Plasma Fundamentals and Applications

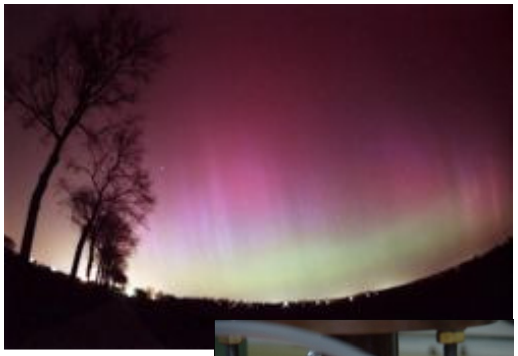
By: Dr. I.J. Van der Walt
Senior Scientist
Necsa

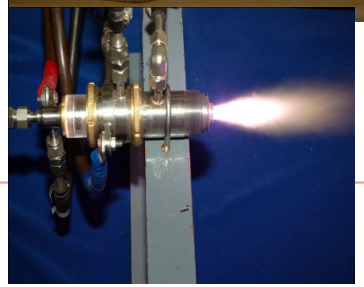
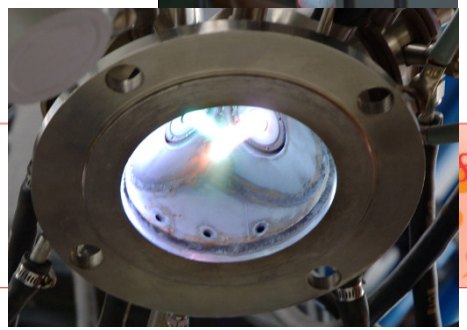
necsa
We're in your world

A Natural Occurring Plasma

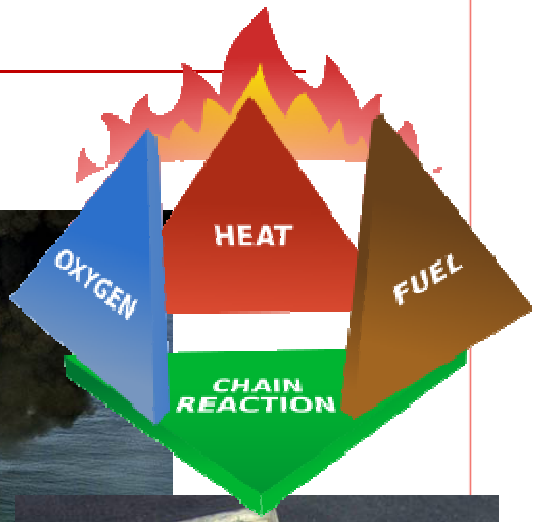
Plasma vs Flame

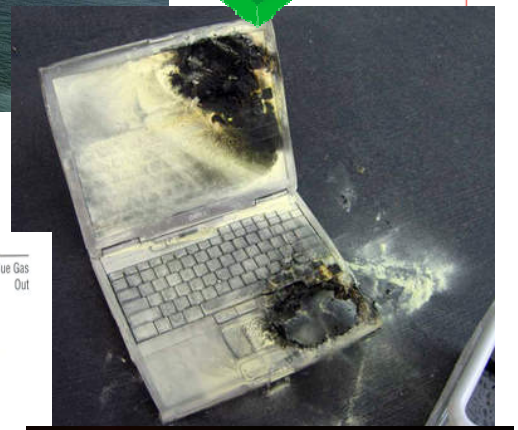
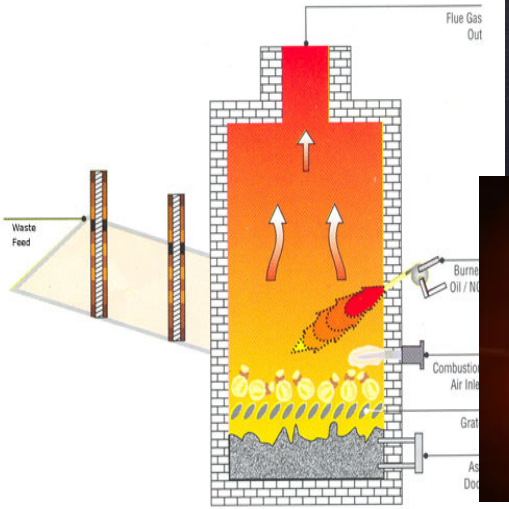
Plasma

Flame

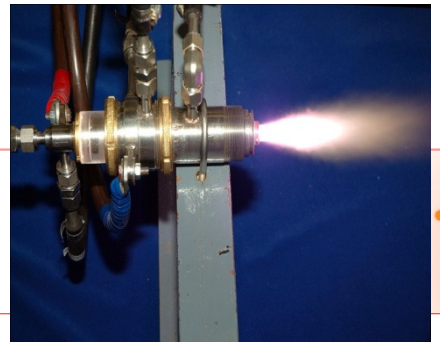
Plasma vs Flame

Plasma

- 1 500 – 20 000 °C
- No O_2 necessary
- Ionisation process
- Electricity is constant energy source
- Small concentrated heat

Flame

- 450 – 2 000 °C
- O_2 necessary
- Oxidation process
- Initiation energy needed before exothermic reaction
- Big flames

