The Cutting Edge of Plasma Physics

Presented by

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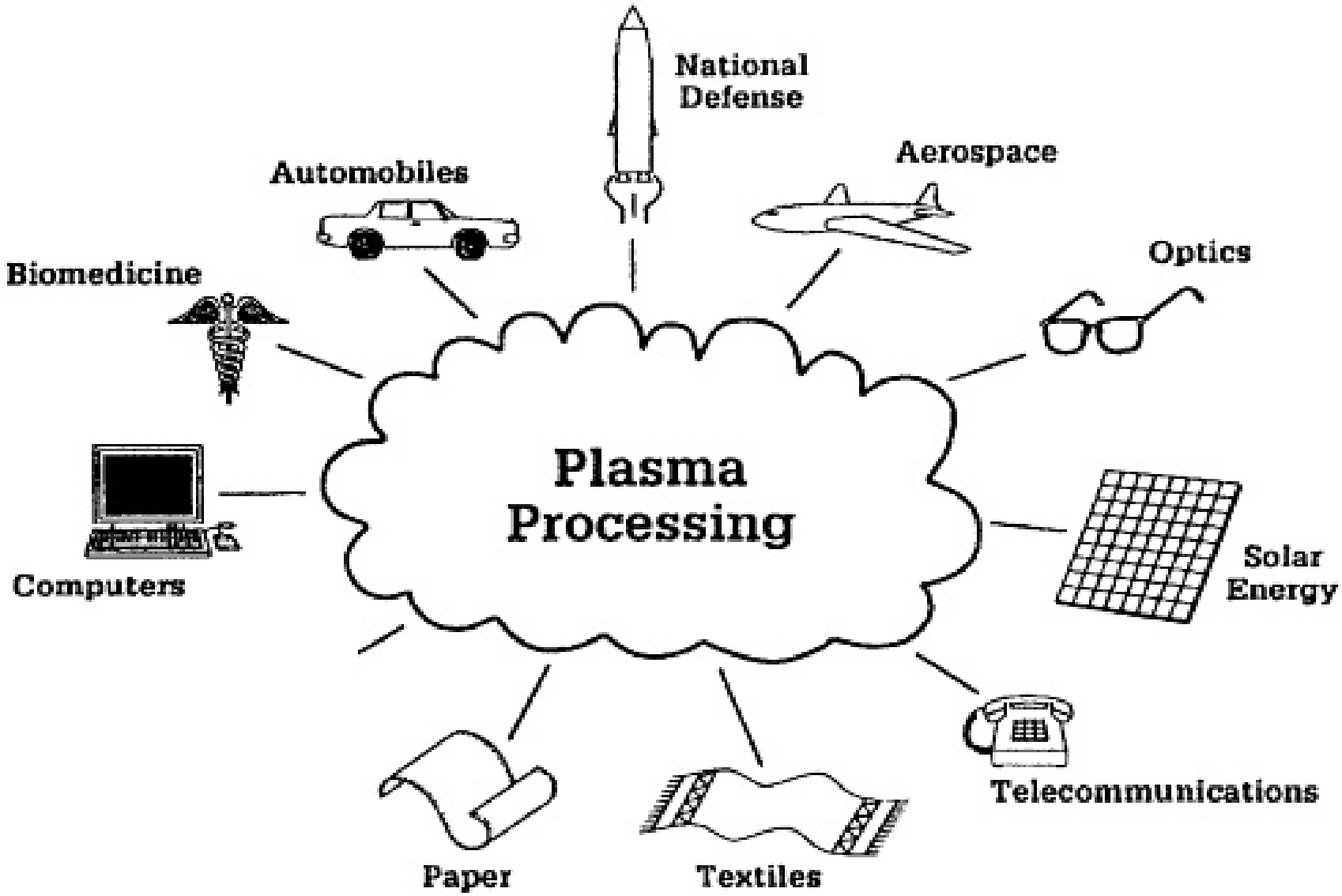
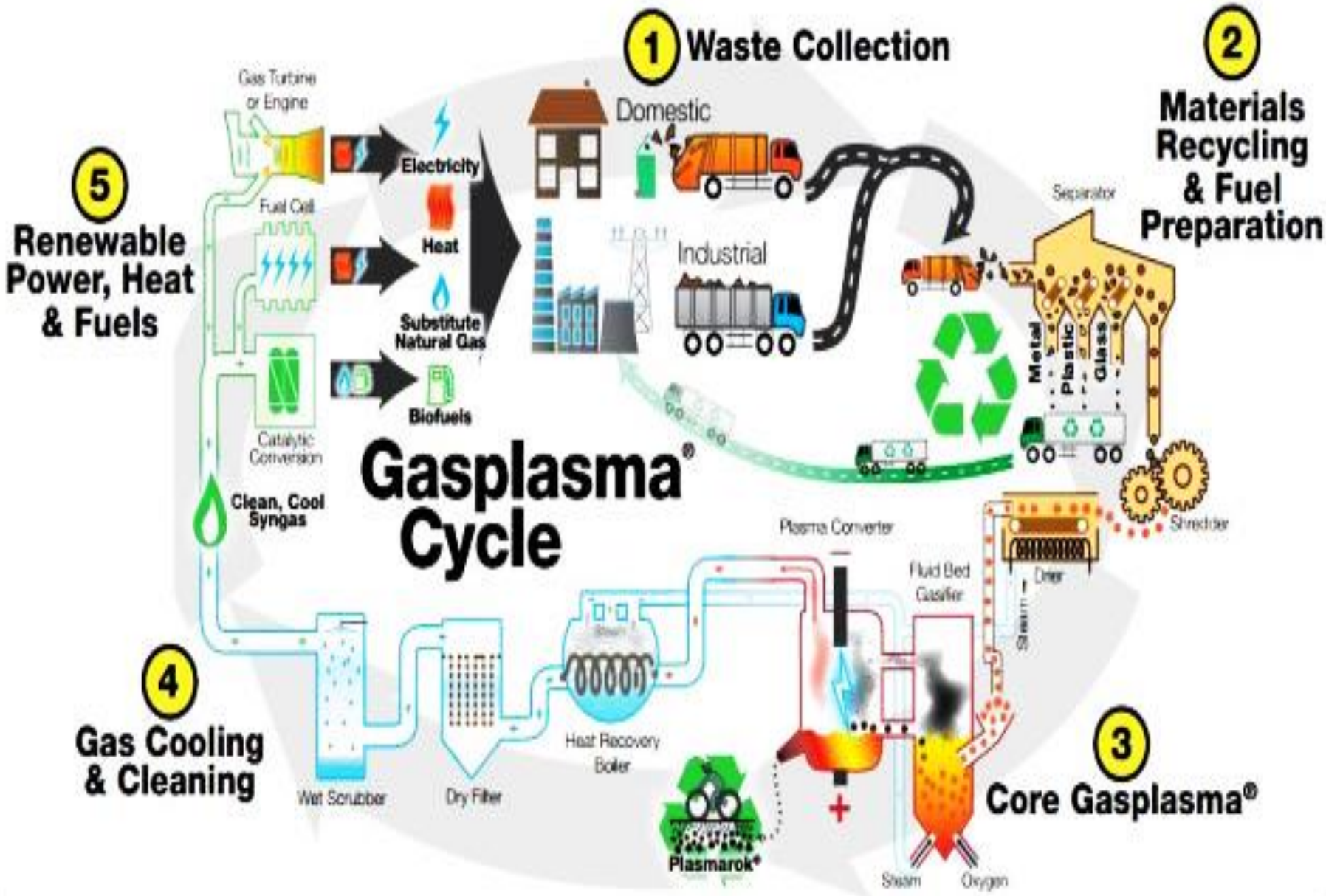
Outlines

- **Introduction**
- **Significance of plasma technologies for the world economy**
- **Overview of plasma physics**
- **Different sources of knowledge**


National Defense
Automobiles
Aerospace
Biomedicine
Optics
Plasma Processing
Computers
Solar Energy
Paper
Textiles
Telecommunications


1 Waste Collection
2 Materials Recycling & Fuel Preparation
3 Core Gasplasma®
4 Gas Cooling & Cleaning
5 Renewable Power, Heat & Fuels
Gasplasma® Cycle
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Metal
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Heat
Substitute Natural Gas
Biofuels

In 2004, the German government 45 000-60 000 people are directly working on building and maintaining plasma technologies.

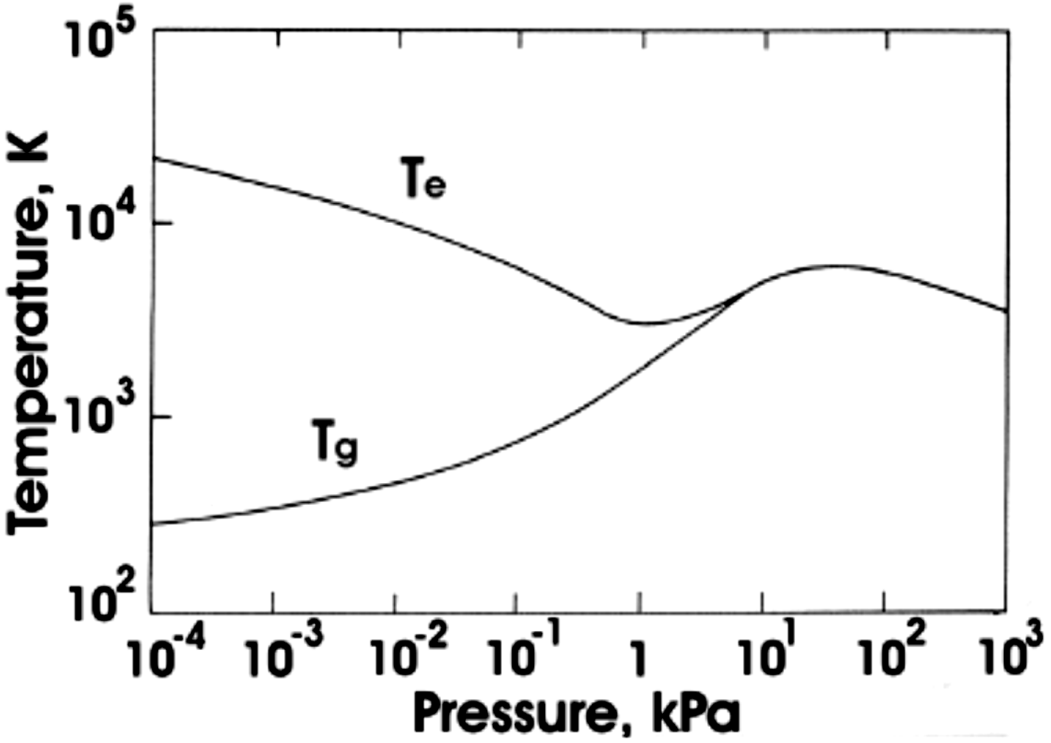
Up to half a million employees were working in manufacturing chains that require a plasma treatment step along the production line.

In 2004, this amounted to 6-7% of all jobs in the German economy or a contribution to the GDP of almost 160 billion Euros.

Similar estimates and shares can certainly be assumed for other highly industrialized countries in Europe, in Asia, the Americas, and for Australia.

