Comparative Local Plasma Diagnostics Performed in DCPN and HCAPN Reactors

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Outline

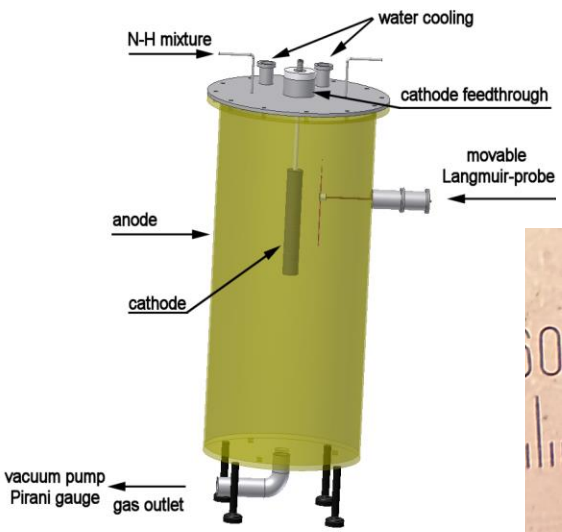
- Introduction – Our plasma reactor
- Plasma diagnostics using Langmuir Probe
- Measurements performed in the DCPN setup
- Measurements performed in the HCAPN setup
- Signal filtering and post processing
- Conclusions

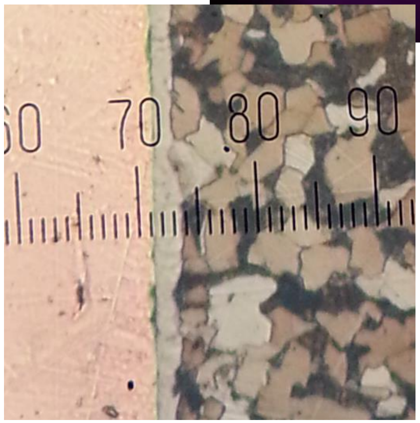
Introduction

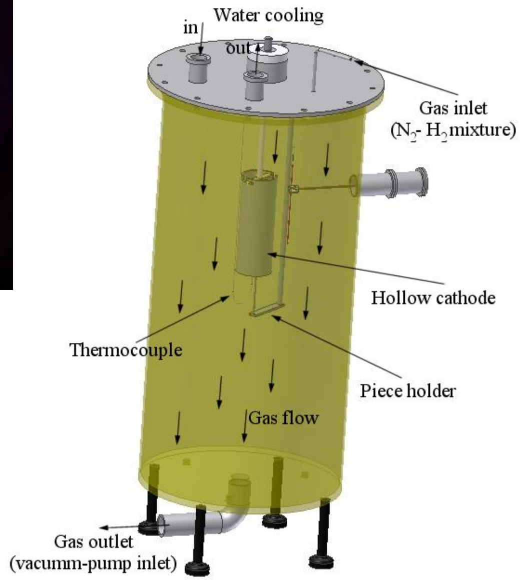
- Our experimental setup – linear plasma reactor, consisting of:

Plasma Nitriding

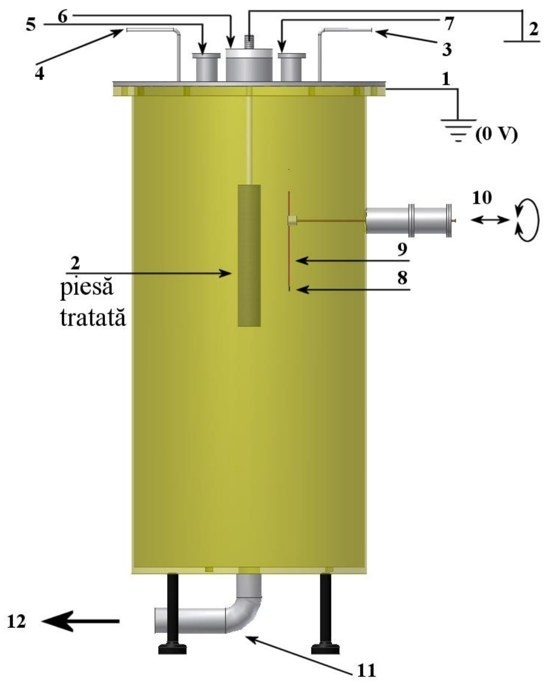
- There are two classical technologies:
  – DCPN ASPN