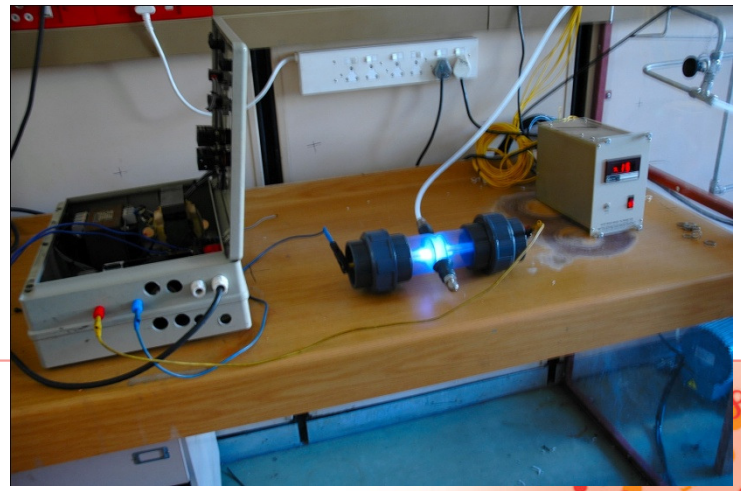


necsa
We're in your world

Plasma vs Flame

Plasma

- Endothermic
- $N_2 + E \rightarrow 2N + \Delta$



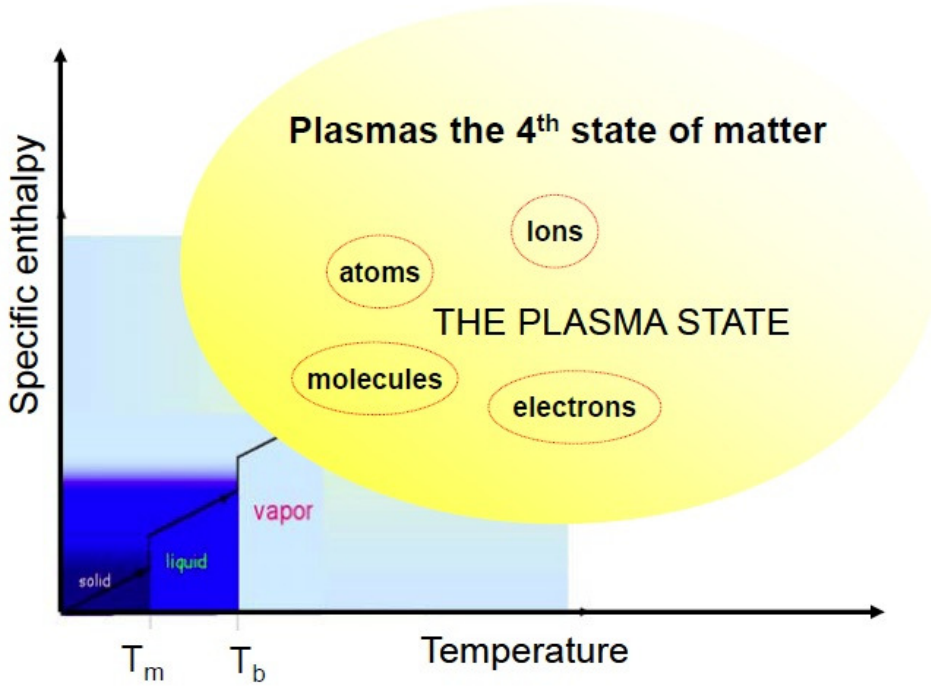
Flame

- Exothermic
- $C_2H_6 + 2.5O_2 + \Delta \rightarrow CO_2 + C + 3H_2O$

necsa
We're in your world

What is a Plasma

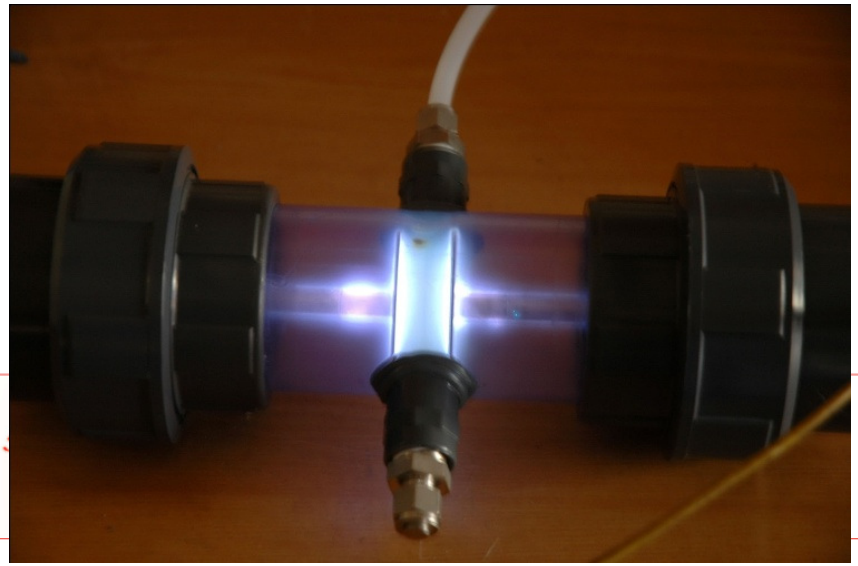
- Fourth state of matter
- Mixture of electrons, ions and neutral particles;
- Exited state species to ground state responsible for luminosity
- Negative and positive species balance each other
- Photons emitted by electrons “bremstrahlung”



M.I. Boulos, P. Fauchais, E. Pfender, Thermal Plasmas: Fundamentals and Applications, Vol 1, Plenum Press, 1994.

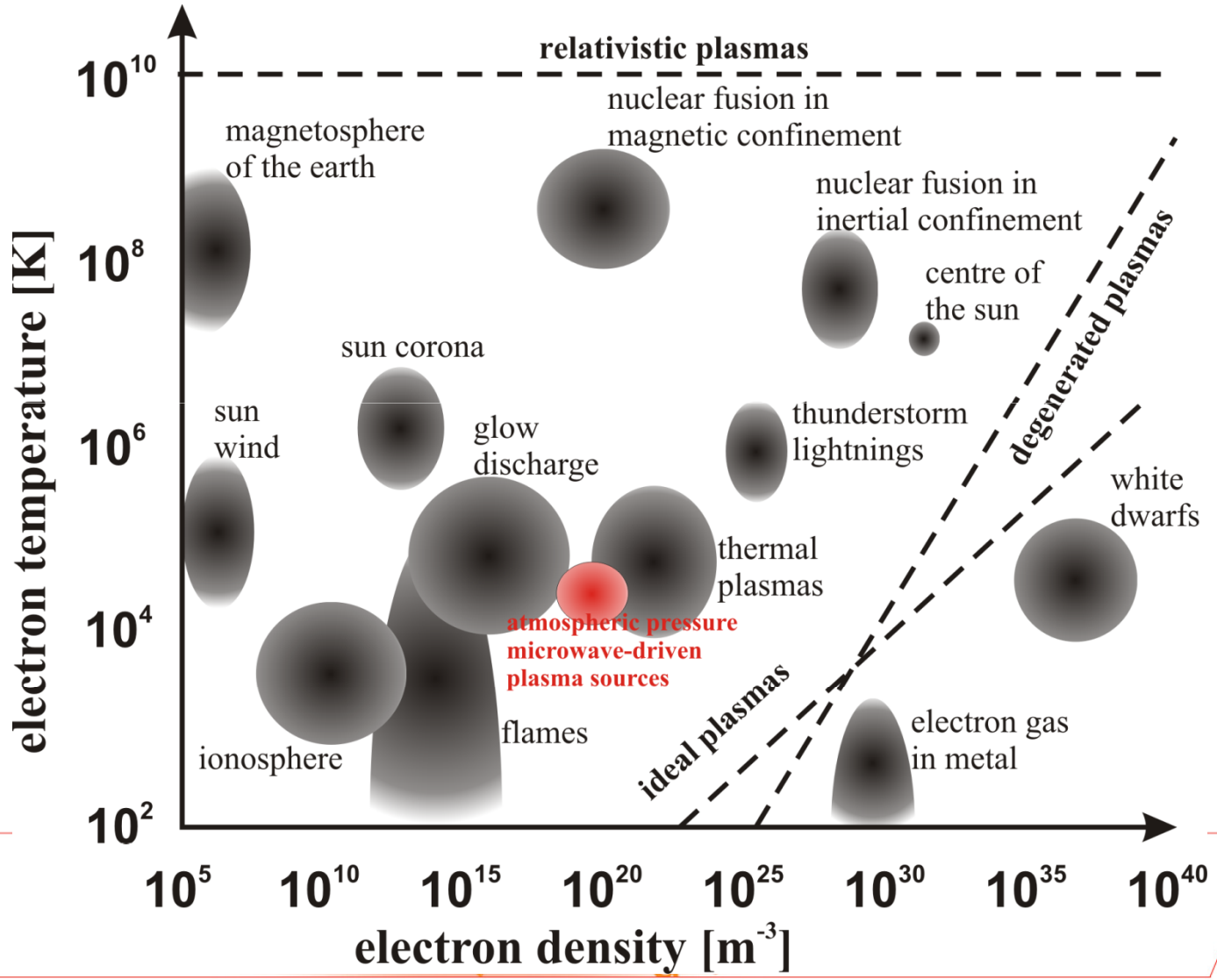
What is a Plasma

- Plasmas are:
  - Electrically conductive;
  - Not a flame!!!;
  - Classified according to ē T and ē ρ;
  - Classified according to the difference between ē T and ion T