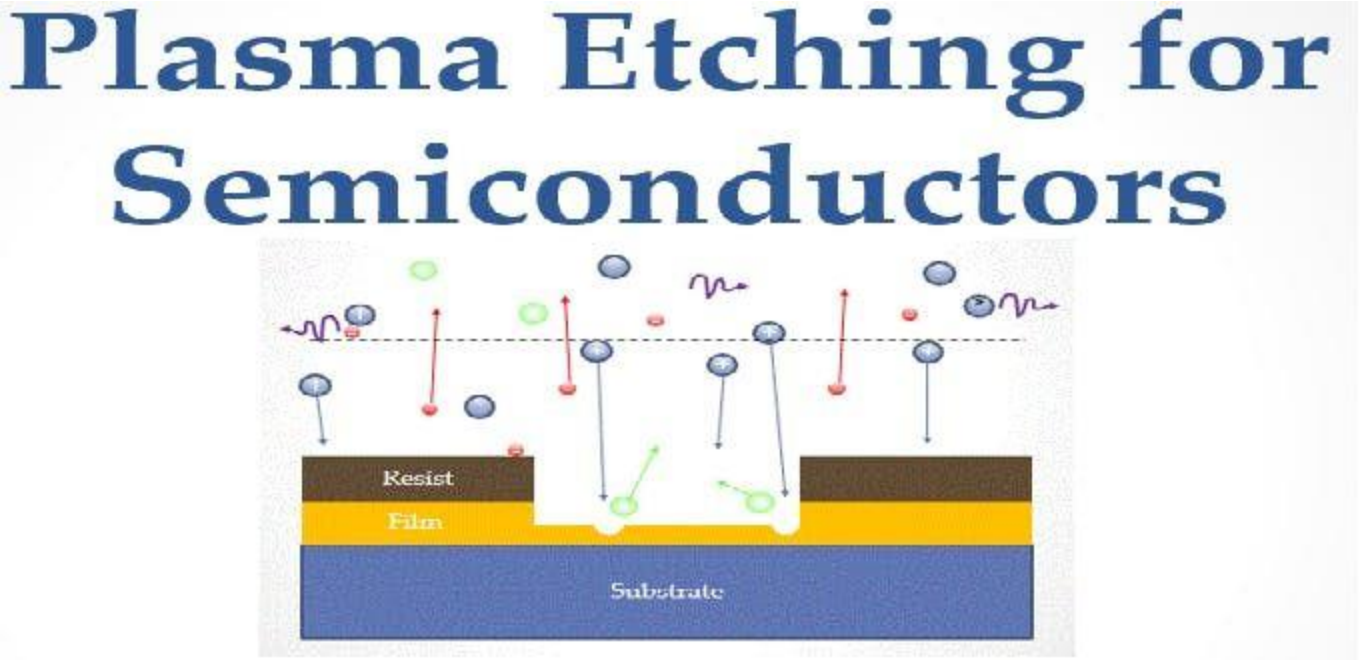
For a growth of the German GDP by 28% from 2004 to 2014, it is safe to assume that the contribution of plasma technologies has proportionally increased.

Cold Plasma



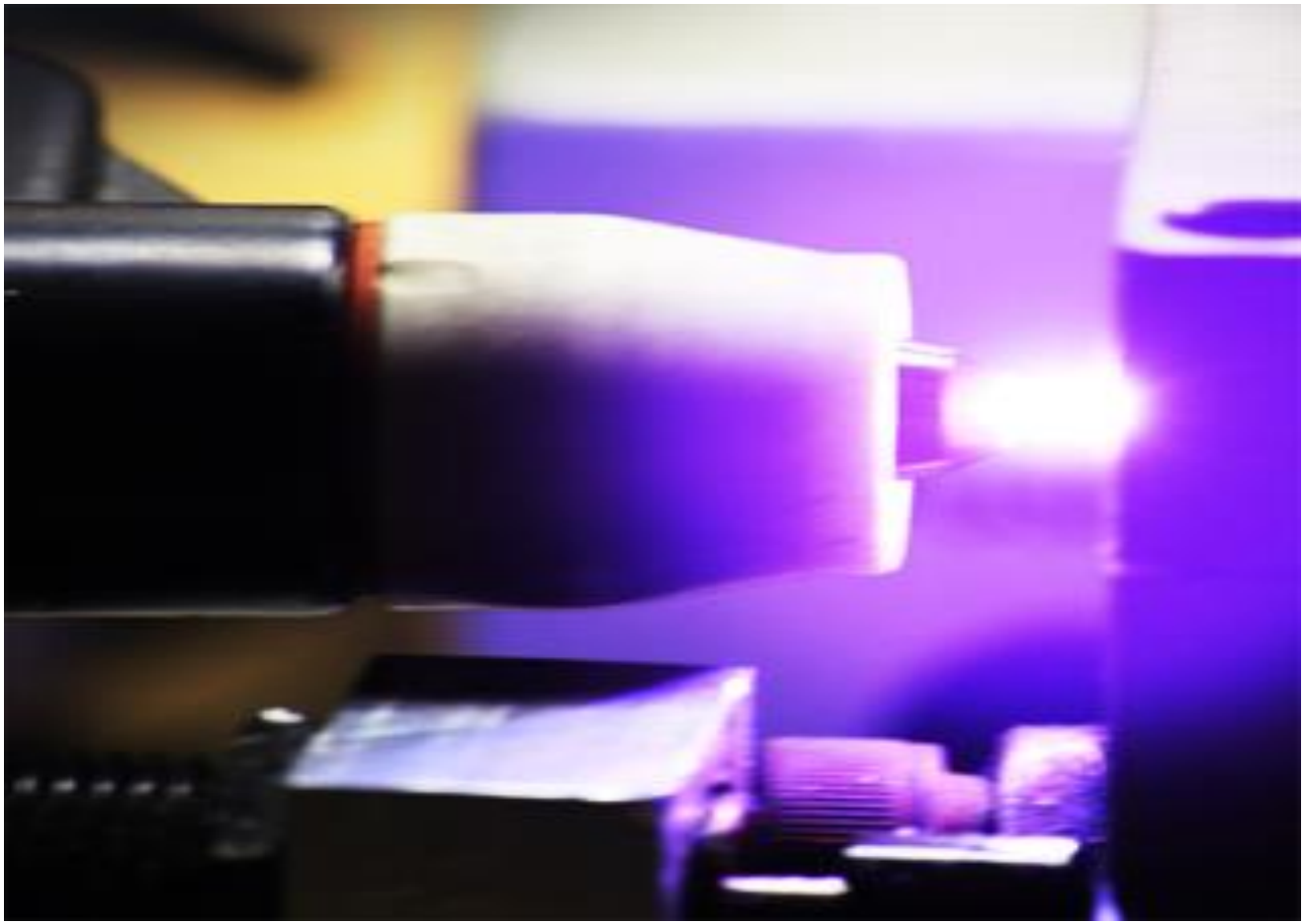
$$(T_e >> T_h)$$

For cold plasma methods, their economic potential was evaluated in a recent Market Research Report, predicting a commercial volume of 2.91 billion USD by 2021.



The US currently dominates about 50% of the global semiconductor market.

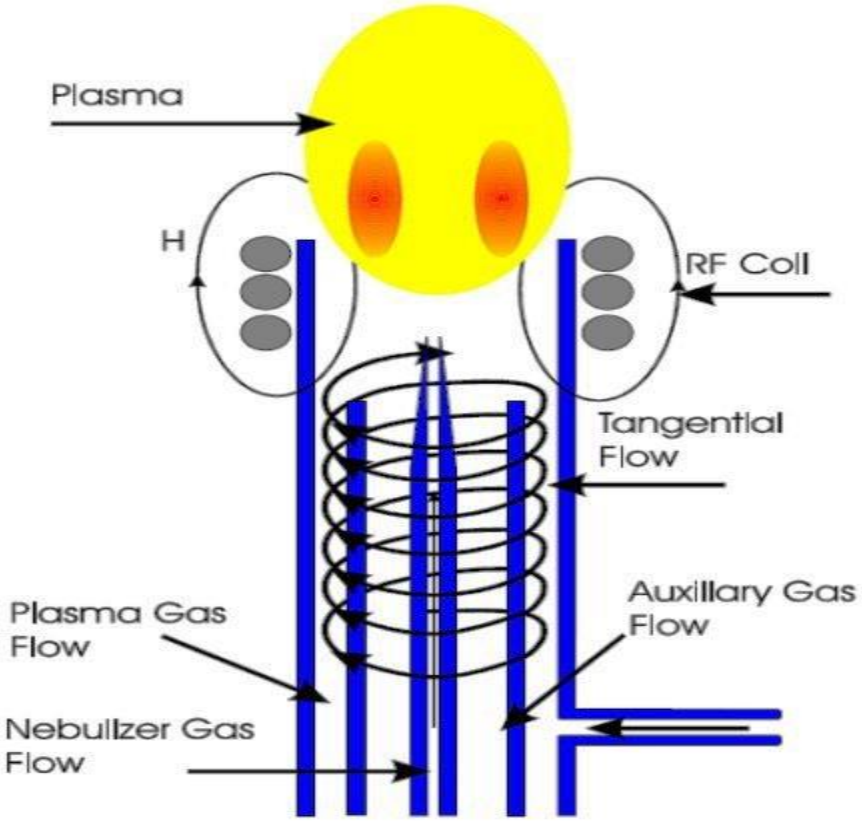
In 2015 the global market for welding products reached 23 billion USD and is expected to exceed 31 billion USD in 2021.