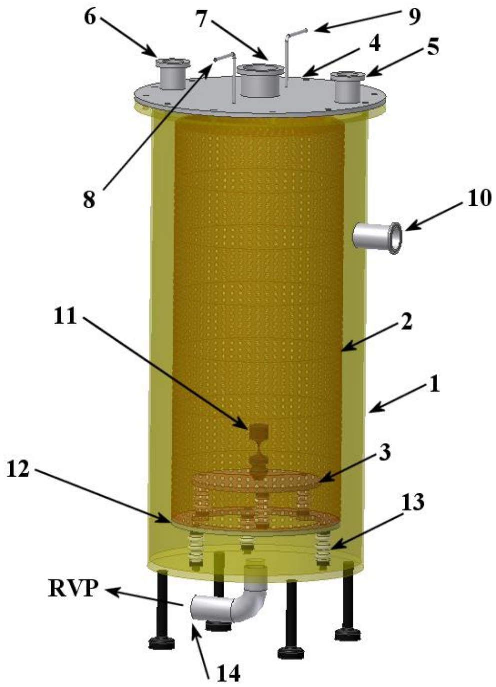
DC Plasma Nitriding



1. Anode
2. Cathode (piece for heat treatment)
3. Gas inlet for the introduction of nitrogen
4. Gas inlet for introducing hydrogen
5. Observation window
6. Electrical isolation (ceramic)
7. Vacuum connection for the probe polarization
8. Cylindrical Langmuir probe
9. Electrical isolation of the probe (ceramic)
10. The mechanism of movement of the probe
11. Exhaust pipe
12. Vacuum pump

Disadvantages: - Only certain steel alloys can absorb nitrogen, Other disadvantages due to the formation of an electrical field (hollow-cathode effect, arcing, edge effect)

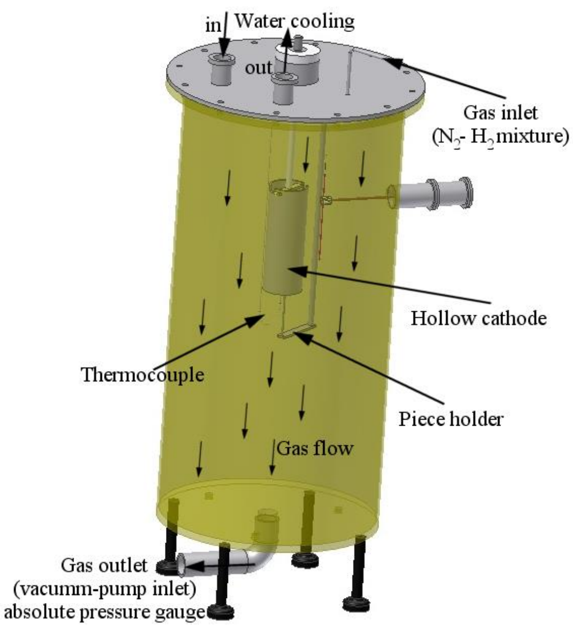
AS- Plasma Nitriding



1. Vacuum chamber (anode)
2. Active Screen (AS – cathode)
3. Sample holder
4. Top lid of the vacuum chamber (anode)
5. Vacuum connection for electric feedthrough,
6. Vacuum connection for axial motion feedthrough
7. Observation window
8. Nitrogen gas inlet
9. Hydrogen gas inlet
10. Vacuum connection for radial motion feedthrough
11. Sample
12. AS cathode holder
13. Electrical isolations
14. Gas exhaust pipe.

Advantages: - Solves or avoids by construction all disadvantages presented at DCPN.

HCAPN- Plasma Nitriding



- the sample is placed inside the cylindrical cathode and it is biased to anodic potential
- the nitrogen-hydrogen gas mixture has a linear and laminar flow through the reactor including the inside of the hollow cathode
- this ensures the homogeneous distribution of the charged and neutral particles around the sample.

Advantages: - The part is placed in the secondary plasma, thus with this setup the disadvantages of the DCPN and ASPN are eliminated.

Local Plasma diagnostic

- Local techniques are based on the study of the voltage-current curves of different electrostatic probes inserted in the plasma, which provide local information on the plasma
- We designed a local plasma diagnostics setup because we proposed to study the distribution and evolution of local plasma parameters during the nitriding process of steel samples
- We use a cylindrical shaped 0,4 mm diameter, 3 mm length probe made of tungsten
- We designed a complex, computer controlled DC power supply to bias the probe and measure the currents
- There are different data processing methods which yield information on local electron density, electron temperature (energy). During nitriding these parameters are influenced by the pressure, discharge voltage, temperature, gas mixture and anode-cathode distance