necsa
We're in your world

Plasmas Classification

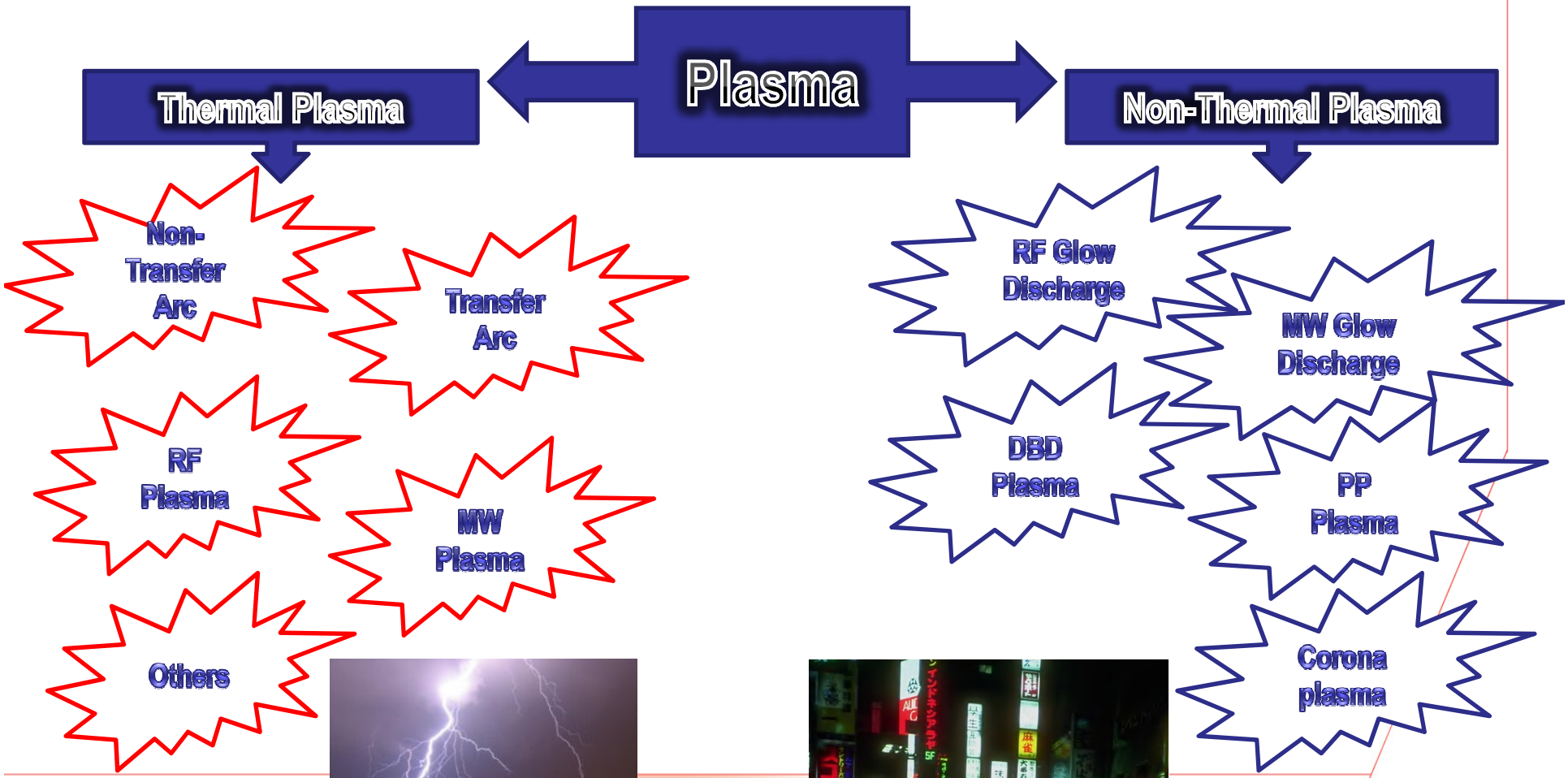


necsa
We're in your world

Different Examples of plasmas

- Lightning
- Auroras
- Fluorescent lamps
- Arc welding
- Melting furnaces
- Household waste destruction
- Plasma TV by means of DBD
- Photo copy machine lights
- Proxima lights
- Analytical instruments

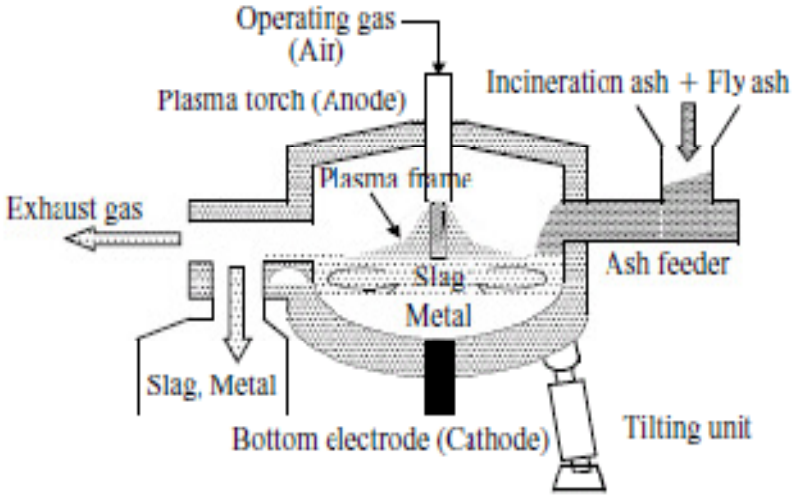
Types of Plasmas



necsa
We're in your world

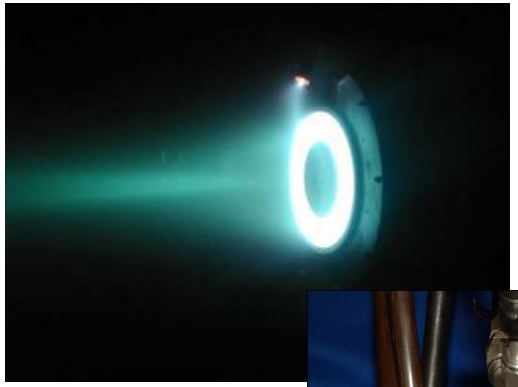
Thermal Plasmas: Transfer Arc Plasma

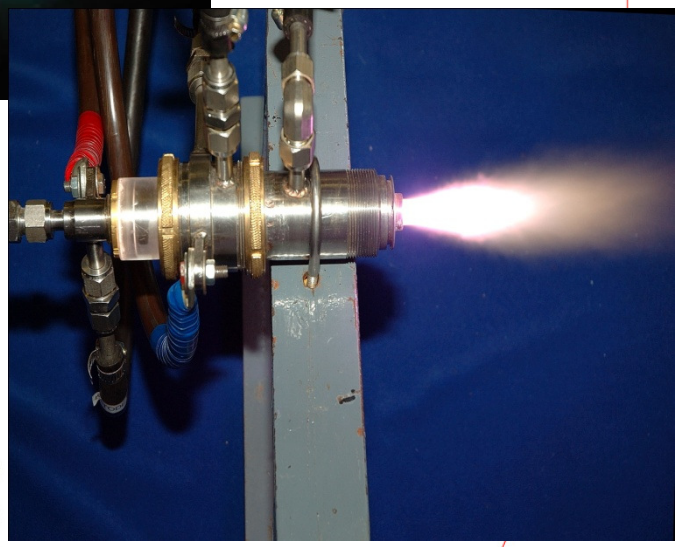
- Useable electrodes
- Effective energy transfer
- Some contamination from electrodes
- Conventional metal melting method

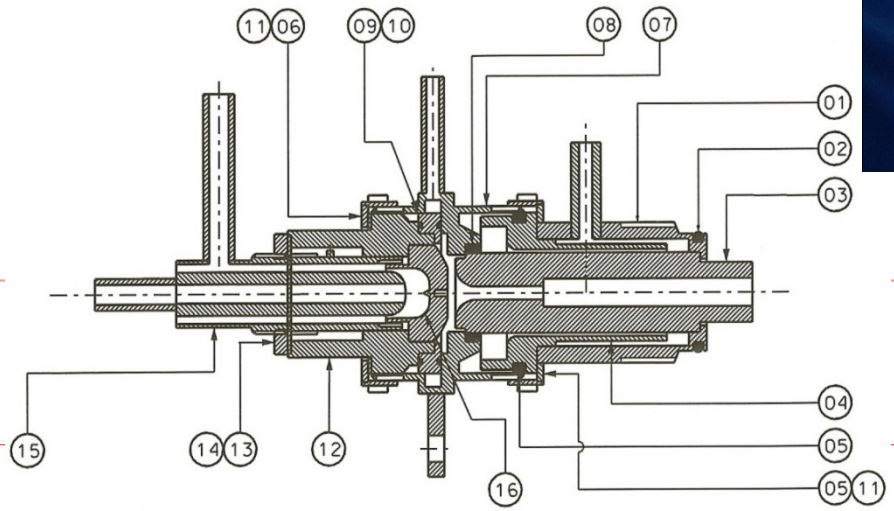


Thermal Plasmas: Non-transfer Arc Plasma

- Non-useable water cooled electrodes
- Energy transfer in the tail flame
- Used in:
  - Plasma spraying
  - Mineral beneficiation
  - Waste destruction