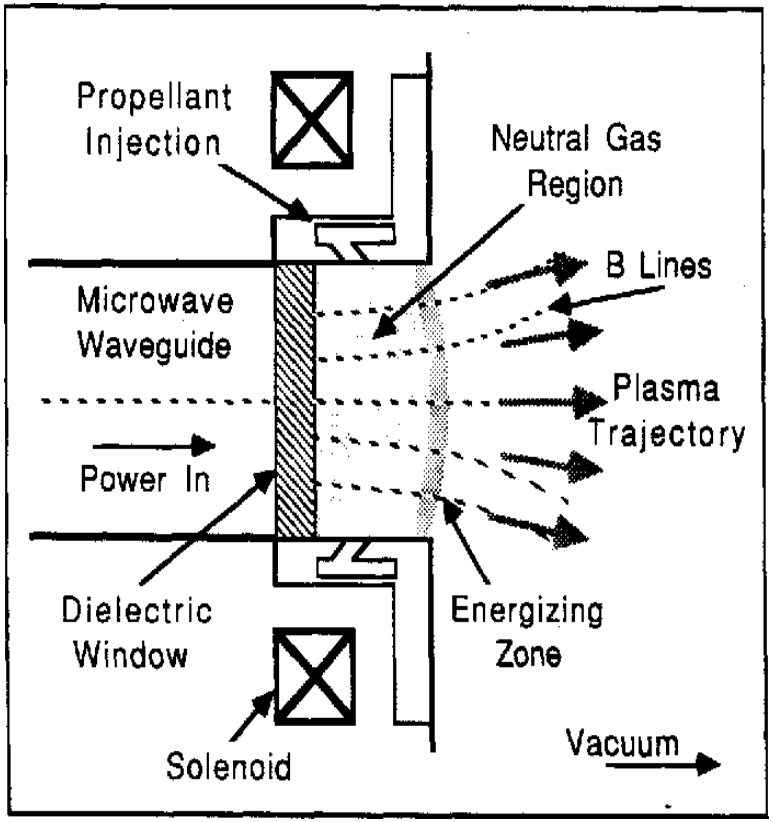


Overview of Plasma Physics

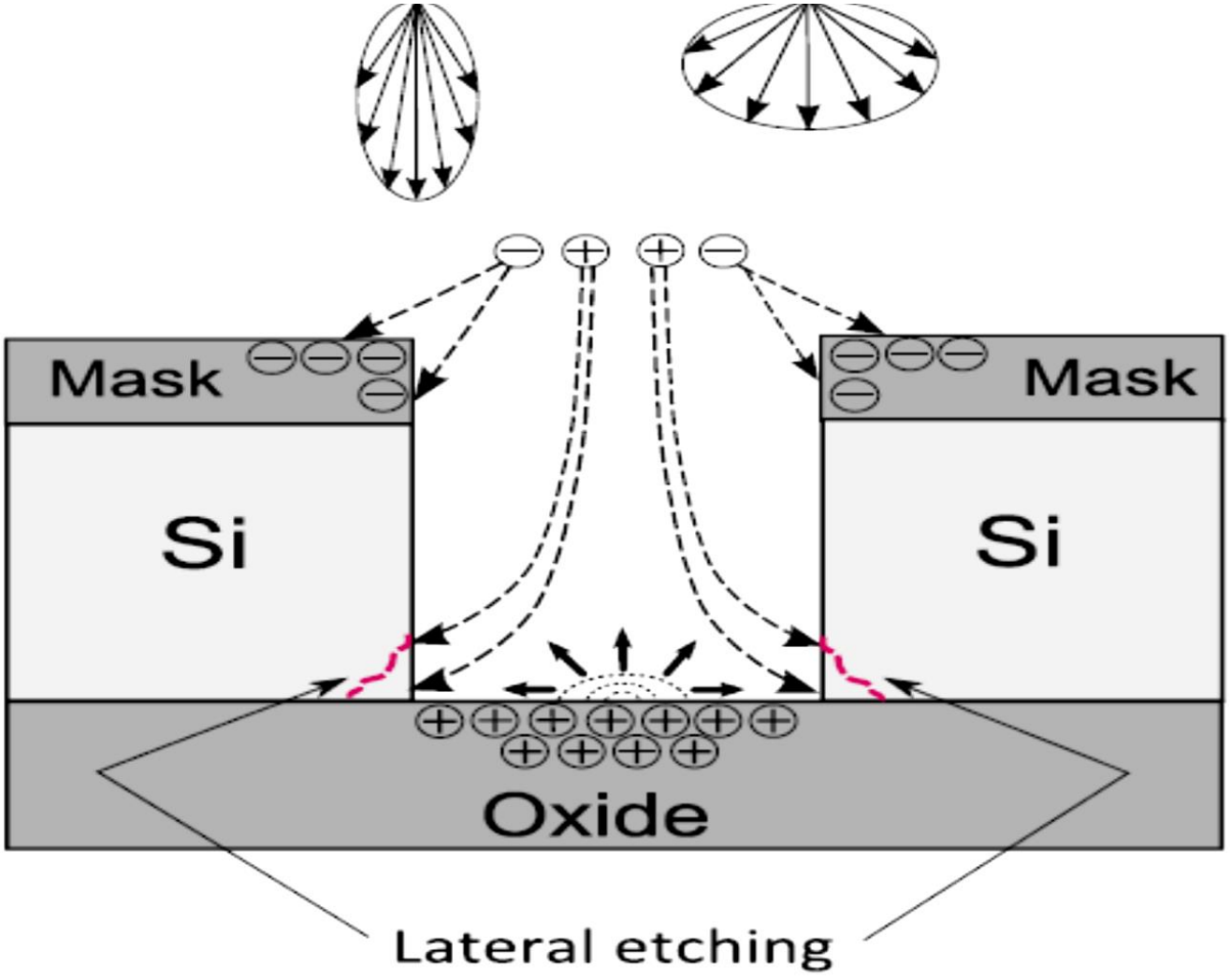
Plasma-etching

For nanosized sample High-density plasma sources, such as inductively coupled plasma (ICP) and electron-cyclotron resonance (ECR) plasma.





charge build-up and UV photon radiatio



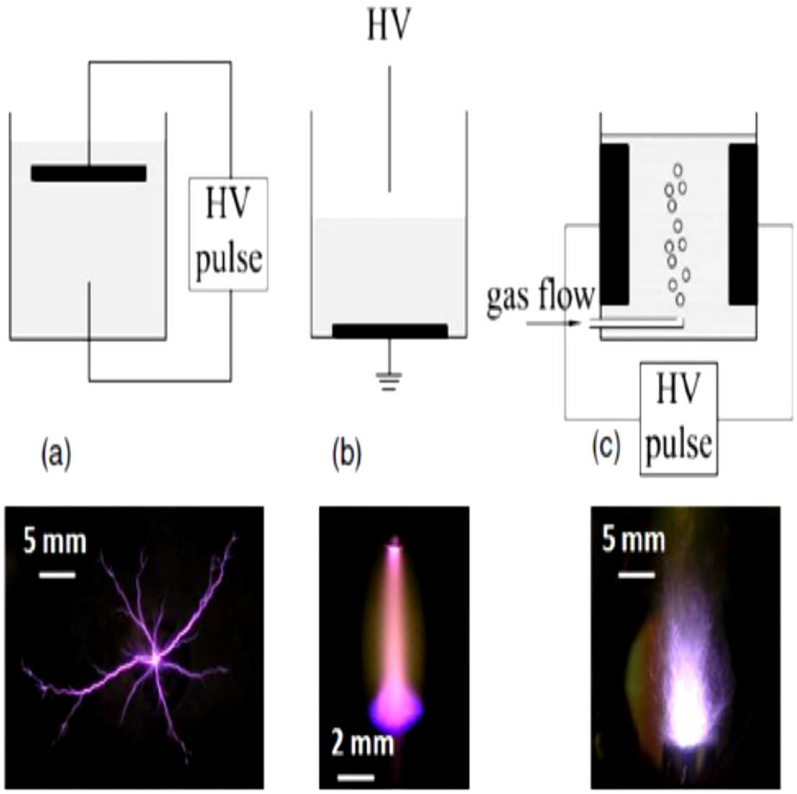
The defect generation due to charge build-up and UV photons were found to occur at a time constant of 10^{-3} s during plasma etchings.

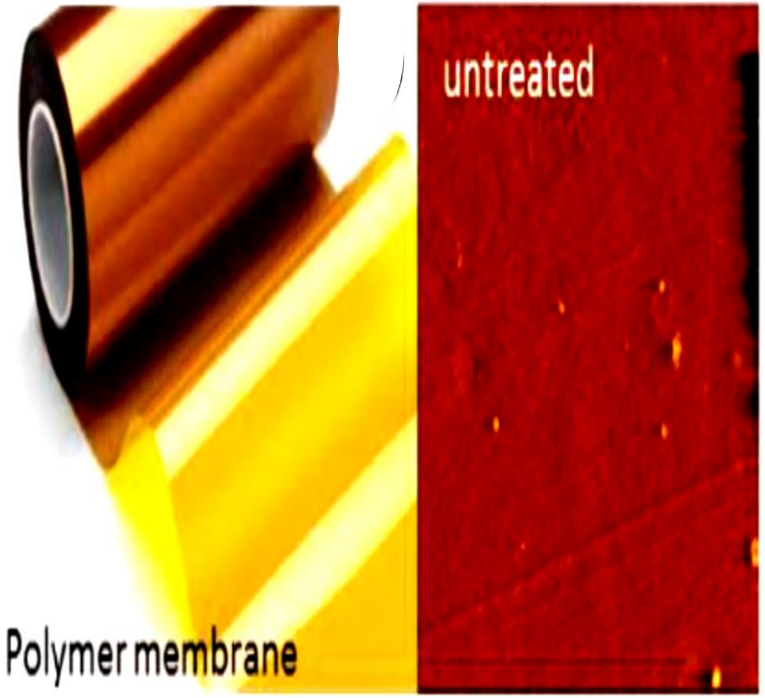
In the future we can use tens-of-microsecond pulse-time modulated plasma etching and neutral-beam etching processes have been proposed.

However, there is UV radiation and the rate of etching is law.

Plasma-Liquid Interaction

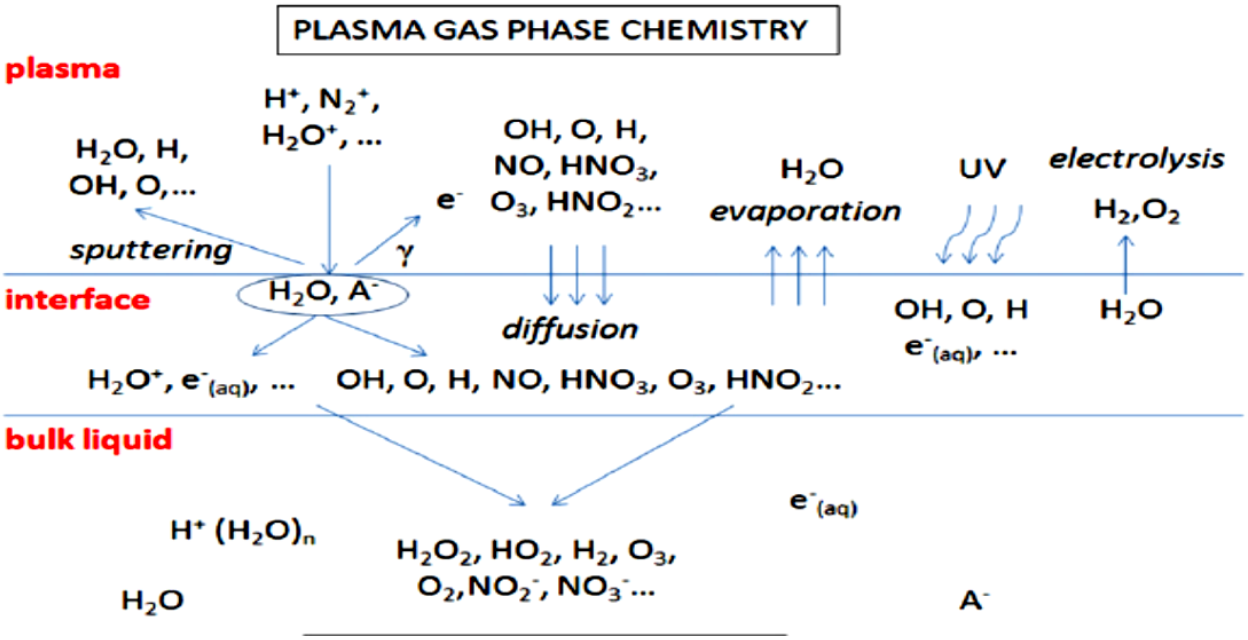
Biological, Chemical, Material and Environmental Applications.