Power Supply for Langmuir Probe

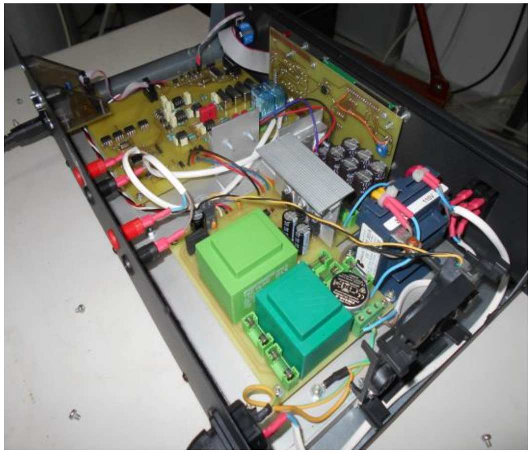
Power supply specifications:

1. Output voltage range: -125VDC…+125VDC
2. Output current: 0…70mA
3. Programmable voltage step: min. 0.01V
4. Current measurement accuracy: 1µA
5. Step time: min. 50ms.
6. Communication interface: RS232 or USB.

Power Supply for Langmuir Probe

Practical realization:

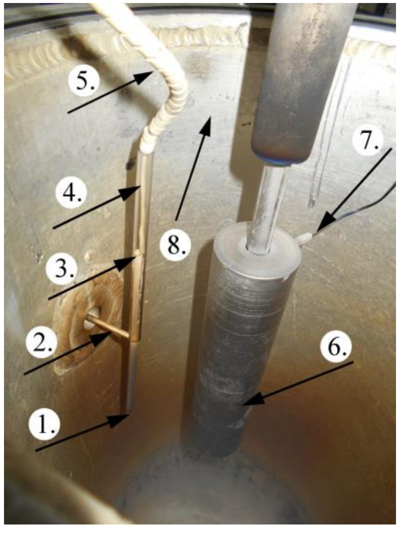
Front view of the power supply



Internal construction of the power supply

Plasma Diagnostics in DCPN

Experimental setup:

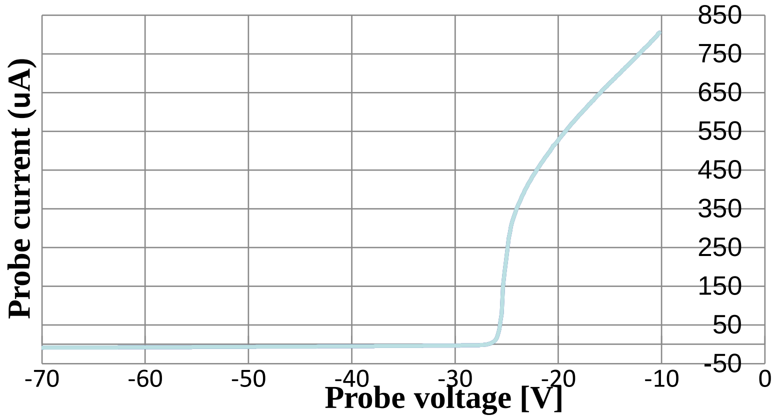


The Langmuir probe installed in the linear plasma reactor in DCPN setup

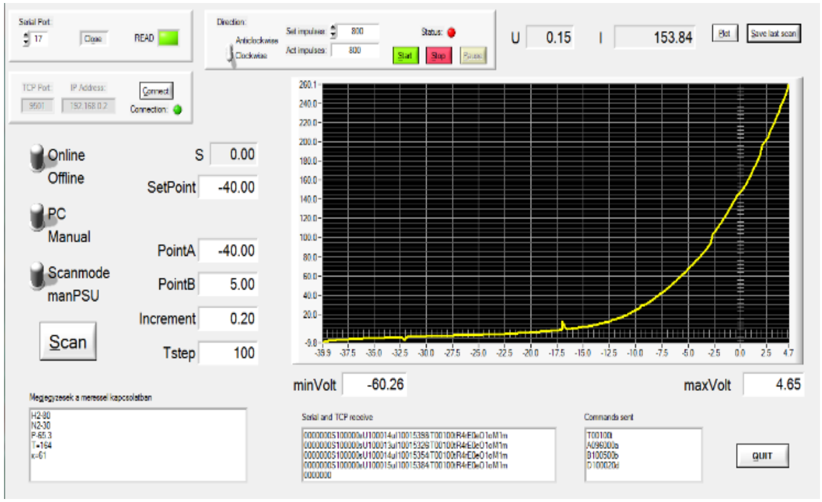
1. Cylindrical probe made from wolfram(3mm long, ∅=4mm)
2. Probe holder, allowing radial movement
3. Ceramic isolator introduced in a glass tube
4. Heat resistant-silicon isolated wire
5. Ceramic rings for thermal isolation of the wire
6. The cathode of the discharge
7. Thermocouple for measurement of the cathode's temperature
8. Grounded anode tube, this is basically the water-cooled wall of the reactor

