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PLASMA STERILIZATION STUDIES:

The plasma as the unique sterilization agent

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Presentation outline

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2. How can we produce plasma?
3. Important parameters on the plasma production
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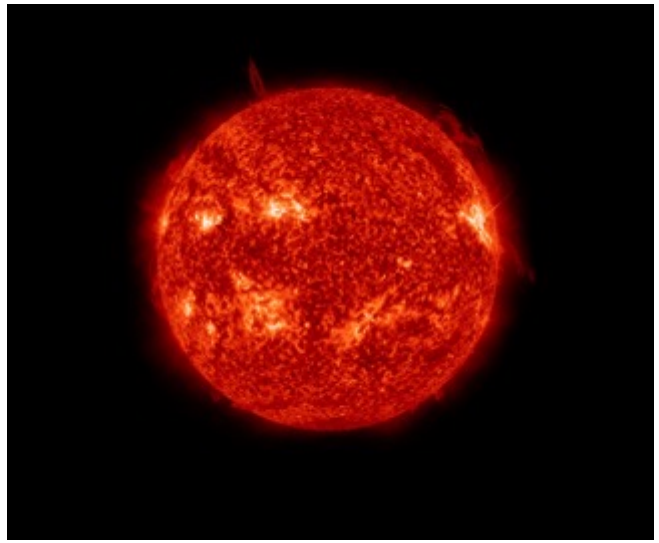
What is the plasma?

- A plasma is a quasineutral gas of charged and neutral particles (free electrons, atoms and molecules) which exhibits collective behavior.
- To be considered a plasma, the system must satisfy certain criteria.
- It is called “the fourth state of matter”;
- Most of the matter in the known universe exists as plasma (stars, interstellar space, shock waves from supernova explosions,…).



How can we produce plasma?

- The most common ways are:
  - ✓ Raising the temperature of a substance until a reasonably high fractional ionization is obtained;
  - ✓ Photoionization;
  - ✓ Electric discharges. ←

Important parameters on the plasma production

- Certain parameters have a direct influence on the charged particles' density, diversity and on the emission of radiation by the plasma:

Precursor gas(es)

Pressure of the gas:
(atmospheric pressure x low pressure discharges)

Power applied on the discharge

The biocidal capability of the plasma

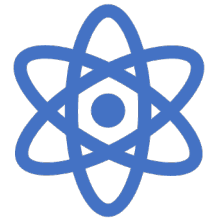
Ultraviolet radiation:

More predominant on low pressure plasmas.

High-pressure plasmas absorb most of the UV radiation produced.

Reactive species:

Especially oxygen-based compounds, like oxides, peroxides and hydroxyl radicals, as well as nitrogen reactive species like the NO_x.



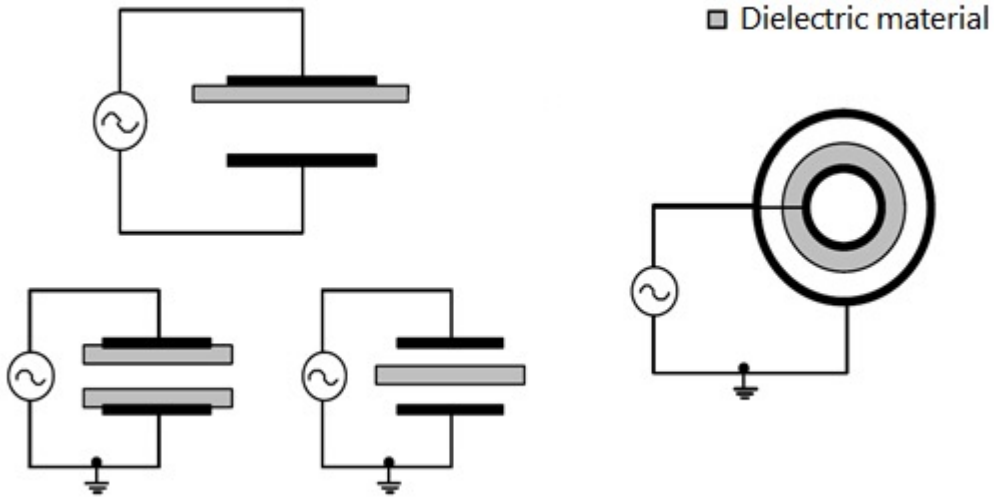
Interaction with charged particles:

Ion and electron bombardment of biofilms.

Cell's membrane electric disruption.

The dielectric barrier discharge (DBD)

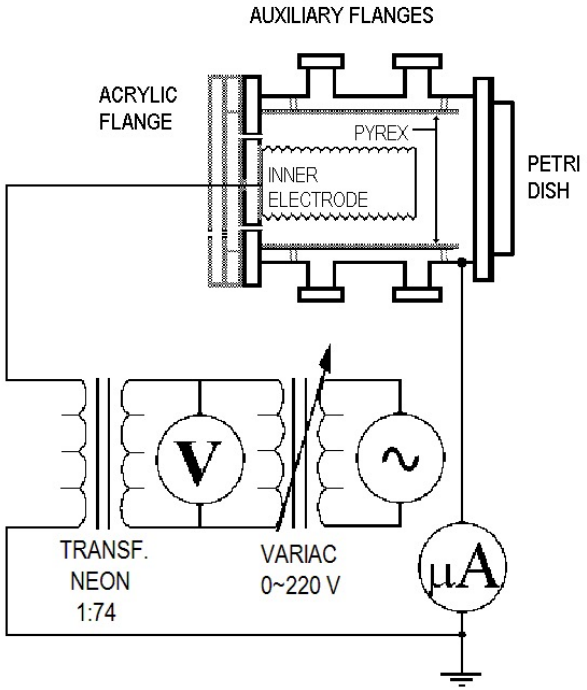
- The DBD occurs between two electrodes separated by one or more layers of a dielectric material and a precursor gas;
- Similar to the discharge produced between metal electrodes;
- One fundamental difference: the DBD needs an alternating electric field to work;
- Limited electric current, avoiding arc or spark discharge;
- The plasma remains “cold”;
- Depending on the plasma parameters and on the properties of the dielectric layers, we can produce various types of DBD, from filamentous to completely diffuse discharges.