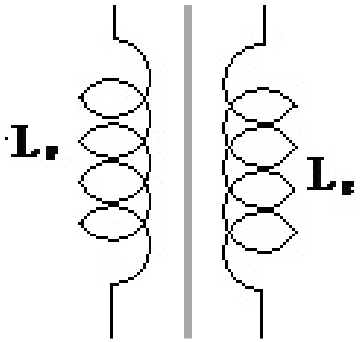


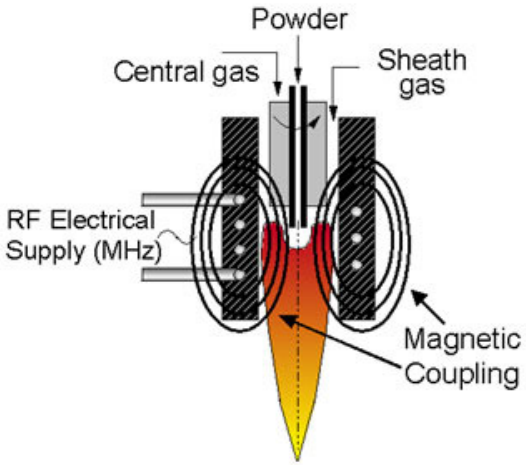


necsa
We're in your world

Thermal Plasmas: Radio Frequency Plasma

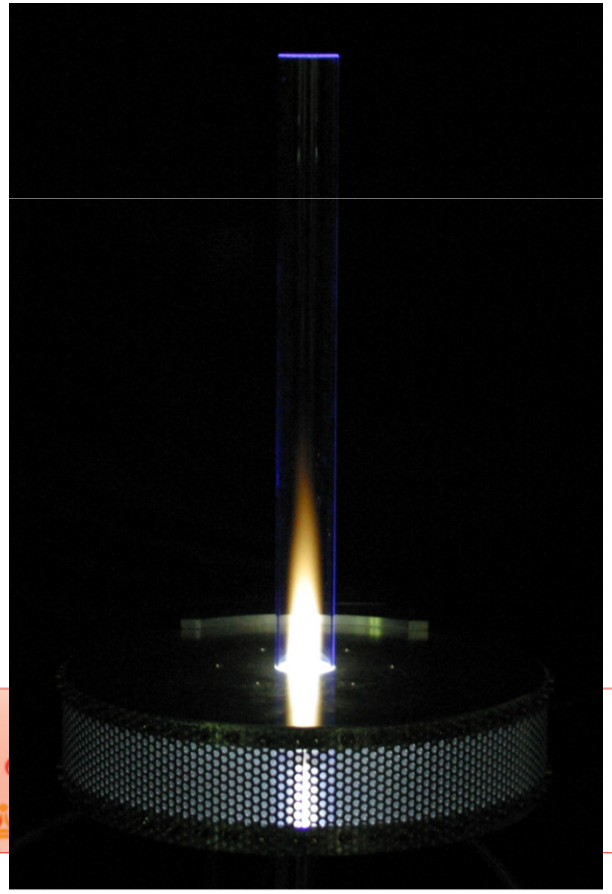
- No electrodes
- Plasma by induction at 13.56 MHz
- Used in:
  - Plasma spraying
  - Analytical instrumentation
  - Waste destruction
  - Nano particle production

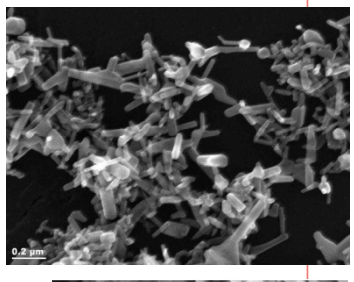


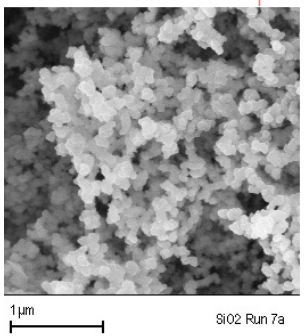


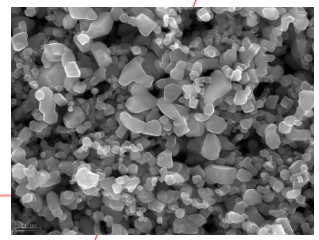
Thermal Plasmas: Micro Wave Plasma

- No electrodes, no coils
- Plasma by MW generation at 2.45 GHz
- Used in:
  - Off gas treatment
  - Nano particle production
  - Surface etching
  - Chemical vapour deposition