Plasma Diagnostics in DCPN

Measurement results:



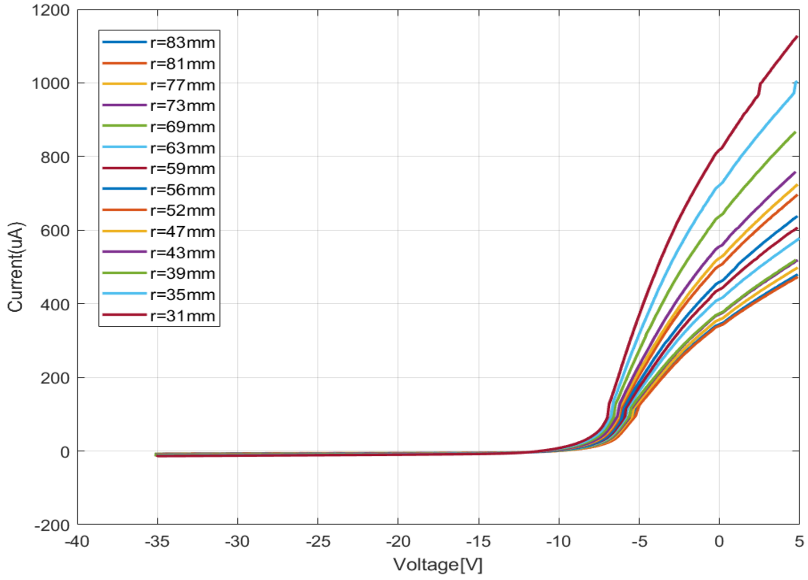
The voltage-current characteristic of the plasma measured with the Langmuir probe and the new power supply



The GUI of the measurement software

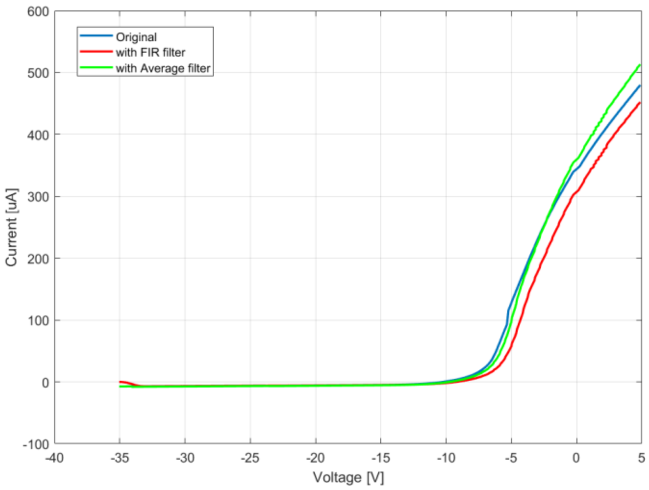
Plasma Diagnostics in DCPN

Measurement results:



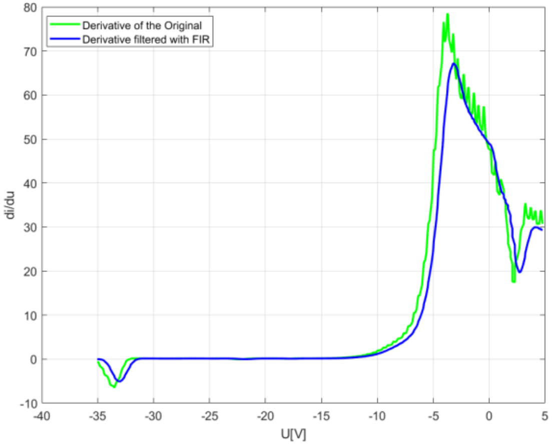
Set of U-I characteristics at 100°C cathode temperature and different probe distances from the cathode

Plasma Diagnostics in DCPN



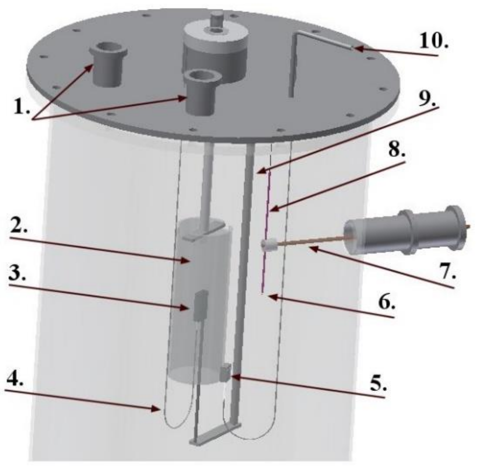
The filtered characteristic.

