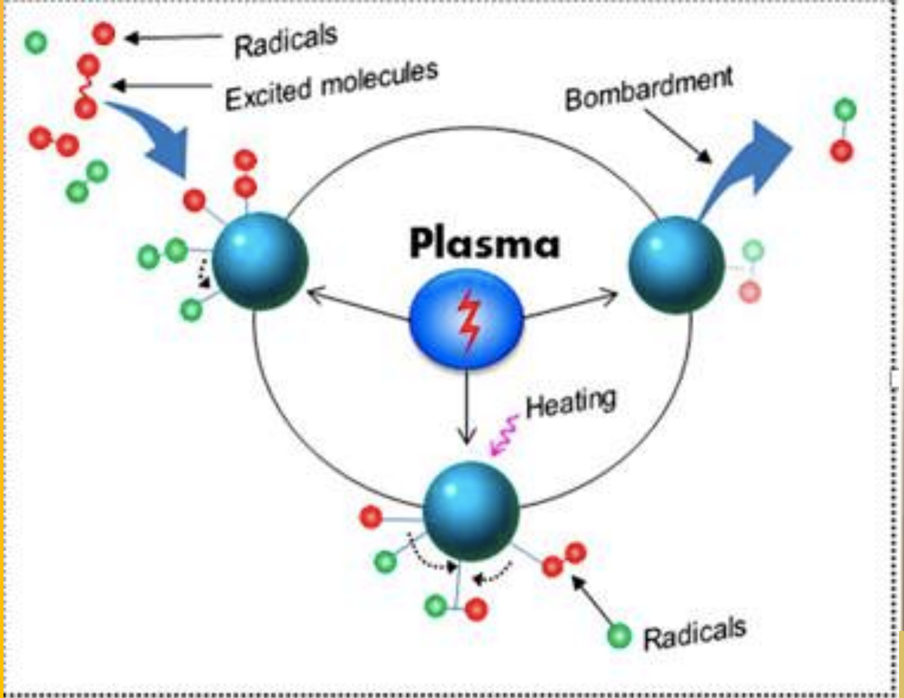


FIG. 7. Cross sections for the electron-impact excitation of the vibrational state (001) of CO_2. Comparison of the beam experiments by Kitajima *et al.*,[32] Antoni *et al.*,[33] and Register *et al.*,[26] and the swarm result of Nakamura[31] is shown.

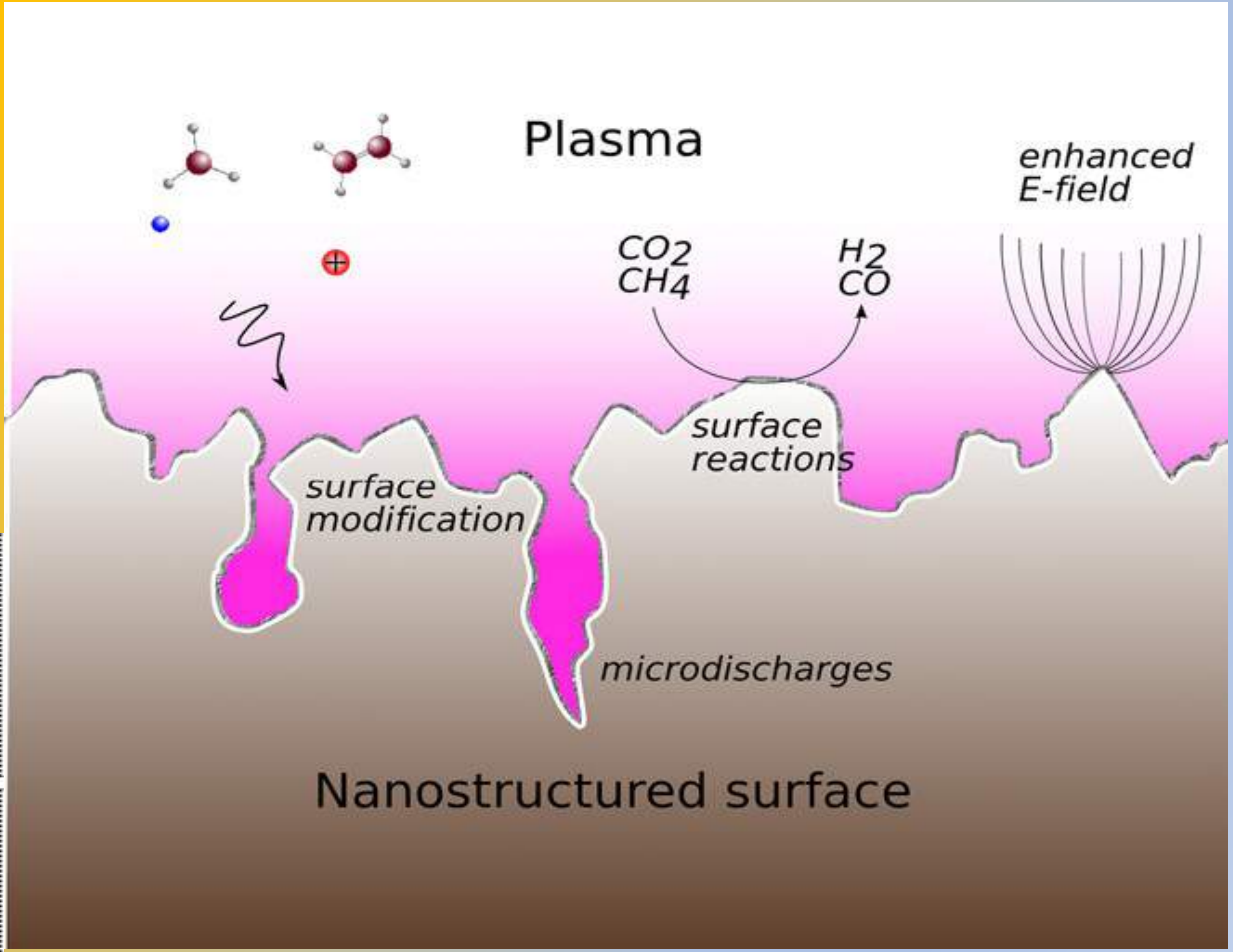
- Vibration excitation of asymmetric stretch mode reaches maximum at electron energy 0.4 eV
- Steady electron drift establishes v_D~ E/n
- E/nσ=Eλ equals potential drop an electron experiences in between collisions
- result E/n = 1.4 10^{-16}Vcm^2