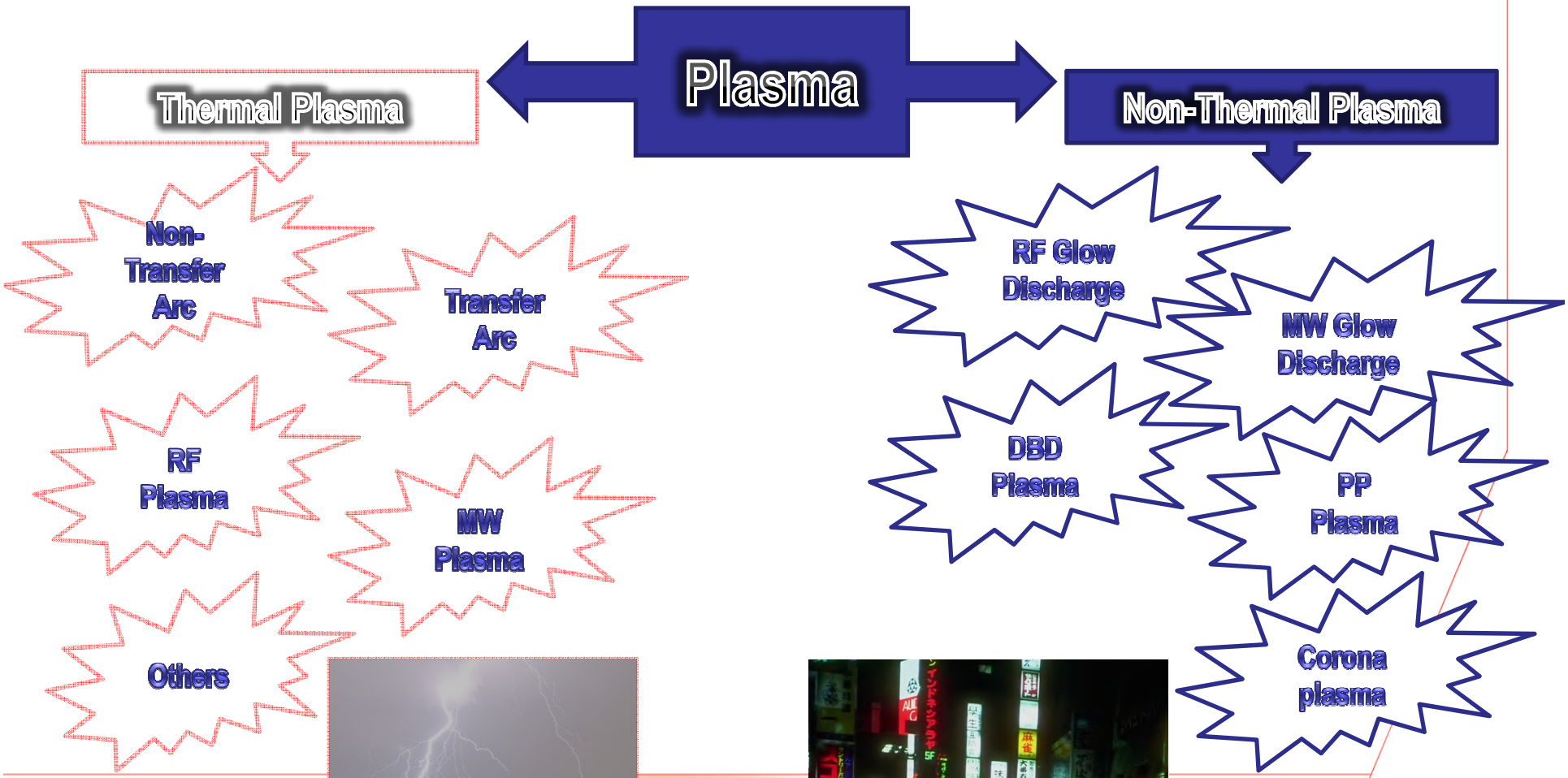




Courtesy of Marieta Leins
Stuttgart University

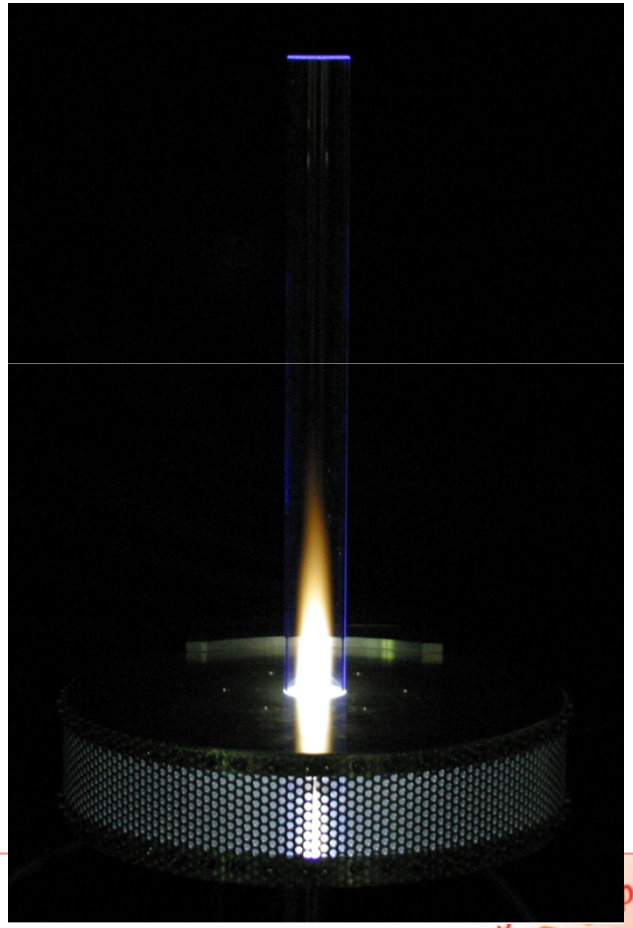
necsa
We're in your world

Types of Plasmas

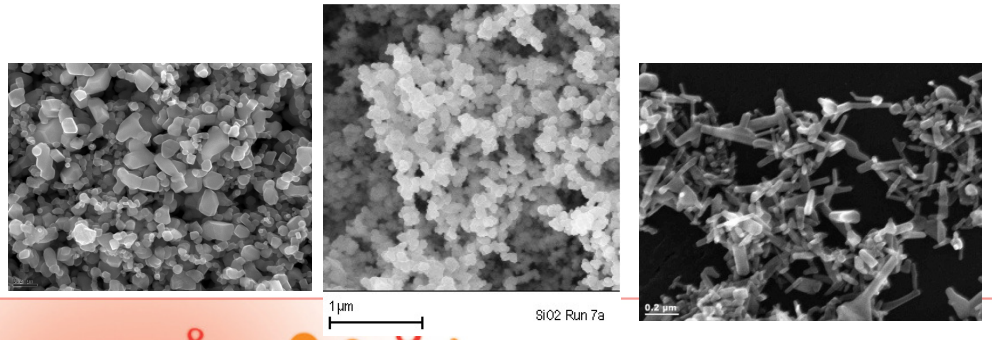


necsa
We're in your world

Non-Thermal Plasmas: Micro Wave

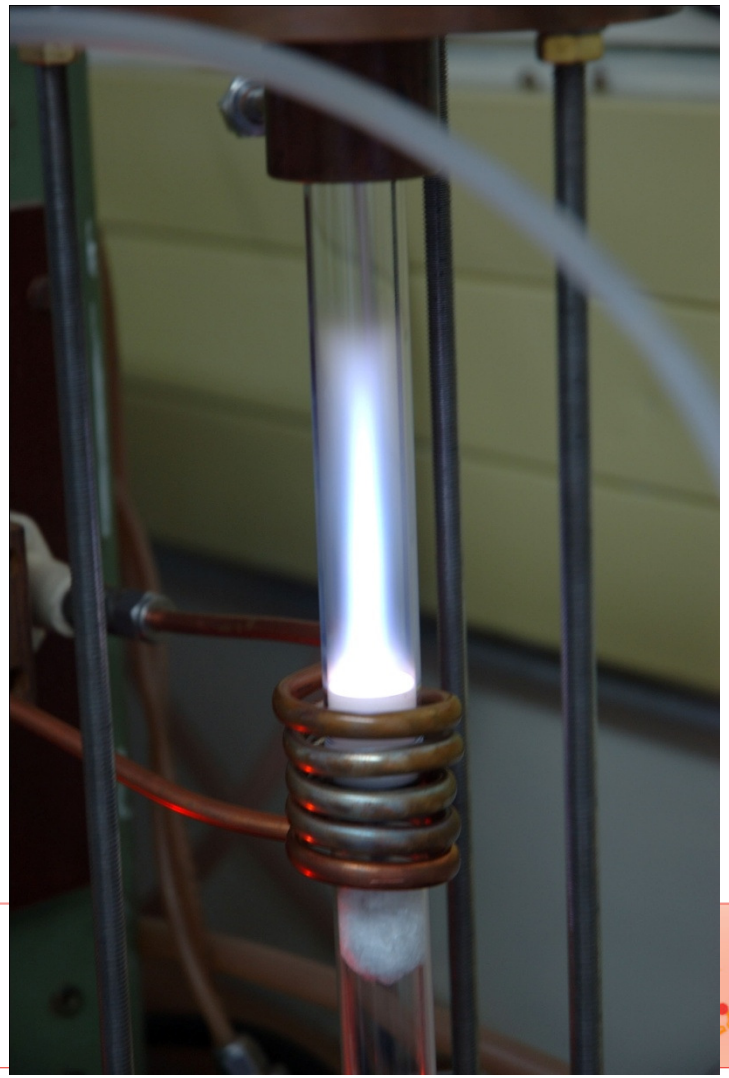


- No electrodes, no coils, low pressure
- Plasma by MW generation at 2.45 GHz
- Used in:
  - Nano particle production
  - Artificial diamond growth
  - Chemical vapour deposition



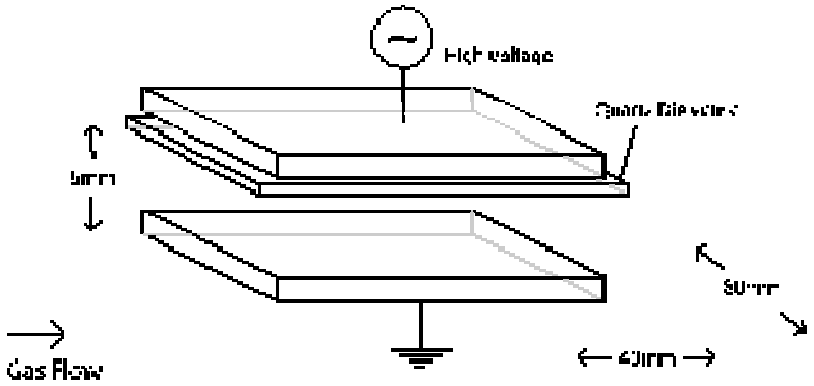
necsa
We're in your world

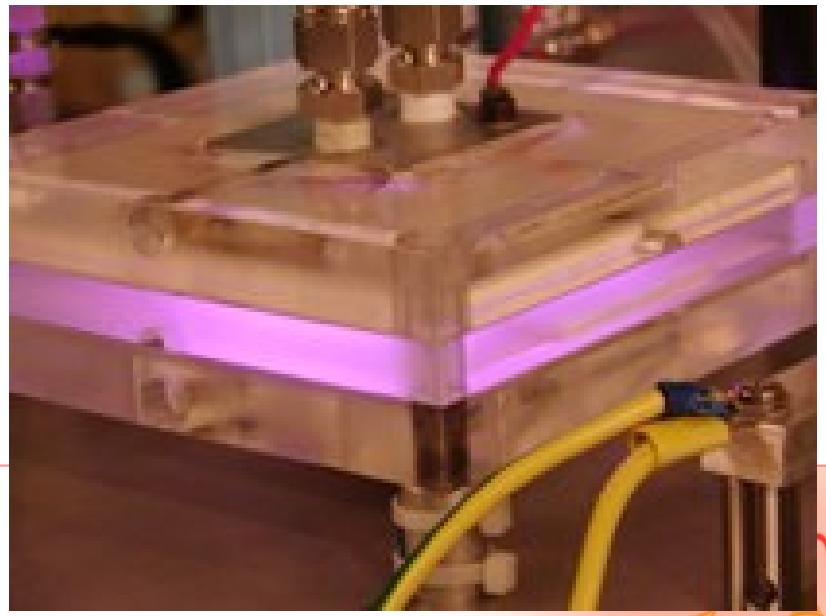
Non-Thermal Plasmas: RF Glow Discharge



- No electrodes, low pressure
- Plasma by RF Induction at 13.56 MHz
- Used in:
  - Surface modification
  - Surface etching
  - Chemical vapour deposition
  - Lighting