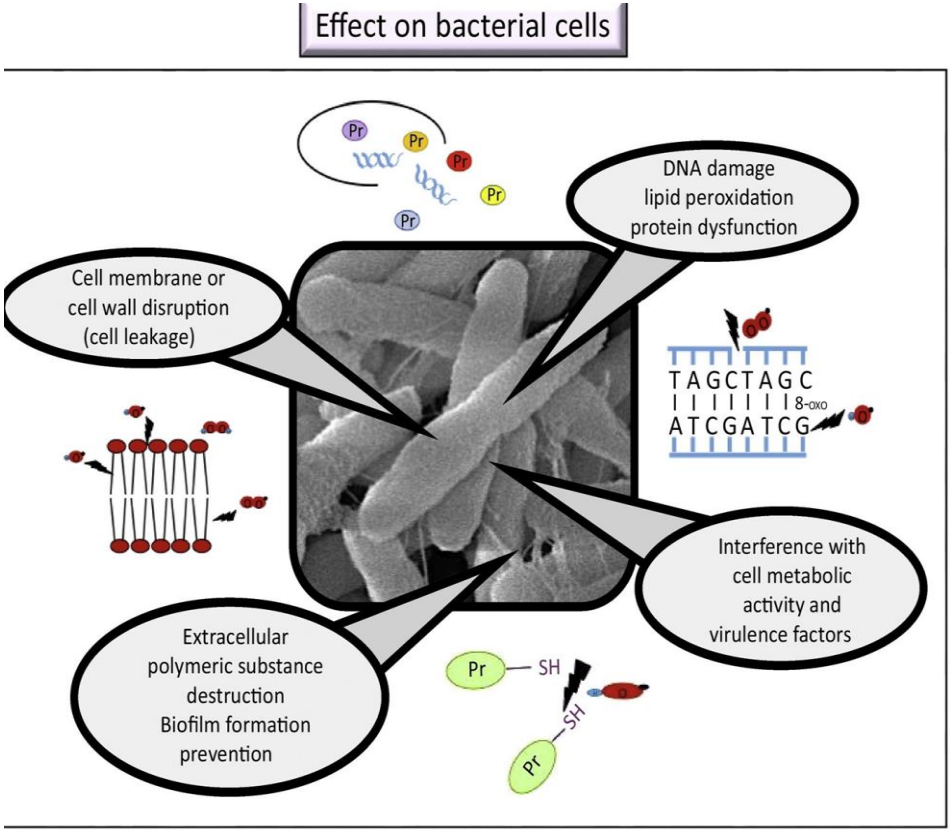


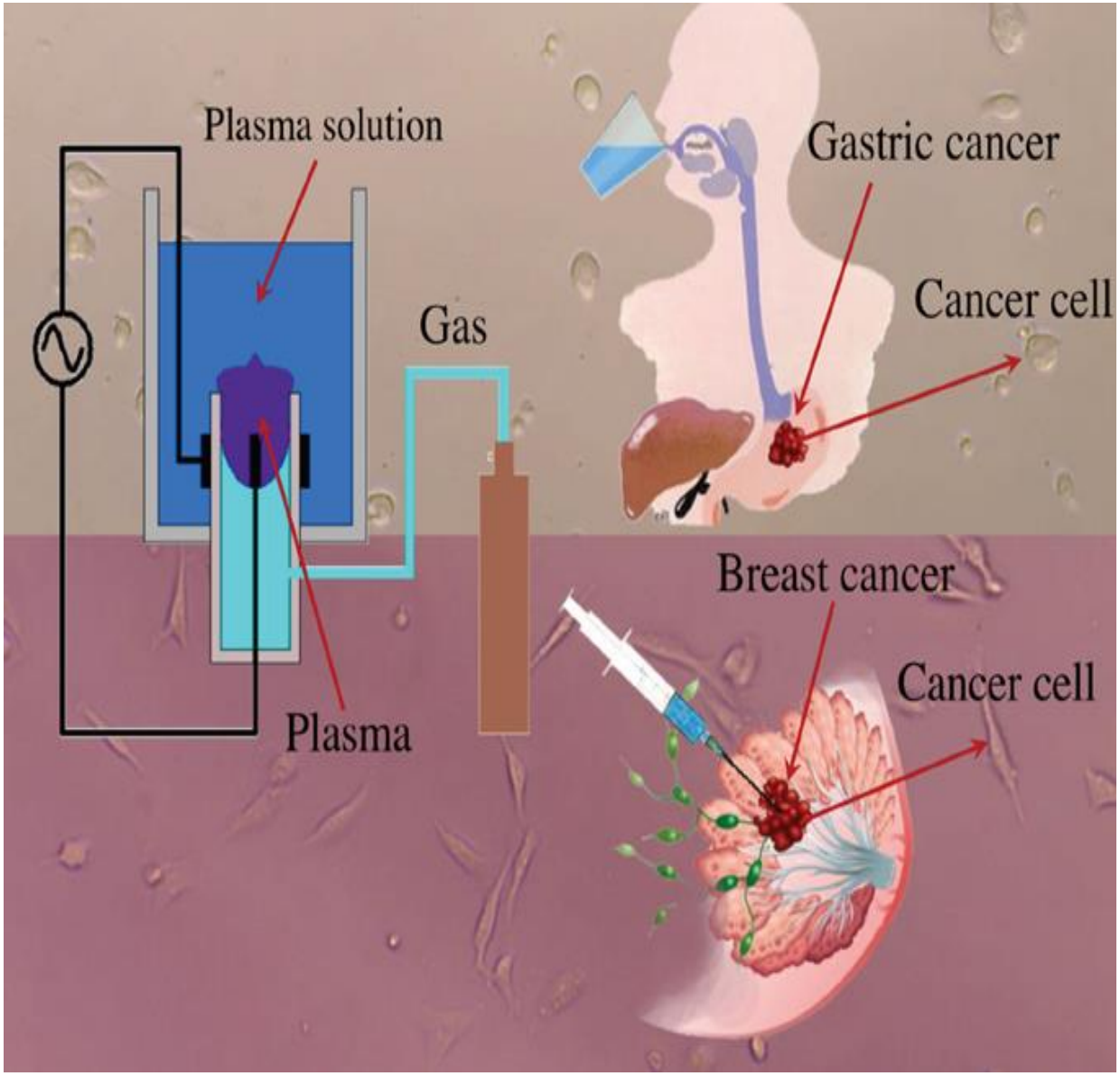
- **The first challenge deals with the breakdown processes and mechanisms in liquids.**

- **The second main challenge is the understanding of the physical and chemical processes occurring at the plasma– liquid interface**



Plasma Medicine




Plasma solution
Gas
Plasma
Gastric cancer
Cancer cell
Breast cancer
Cancer cell


AD-TEC

- **What are the fluxes and energies of the various species that the plasma delivers to the cells and tissues?**

- **How do human tissues and human beings react when subjected to plasma treatment?**

(Micro)biology and medicine

- **How do bacteria and their signalling, spores, fungi and prions behave under plasma exposure?**
- **How do animal or human cells behave under plasma exposure? How cytotoxic is the plasma?**
- **How do human tissues and human beings react when subjected to plasma treatment?**

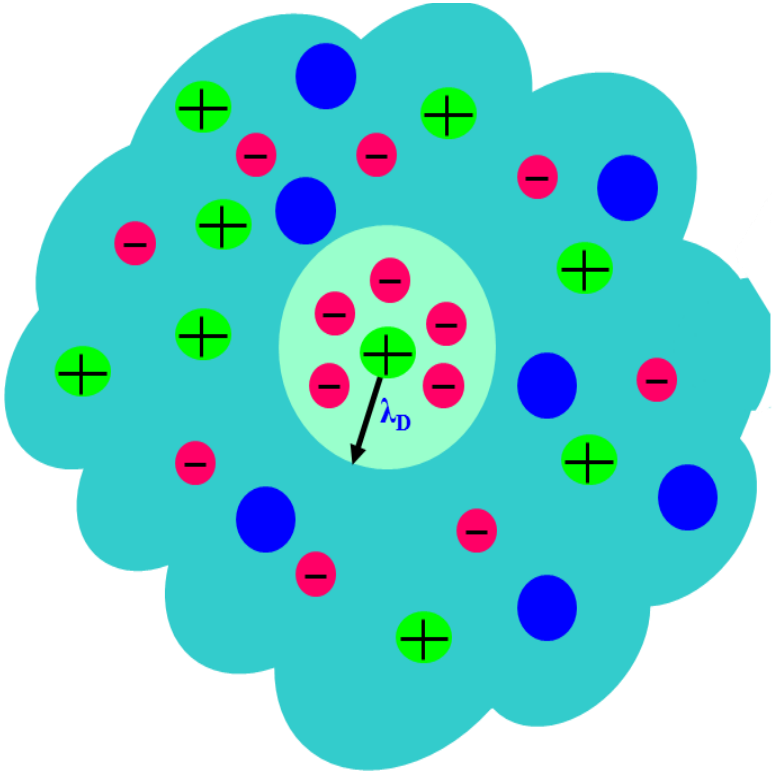
Classical plasma

$$\lambda_D \equiv \left(\frac{\varepsilon_0 K T_e}{n e^2}\right)^{1/2}$$

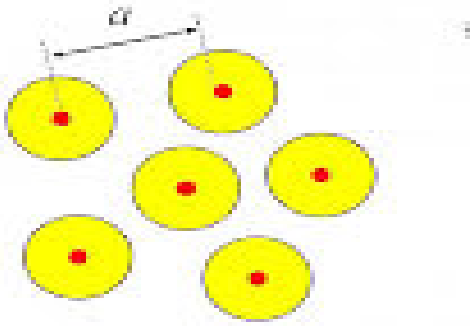
$$\omega_p = \left(\frac{n_0 e^2}{\varepsilon_0 m}\right)^{1/2}$$

$$N_D = n\frac{4}{3}\pi\lambda_D^3$$

1. $\lambda_D \ll L$.
2. $N_D \gg 1$.
3. $\omega\tau > 1$.