(a) Thermal catalysis

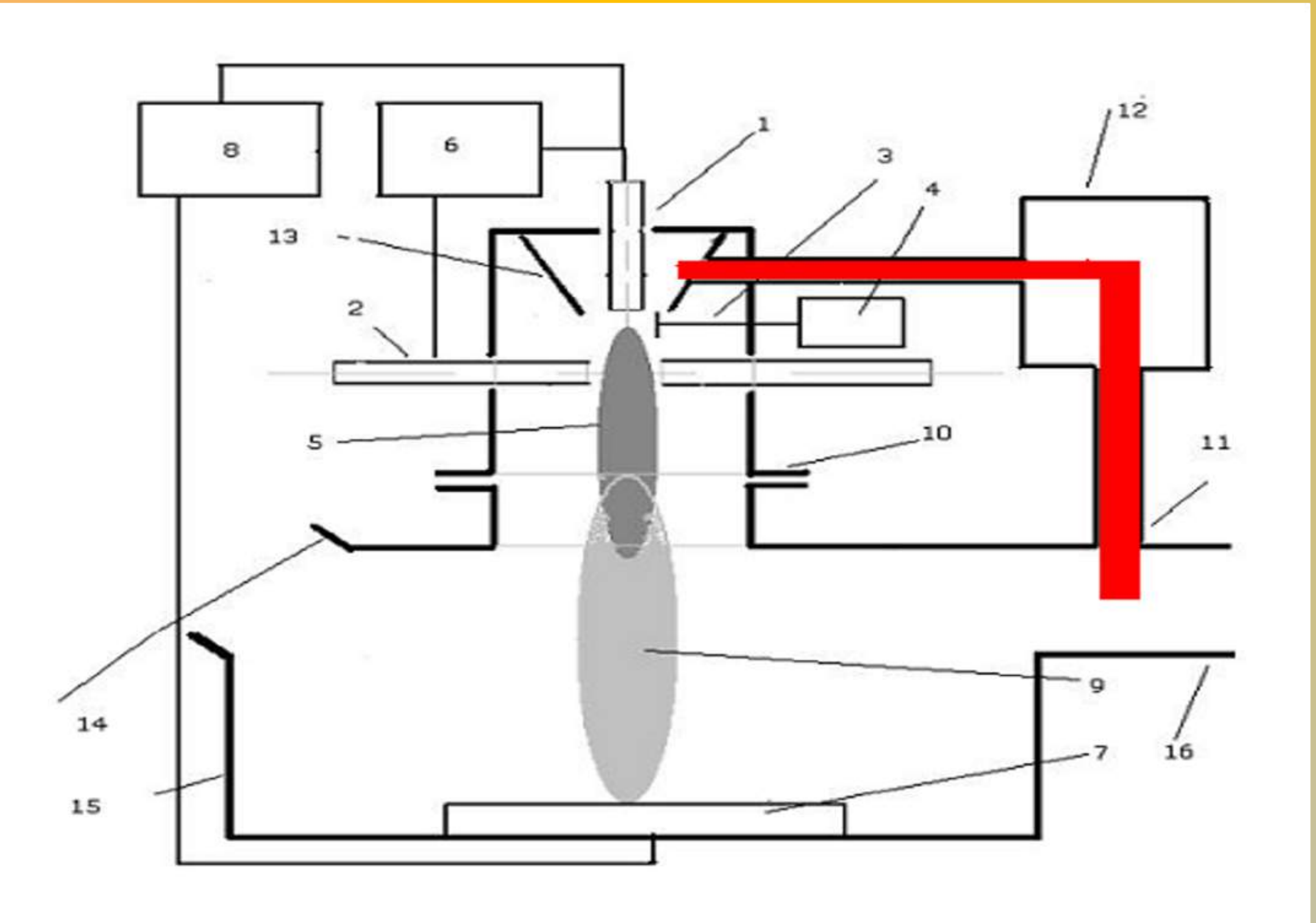


(b) Plasma-catalysis



Plasma- Catalyst Synergism

Large gas throughput required to stabilize the arc results in product gas dilution and reduction in energy efficiency



Endogenous Gas Fed Plasma Torch

pyrolysis product gas is extracted and used for the arc stabilization, improving heat transfer without diluting the pyrolysis gases

35 % increase in pyrolysis efficiency

improves the heat distribution in the primary chamber

increases electrode life by reducing the electrode erosion rate.

PLASMATECH Inc.

A knowledge-based commercial entity spun off from IPR can overcome its present limitations and concentrate on commercial exploitation of technologies selected from the large pool of its knowledge-base on the basis of profitability.