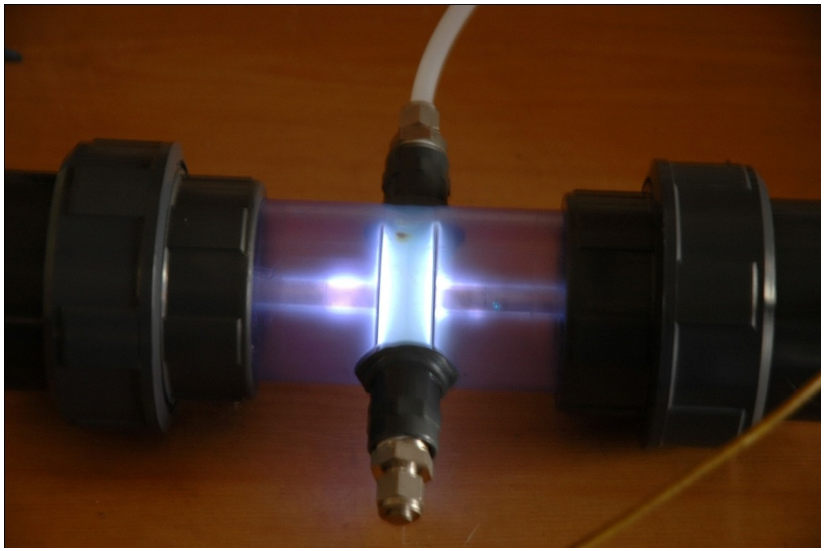
Non-Thermal Plasmas: Dielectric Barrier Discharge



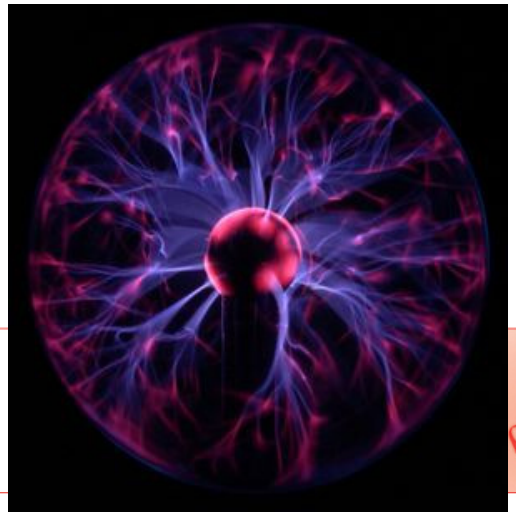


- 2 electrodes separated by a dielectric layer at ambient pressure
- Plasma by dielectric barrier discharge at 1 - 100 MHz
- Used in:
  - Ozone (O_3) production

Non-Thermal Plasmas: Pulsed Power Plasma



- 2 electrodes at ambient pressure
- Nano second thermal plasma 10 – 100 kHz
- Used in:
  - Off gas treatment

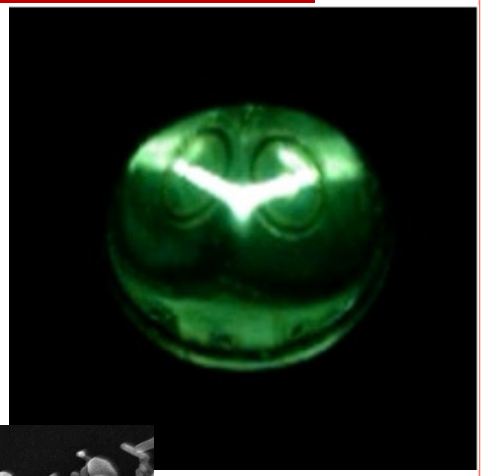


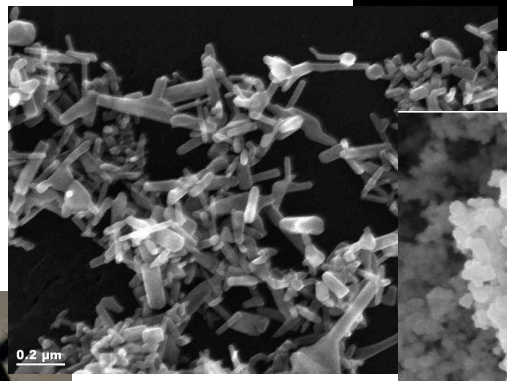
Non-Thermal Plasmas: Corona Discharge

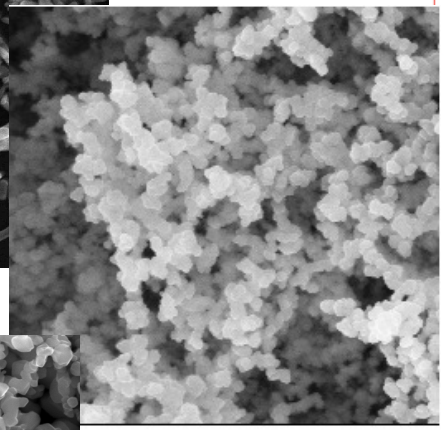
- 2 electrodes at ambient pressure
- Nano second thermal plasma 10 – 100 kHz
- Used in:
  - Off gas treatment
  - Ozone production
  - Surface activation

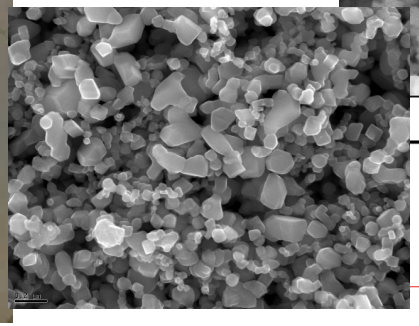
Plasma Chemistry

- Chemistry with inert chemicals like C, ZrO_2, SiO_2, TiO_2, Al_2O_3, ZnO, etc.
- Chemistry with inert chemicals like CF_4, N_2, Ar, etc.
- Manufacturing of nano particles.







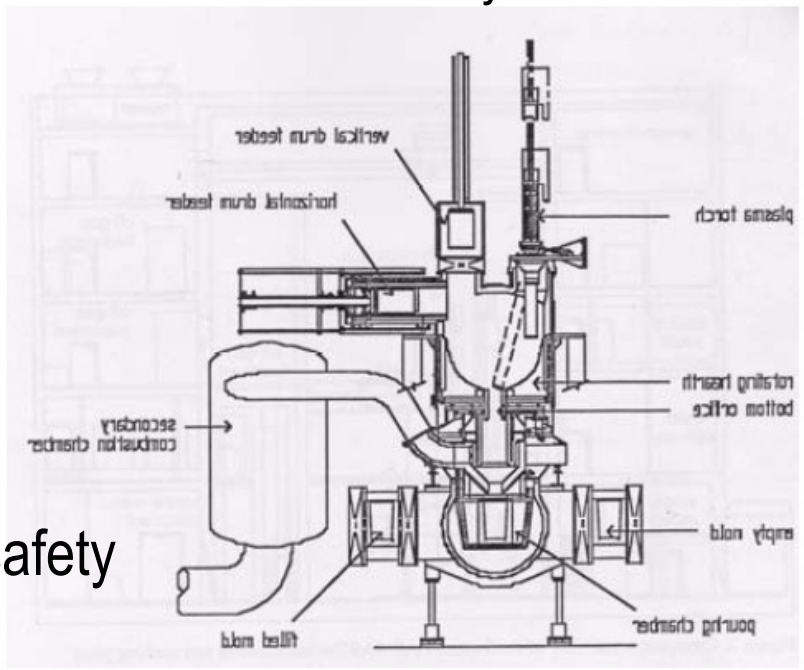


necsa
We're in your world

Plasma Nuclear Application

- Low level nuclear waste treatment
- Volume reduction (>90 %)
- Uranium recovery
- Vitrification
- Treat the whole drum
- No sorting
- Increased chemical and radiological safety
- Technology is mature
- Technology is applied on nuclear sites
- Small footprint