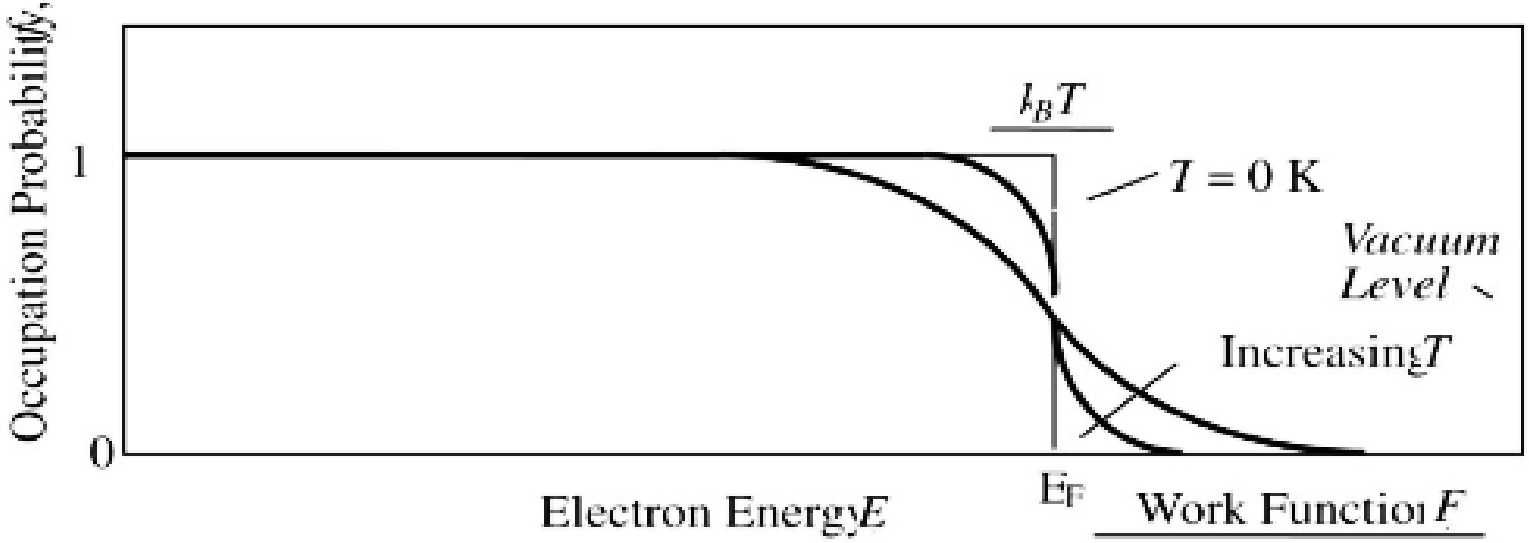


$$\lambda_B \geqslant d$$



Fermi-Dirac Distribution

$$f(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{k_B T}\right)}$$



$$k_B T_F \equiv E_F = \frac{\hbar^2}{2m} \left(3\pi^2\right)^{2/3} n^{2/3}$$

For classical state we have

E_c =1/2 kT

Thus at T=0, E_c =0, but $E_f \neq 0$

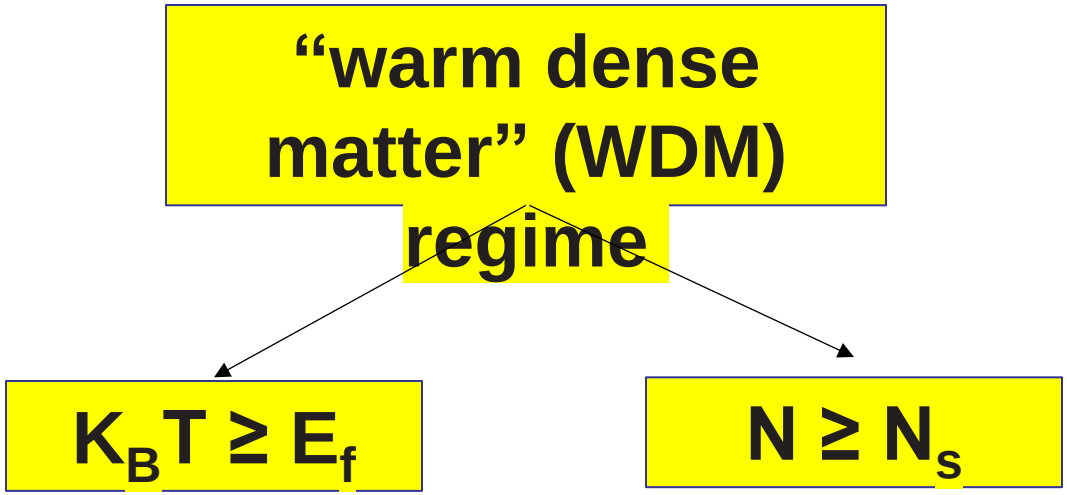
$$\lambda_F = \frac{v_F}{\omega_p} \quad , \quad v_F = \frac{\hbar}{m} \left(3\pi^2 \; n\right)^{1/3}$$

N_D<1

Classical Plasma	Quantum Plasma
$\lambda_D = \left(\frac{\epsilon_0 k T_e}{n_e e^2}\right)^{\frac{1}{2}} << L$	$\lambda_B \geqslant d$
$\chi = \frac{T_F}{T} < 1$	$\chi \geqslant 1$
$g_C \propto n^{1/3} < 1$	$g_Q \propto \frac{1}{n^{1/3}} < 1$

The electron temperature inside a fluorescent light bulb is about 20,000 K. “My, it doesn’t feel that hot!”

!

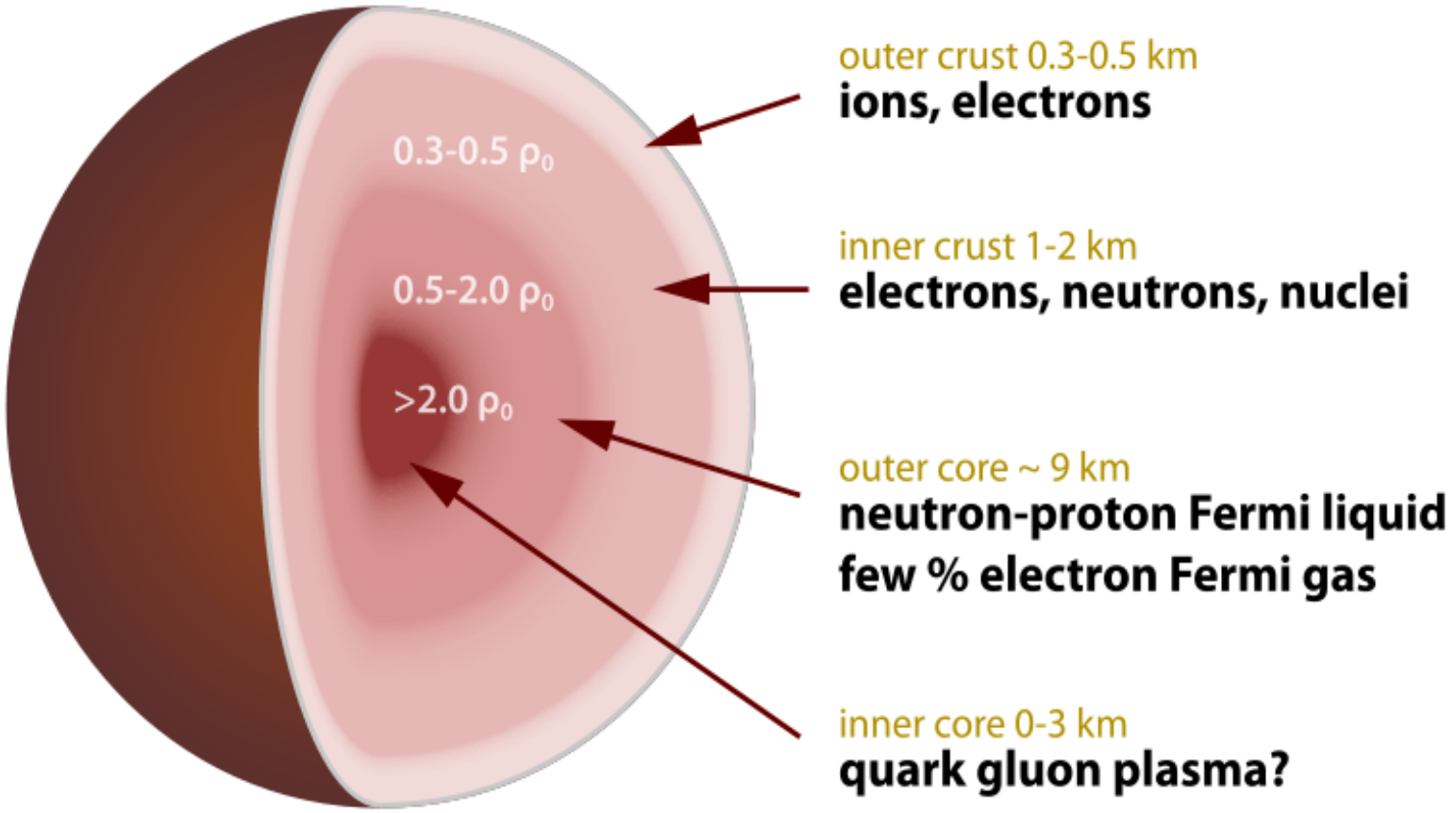


Warm dense matter regime defines states of matter between solids and plasmas.

After the star exhaust the nuclear fuel it becomes white dwarf

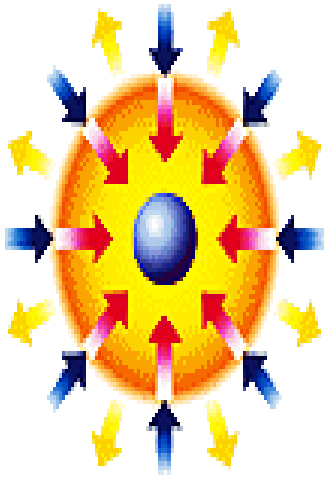
Fig. 3

Neutron stars are created when giant stars die in supernovas and their cores collapse, with the protons and electrons essentially melting into each other to form neutrons.

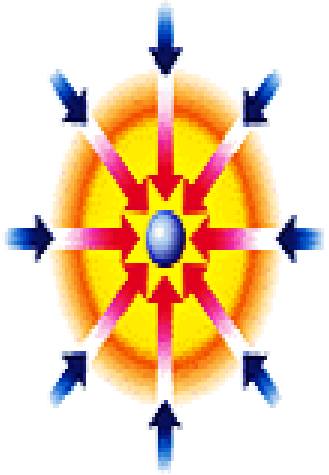


Inertial Confinement Fusion

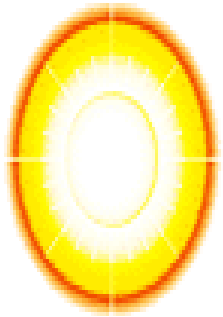
1) Atmosphere formation: Laser beams rapidly heat the surface of the fusion target forming a surrounding plasma envelope.



2) Compression: Fuel is compressed by the rocket-like blowoff of the hot surface material.