The derivative of the current versus the voltage and the filtered derivative



Plasma Diagnostics in HCAPN

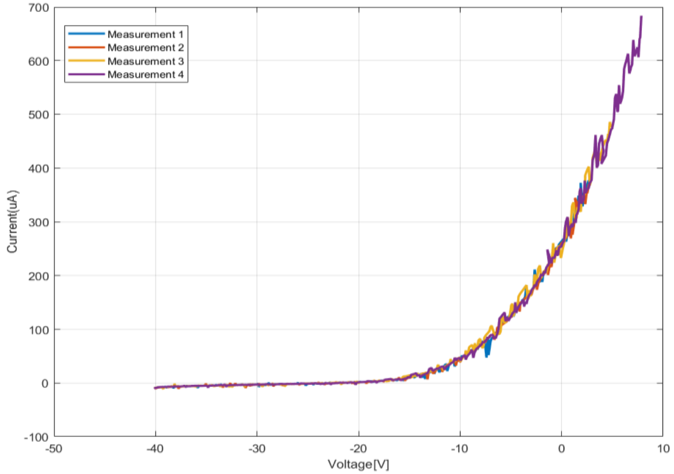
Experimental setup:



The Langmuir probe installed in the linear plasma reactor in DCPN setup

1. Cooling water inlet and outlet
2. Hollow cathode
3. Treated part, biased on anodic potential
4. Thermocouple connection for measurement of the part's temperature
5. Thermocouple holder for the hollow cathode temperature measurement
6. Langmuir probe
7. Probe holder
8. Ceramic isolator
9. Part holder
10. Gas inlet.

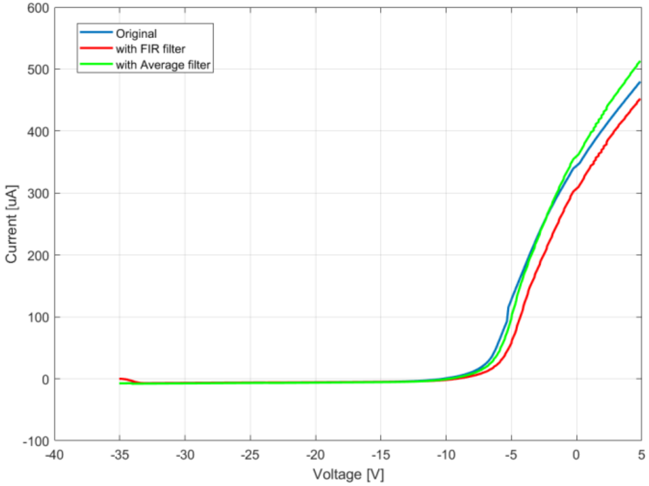
Plasma Diagnostics in HCAPN



Measurements inside the hollow cathode

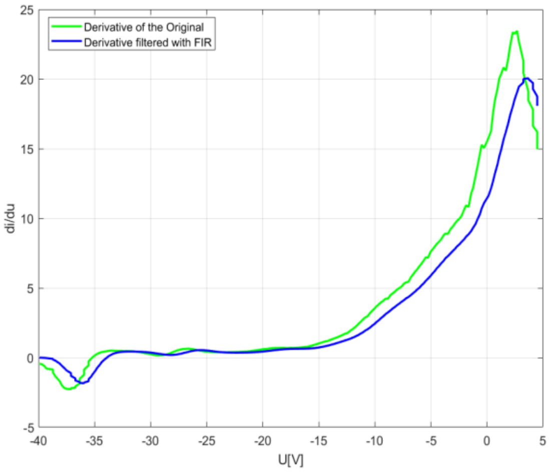
Picture about the real-time measurment

Plasma Diagnostics in HCAPN



The filtered characteristic.

The derivative of the current versus the voltage and the filtered derivative



Plasma Diagnostics DCPN, HCAPN

Conclusions:

- We succeeded to perform measurements inside and outside the hollow cathode in the HCAPN setup and we can compare the measurements with the DCPN results
- Most important achievement: successful redesigning of the automated local plasma diagnostics data collection system.
- Post processing of the measurement has been performed.

THANK YOU FOR THE ATTENTION

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