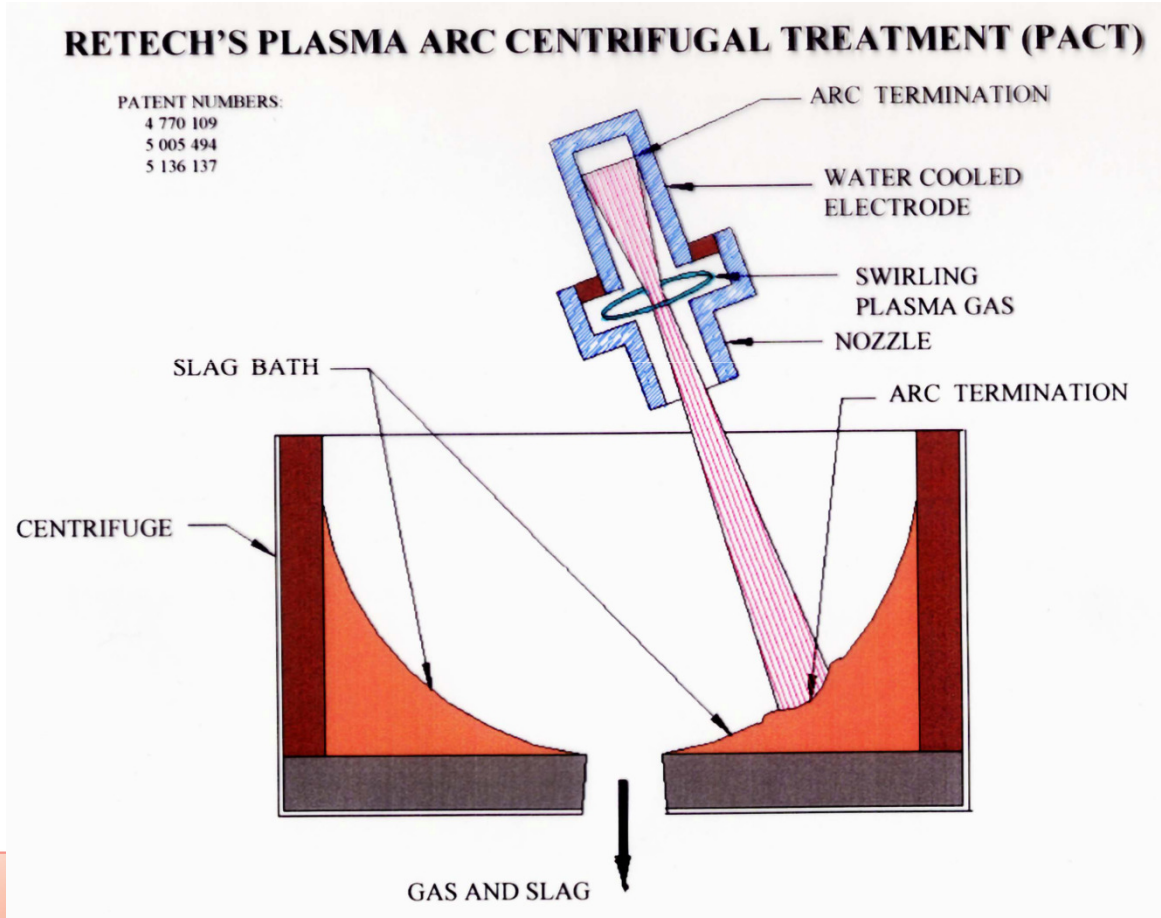
Plasmarc system



SA course on thermal plasmas
October 28-29 2011

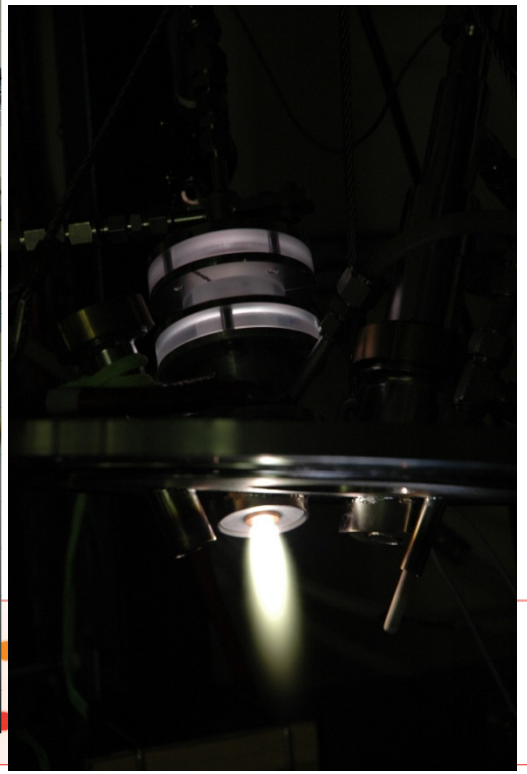
Plasma Nuclear Application

- Different suppliers in the world
  - Retech scientific
  - Europlasma
  - Tetronics
  - Scanarc
  - Nukem
  - Westinghouse
  - Phoenix Solutions



Plasma Nuclear Application

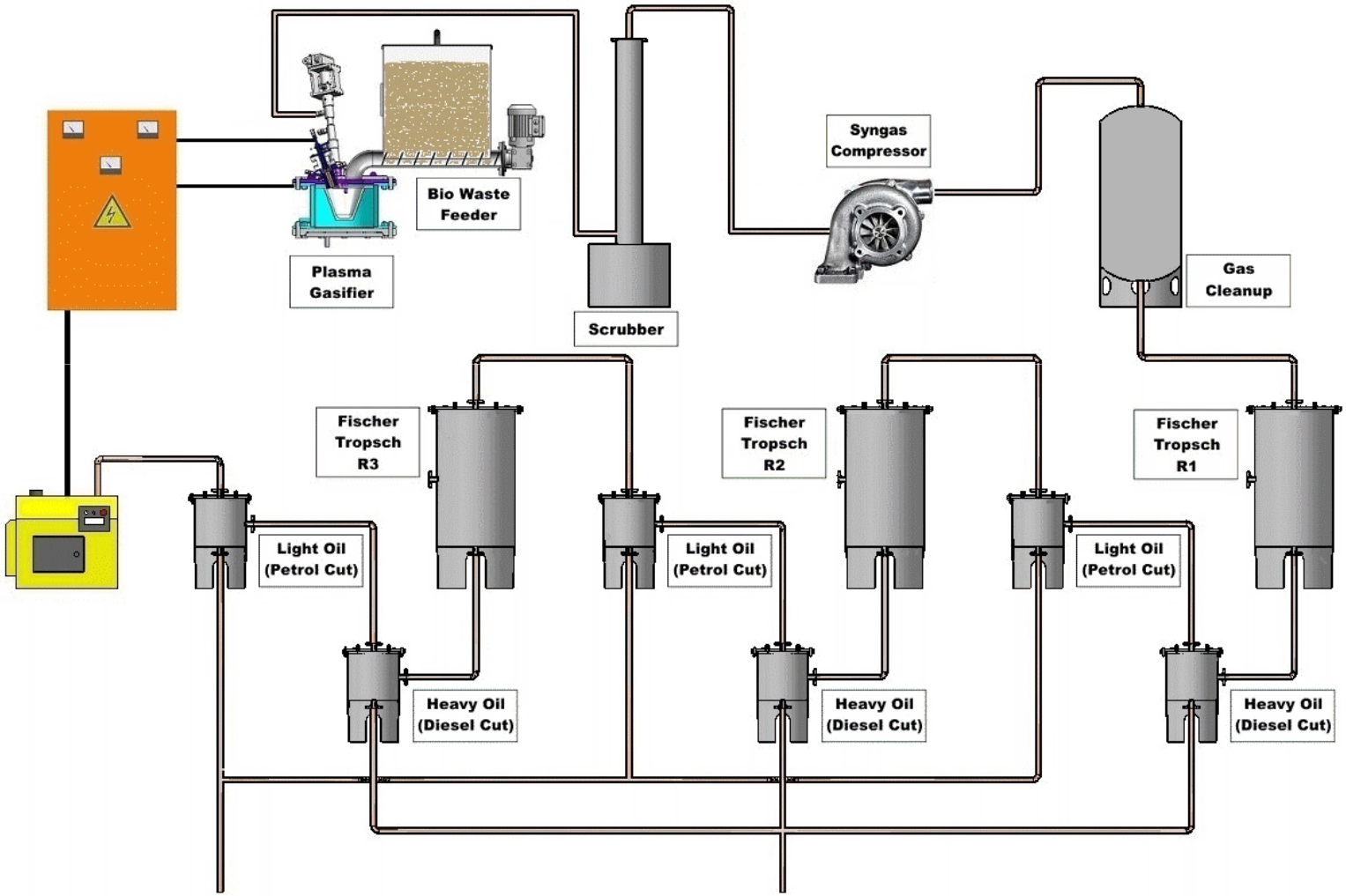
Necsa demonstration plasma nuclear waste volume reduction