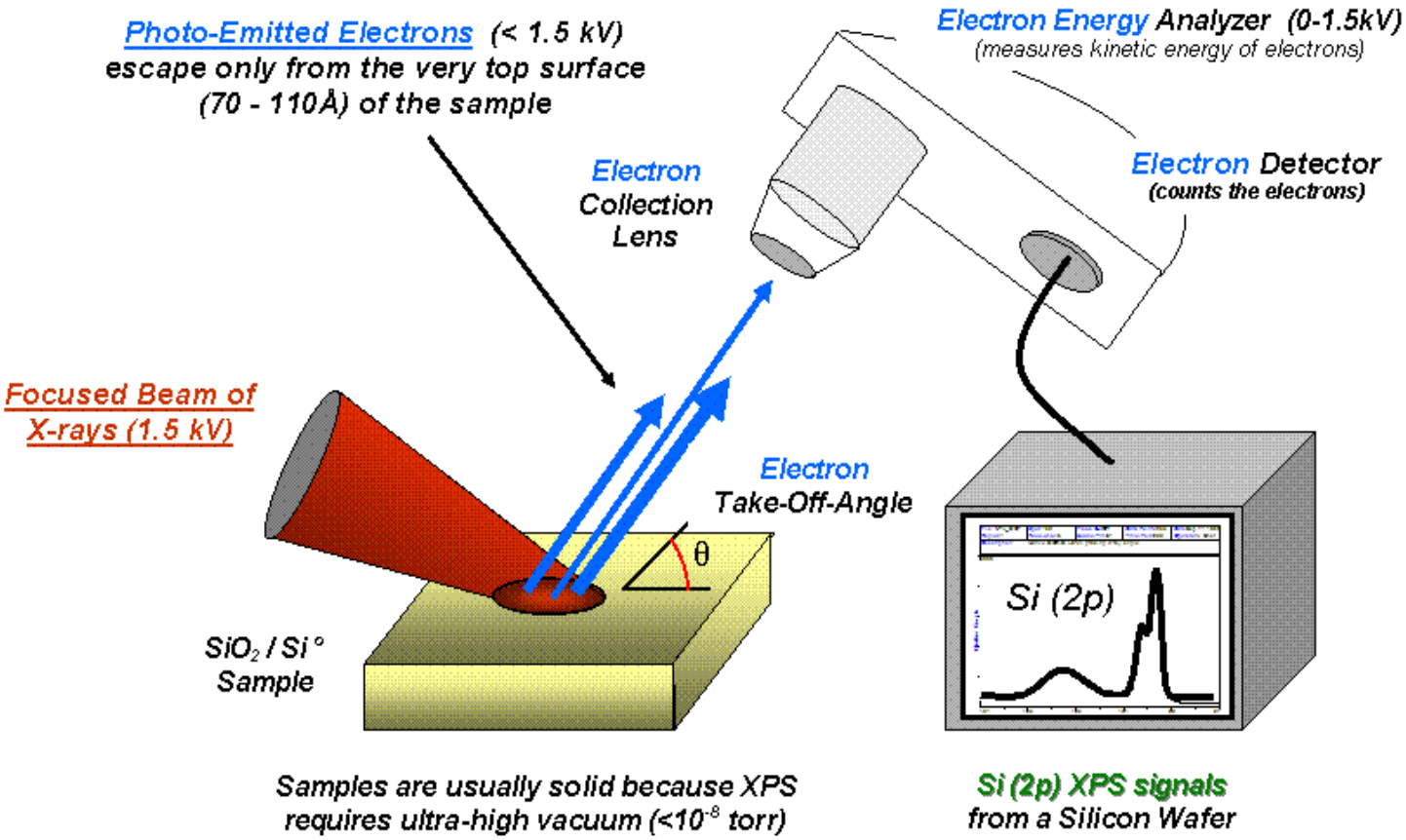


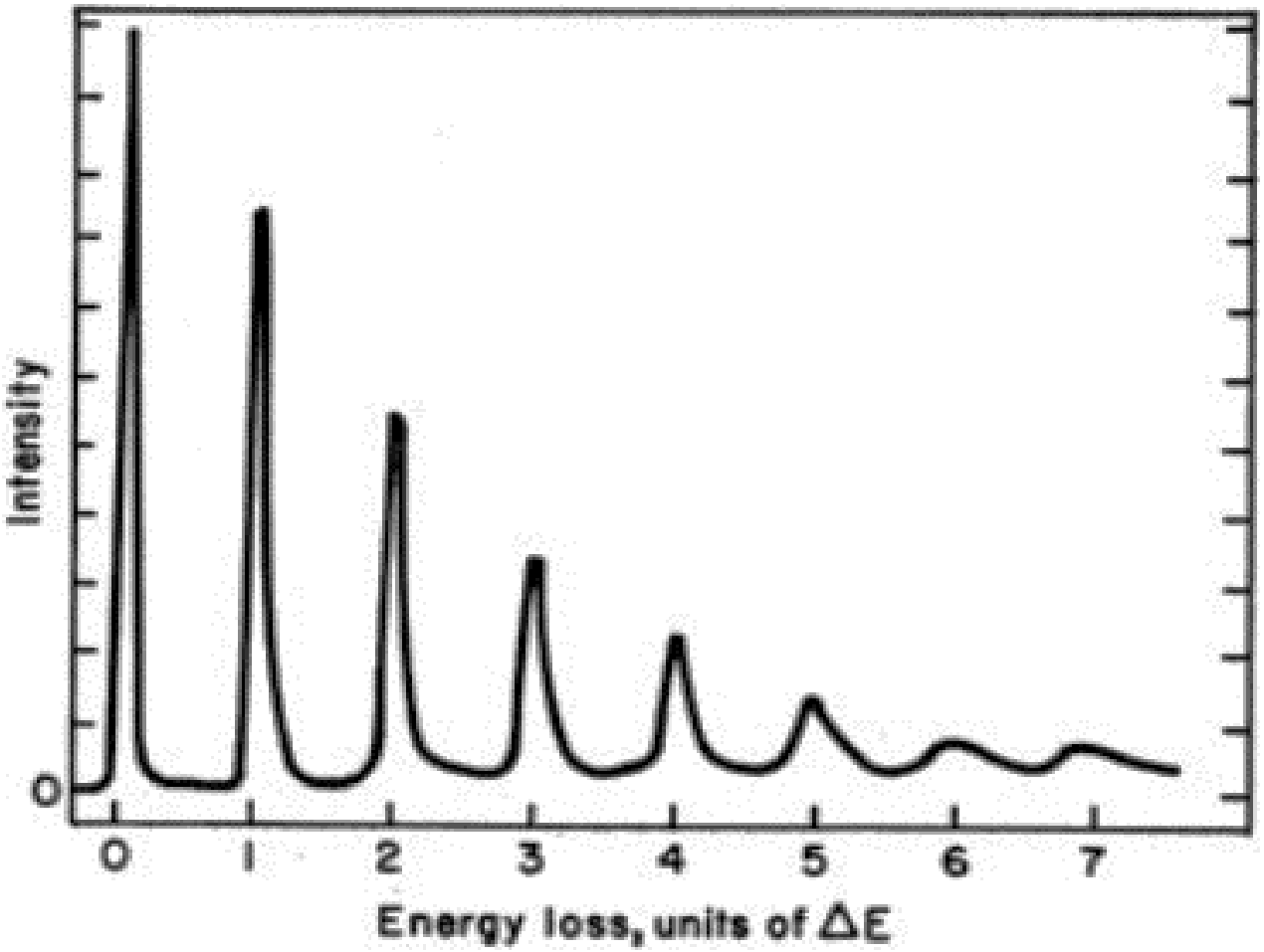
3) Ignition: During the final part of the laser pulse, the fuel core reaches 20 times the density of lead and ignites at 100,000,000 degrees Celsius.



4) Burn: Thermonuclear burn spreads rapidly through the compressed fuel, yielding many times the input energy.

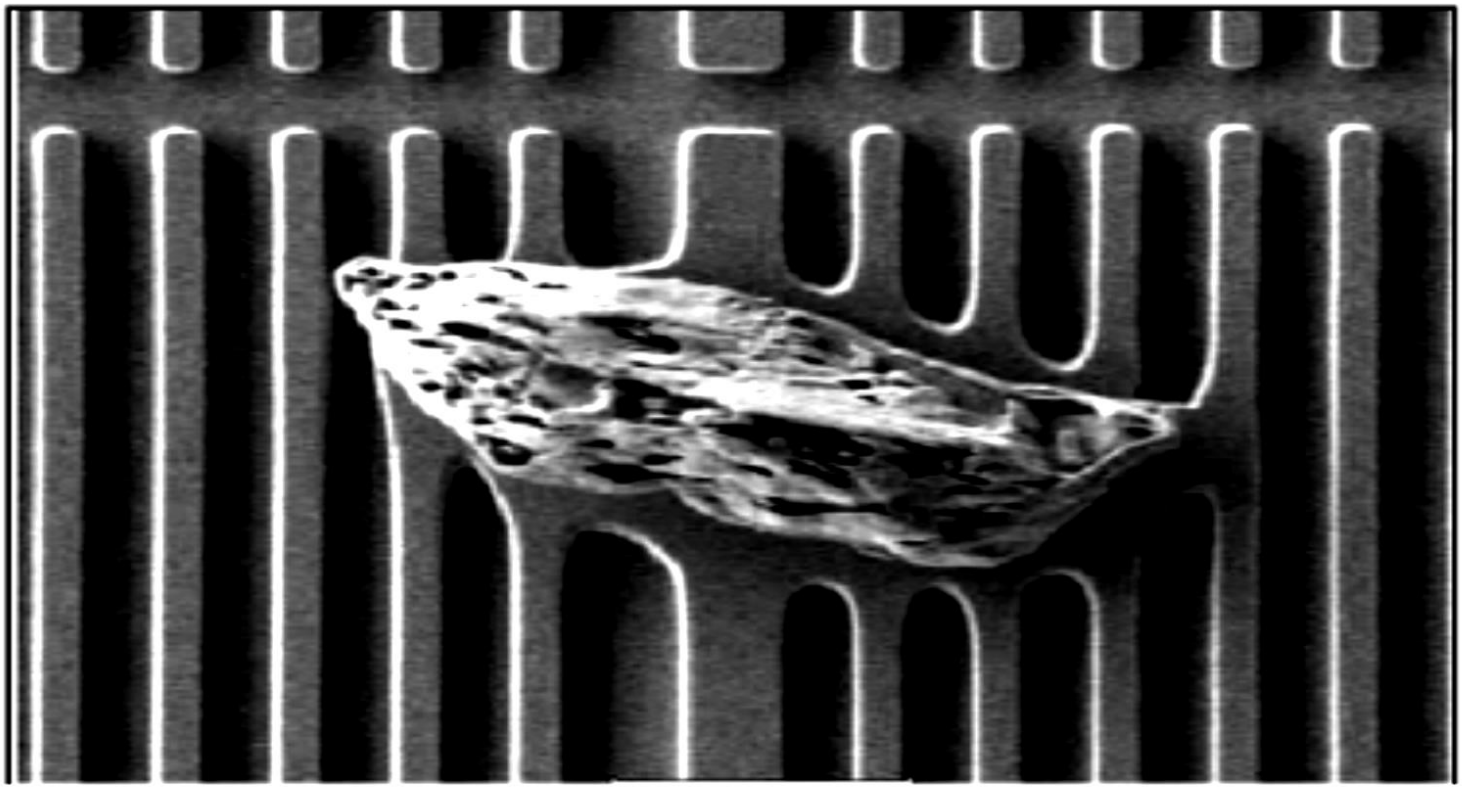
Recent experimental results on x-ray scattering suggest that quantum mechanical effects are indeed important in dense plasmas