Benefit

- **Benefit to the greater South Africa**
  - Solution to serious municipal waste problems;
  - Solution to medical waste problems;
  - Solution to various other waste problems;
  - Takes pressure off fuel supply to remote areas;
  - Takes pressure off electricity supply to remote areas;
  - Promotes the decrease of the carbon footprint;
  - Opportunity for renewable energy supply;
  - Job creation;
  - Trade waste for electricity.

BeauTi-fueL™


Syngas Compressor
Bio Waste Feeder
Plasma Gasifier
Scrubber
Gas Cleanup
Fischer Tropsch R3
Fischer Tropsch R2
Fischer Tropsch R1
Light Oil (Petrol Cut)
Light Oil (Petrol Cut)
Light Oil (Petrol Cut)
Heavy Oil (Diesel Cut)
Heavy Oil (Diesel Cut)
Heavy Oil (Diesel Cut)

BeauTi-fueL™

http://www.rchelicam.co.za/preview/CCR_Expo/Climate_Smart_CTN_Outside.html

BeauTi-fueL™

Waste-to-Energy Application sectors

- **Product capabilities**

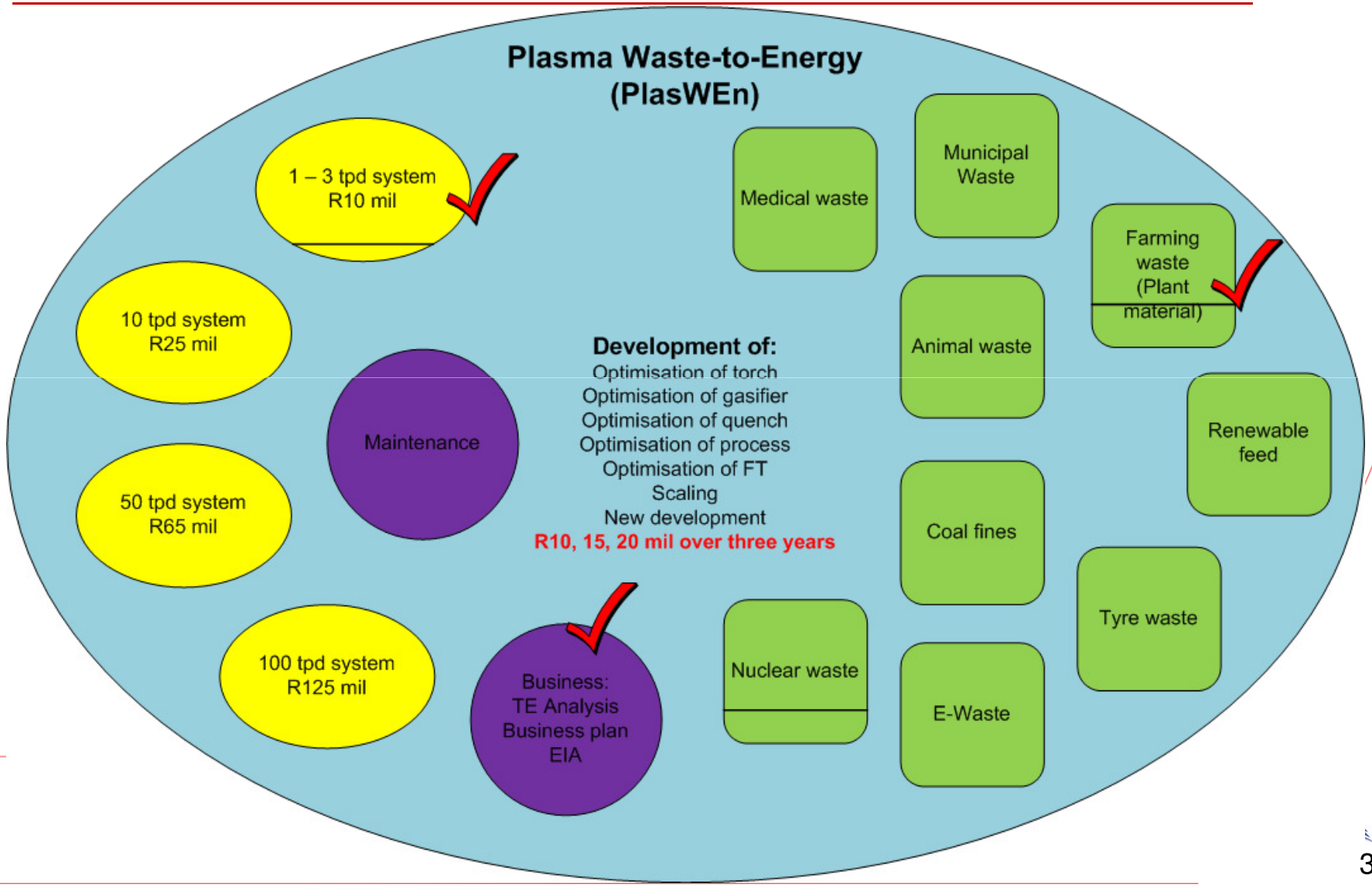
	Electricity only	Electricity and fuel	Unit size (tpd)
Municipal land fill sites		X	100 – 200
De-localised municipal waste sites	X		1 – 10
Farming plant waste		X	1 – 3
Farming animal manure waste		X	1 – 3
Renewable feedstock		X	100 – 200
Tyre waste		X	10 – 50
Medical waste	X		1
Toxic waste	X		1
Nuclear waste	X		10

Technical data

- **Up-scaling modular systems (50 % accuracy)**

Plant	1	10	50	100
Feed quantity	~2 - 3 tpd	~10 - 15 tpd	~50 - 70 tpd	~100 – 150 tpd
Plasma size	30 kW	150 kW	500 kW	1000 kW
Availability	2012	2013	2015	2017
Estimated Development Cost	R10 mil	R25 mil	R60 mil	R125 mil
Electricity only or	150 kW	750 kW	3.75 MW	7.5 MW
Diesel and Electricity	2 bbl 50 kW	10 bbl 250 kW	50 bbl 1.25 MW	100 bbl 2.5 MW

Funding


Plasma Waste-to-Energy
(PlasWEn)
1 – 3 tpd system
R10 mil
10 tpd system
R25 mil
50 tpd system
R65 mil
100 tpd system
R125 mil
Maintenance
Business:
TE Analysis
Business plan
EIA
Development of:
Optimisation of torch
Optimisation of gasifier
Optimisation of quench
Optimisation of process
Optimisation of FT
Scaling
New development
R10, 15, 20 mil over three years
Medical waste
Municipal Waste
Farming waste (Plant material)
Animal waste
Renewable feed
Coal fines
Tyre waste
Nuclear waste
E-Waste

Thank You!!!