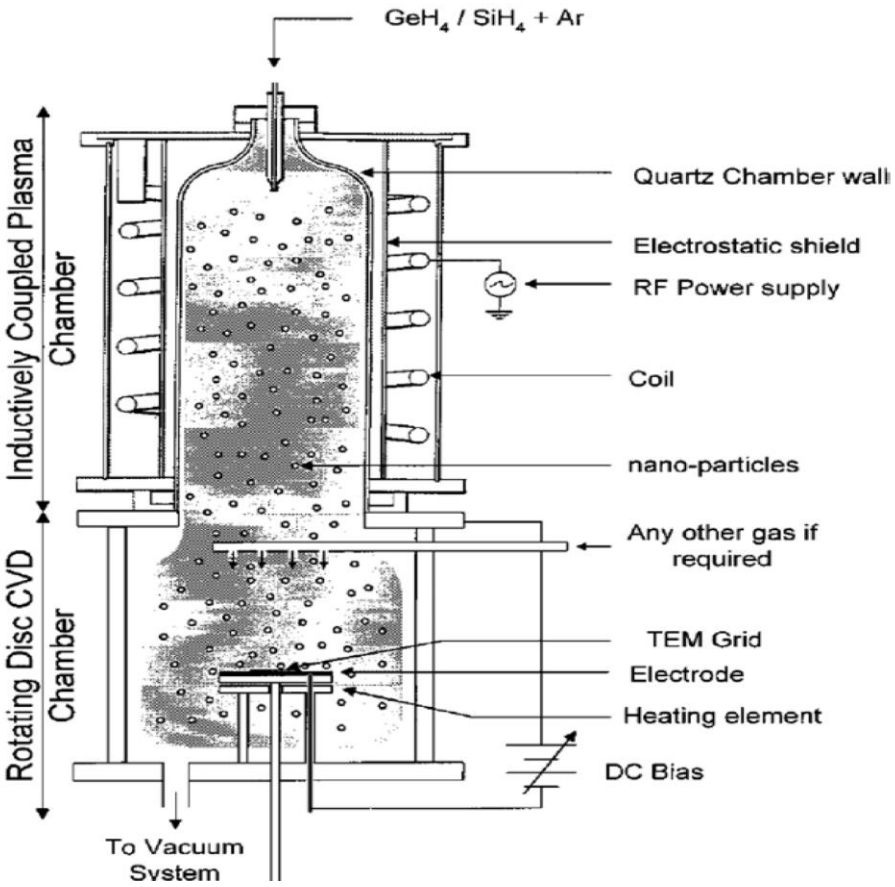

Intensity
0
0
1
2
3
4
5
6
7
Energy loss, units of ΔE

Dust Plasma

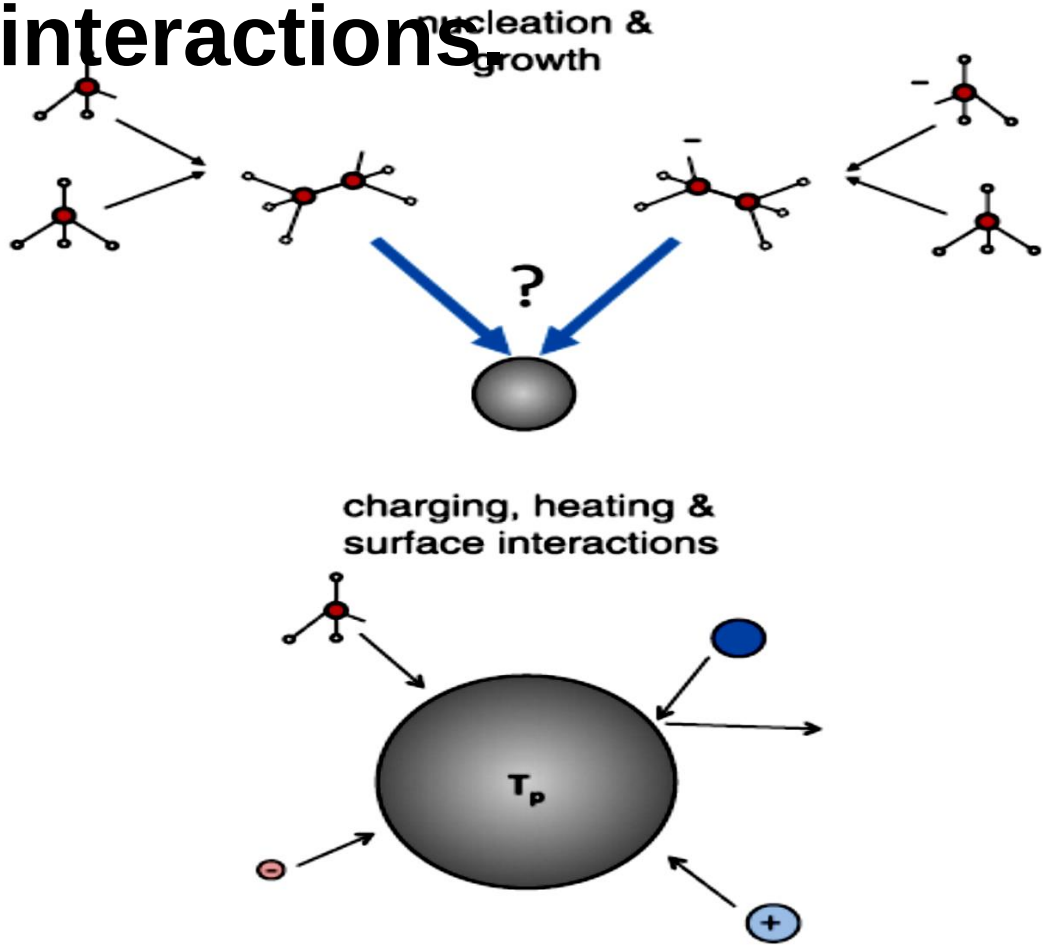
It was initially viewed as a contamination problem in semiconductor processing.



Using plasmas as sources of new nanomaterials.



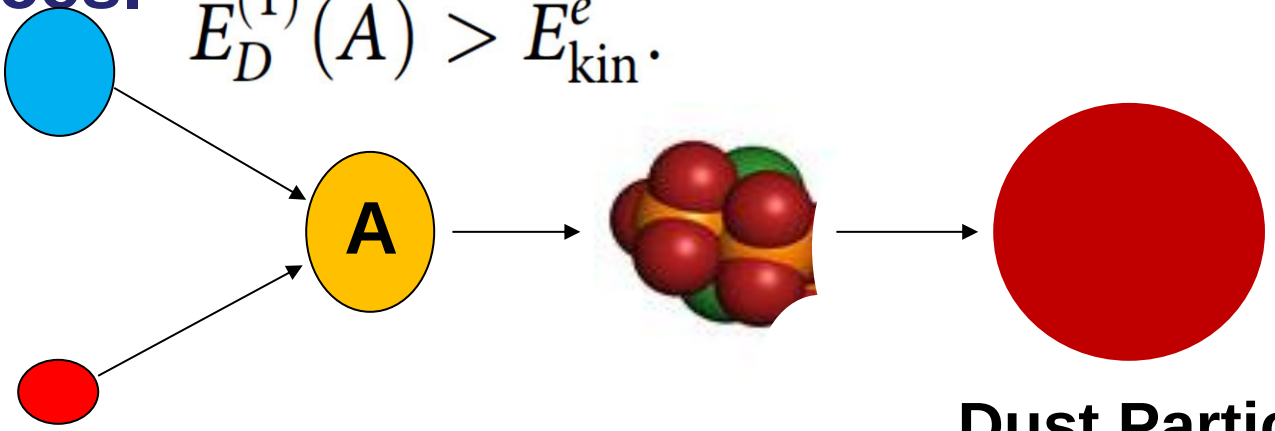
Challenges in understanding nanodusty plasmas:
nucleation, growth, charging, heating and surface interactions.



The concept of quantum dusty plasma

objects as white dwarf stars and the outer envelope of neutron stars, as well as metals and micro- and nanoelectromechanical devices.

$$E_D^{(1)}(A) > E_{\text{kin}}^{e}.$$



Dust Particle

$$E_D^{(N_A)}(A) \sim 1\ldots5\ \text{eV} \quad (\text{where } N_A \geq 100),$$

$$T_e \sim 11\,500\text{–}60\,000\ \text{K}, \qquad T_m \lesssim 5000\ \text{K}$$

$$T_s > \left(n_e T_e^{3/2} + T_e^4 \right)^{1/4}$$

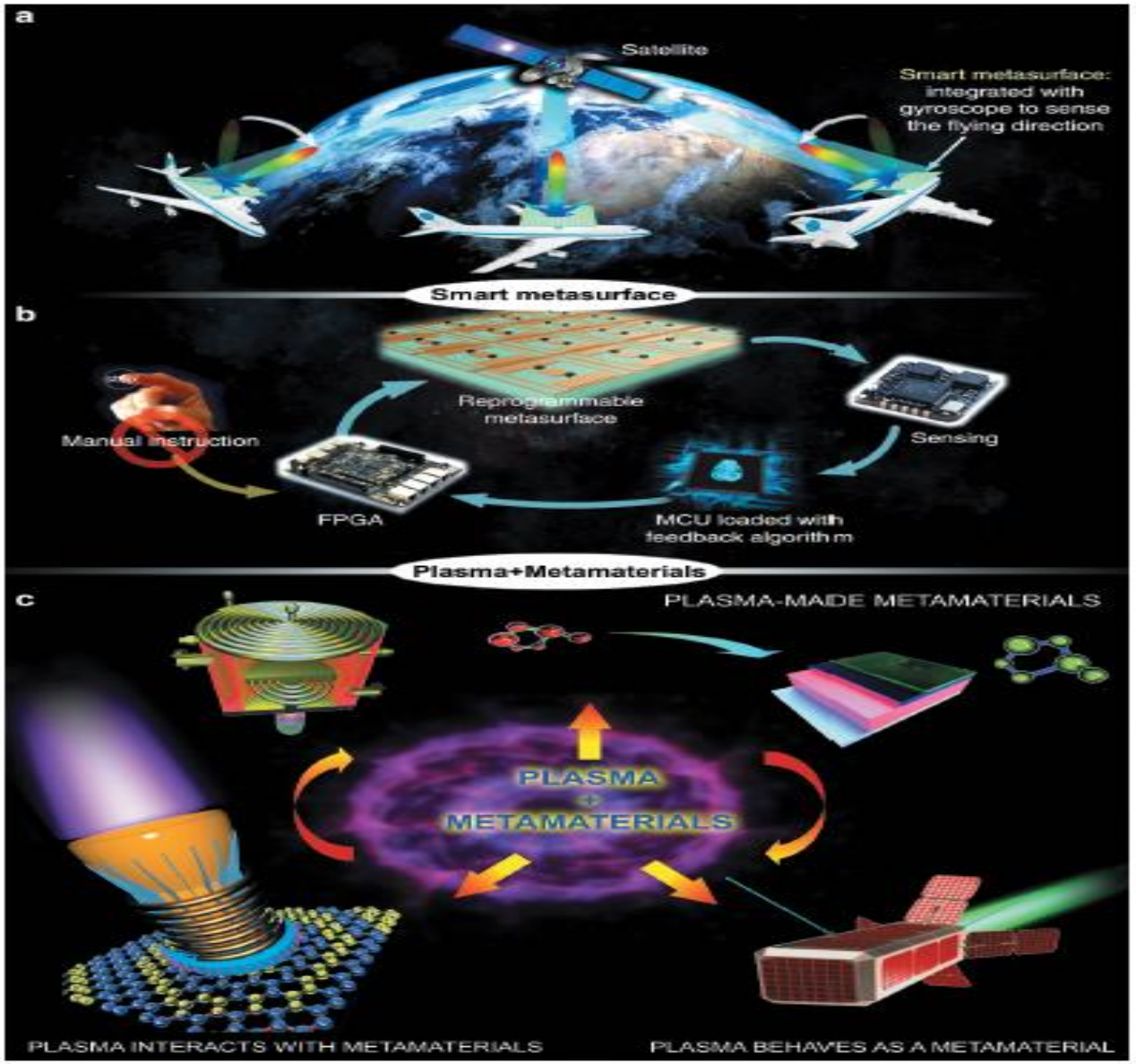
$$n_e \gtrsim 10^{23} \ \mathrm{cm}^{-3}$$

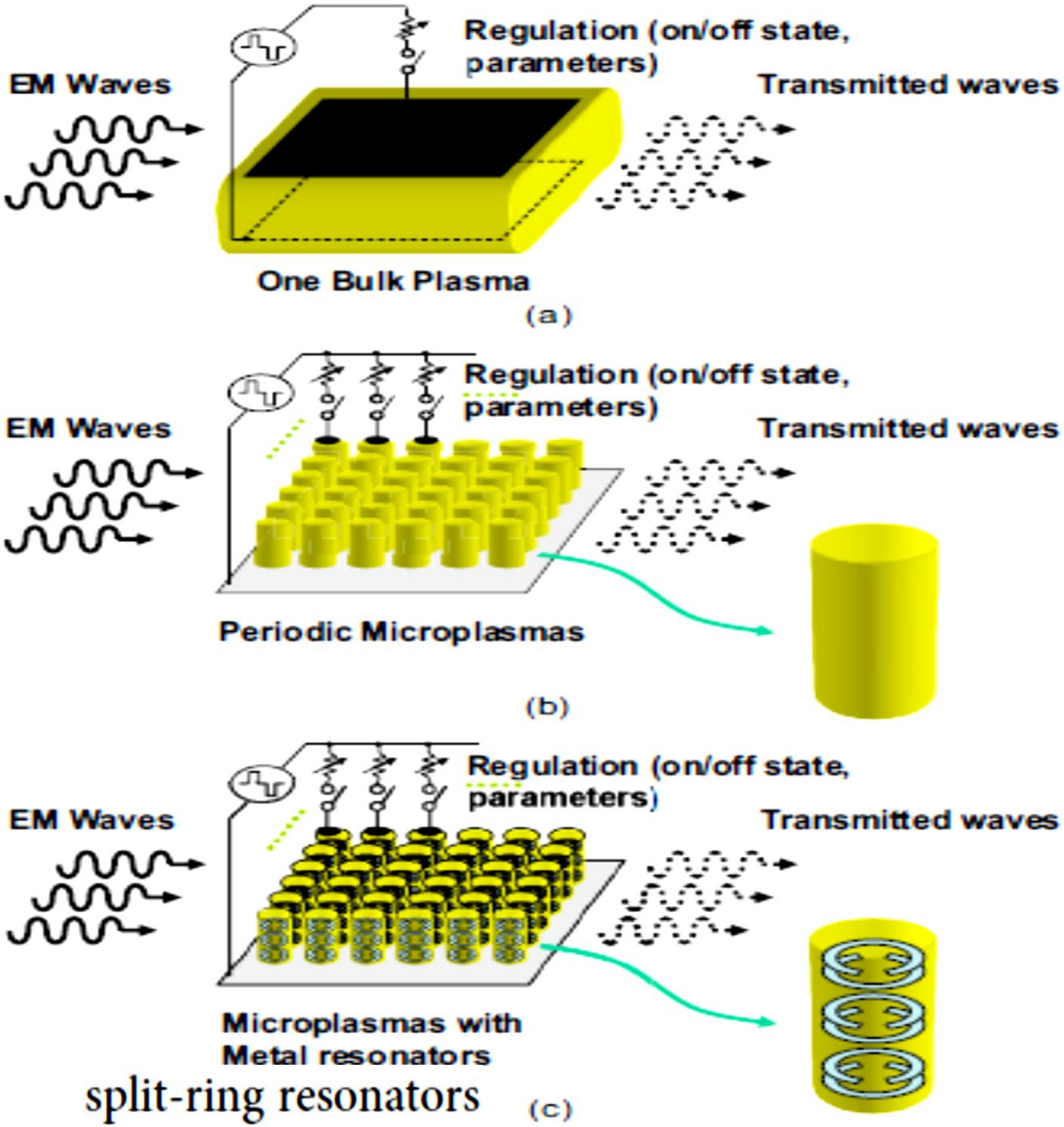
$$T_s > 10^5 \ \mathrm{K}$$

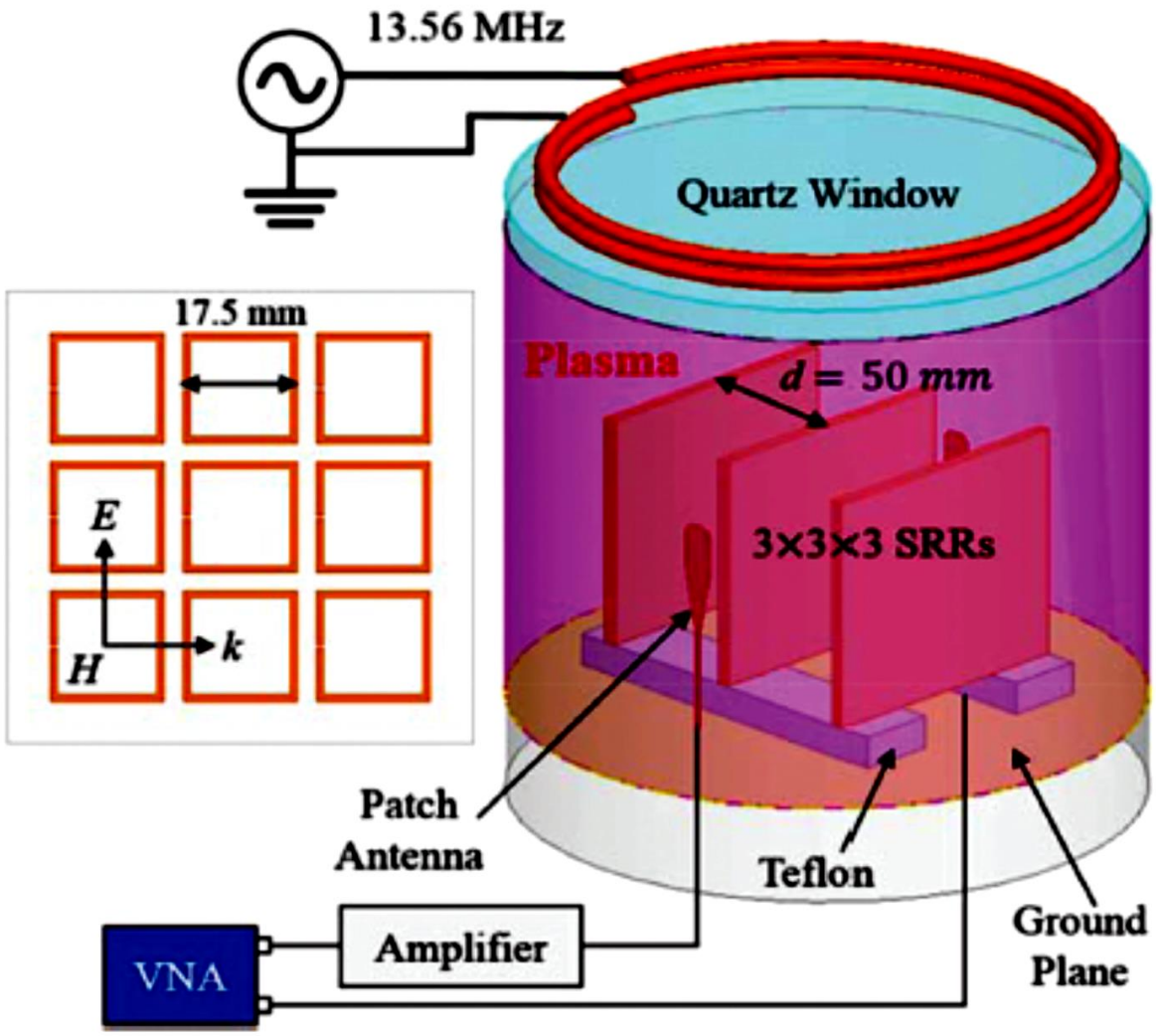
Sputtering of the dust material.

Plasma as Metamaterial

The index of refraction is real and negative if both (ϵ) and μ are




Regulation (on/off state, parameters)
EM Waves
Transmitted waves
One Bulk Plasma
(a)
Regulation (on/off state, parameters)
EM Waves
Transmitted waves
Periodic Microplasmas
(b)
Regulation (on/off state, parameters)
EM Waves
Transmitted waves
Microplasmas with Metal resonators
split-ring resonators
(c)

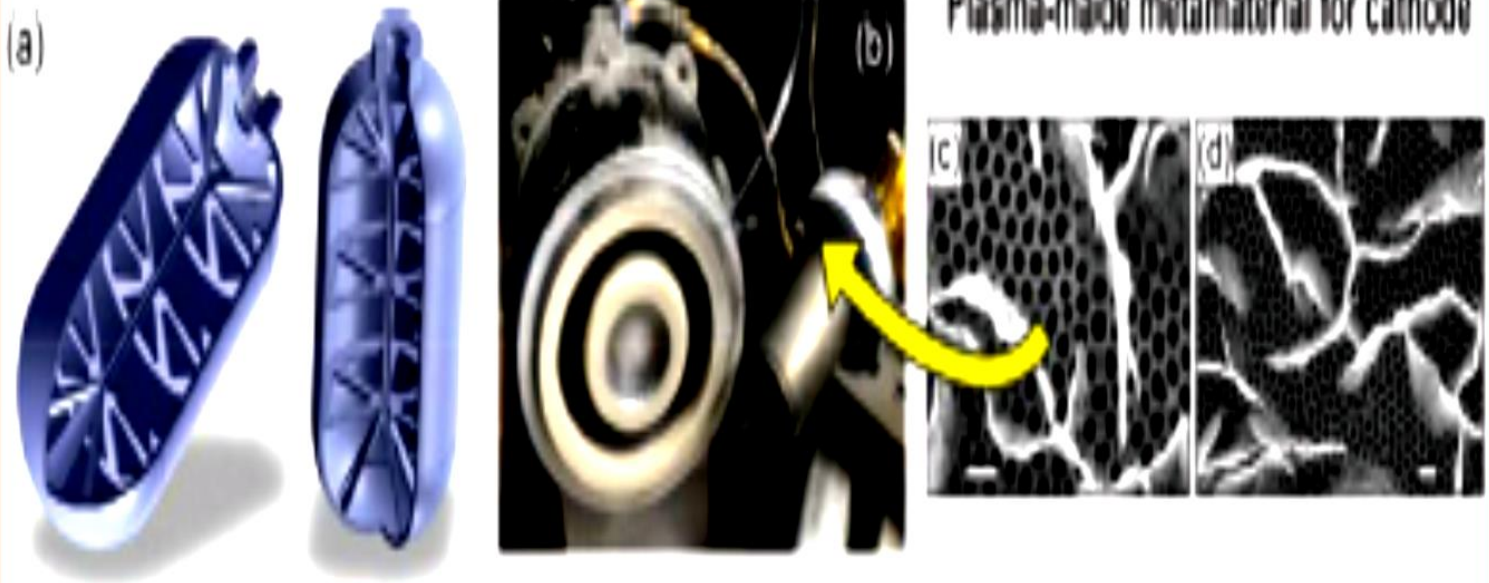

13.56 MHz
Quartz Window
17.5 mm
Plasma
d = 50 mm
E
H
k
3×3×3 SRRs
Patch
Antenna
Teflon
Ground
Plane
VNA
Amplifier

PLASMA-MADE AND PLASMA-TREATED MATERIALS IN AEROSPACE: EXAMPLES

Plasma-treated tanks for Cubesat

Thruster and cathode

Plasma-made metamaterial for cathode



While the studies on plasmas as metamaterials are currently at the initial stage of development, such structures could be very promising for various aerospace applications, including micro-thrusters, electronics elements and energy conversion devices.

Solar Wind

the Solar wind originates from the Solar Corona, expands into the universe and impacts the Earth' magnetosphere and ionosphere, the two plasma layers surrounding Earth's gaseous atmosphere.

Solar energetic particle events are important, as they can arise suddenly and lead to space weather conditions near Earth that can be potentially harmful to astronauts. Unraveling the sources, acceleration and transport of solar energetic particles will help us better protect humans in space in the future.

A Bill Gates Venture Aims To Spray Dust Into The Atmosphere To Block The Sun. What Could Go Wrong?

Different Sources of Knowledge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For children from ages 6 to 14: It provides entertaining educational activities and resources

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اكتشف المزيد

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