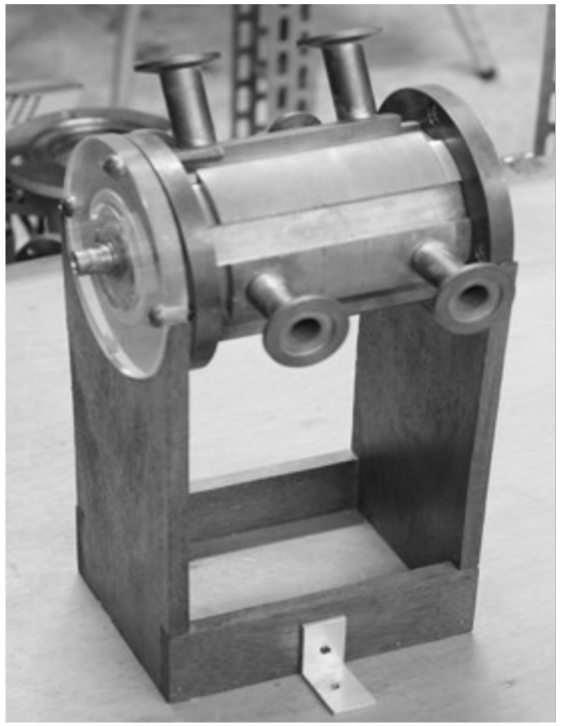


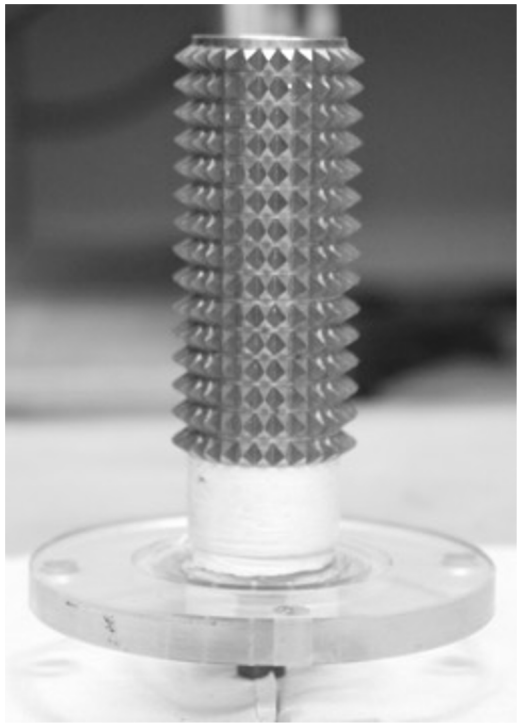
Our apparatus – the plasma source

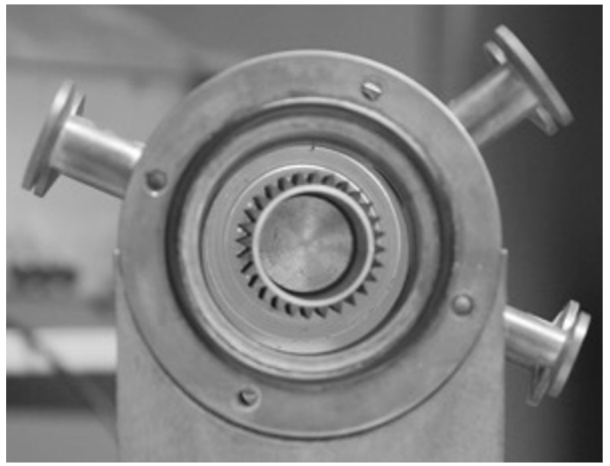
Single dielectric barrier discharge:

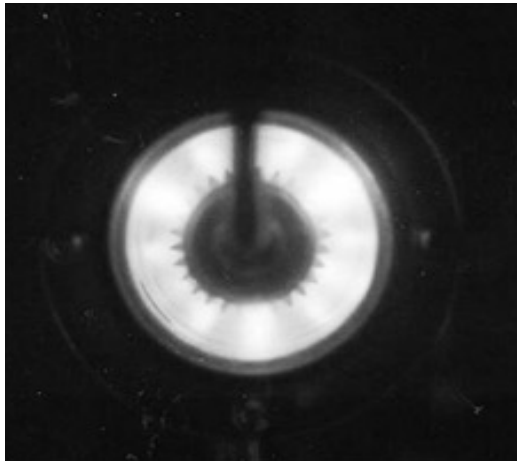
- Internal electrode: stainless steel spiky cylinder;
- External electrode: brass coated with Pyrex® glass, with windows for diagnostics;
- VARIAC voltage regulator;
- 1:74 Voltage transformer;
- HEPA air filters.









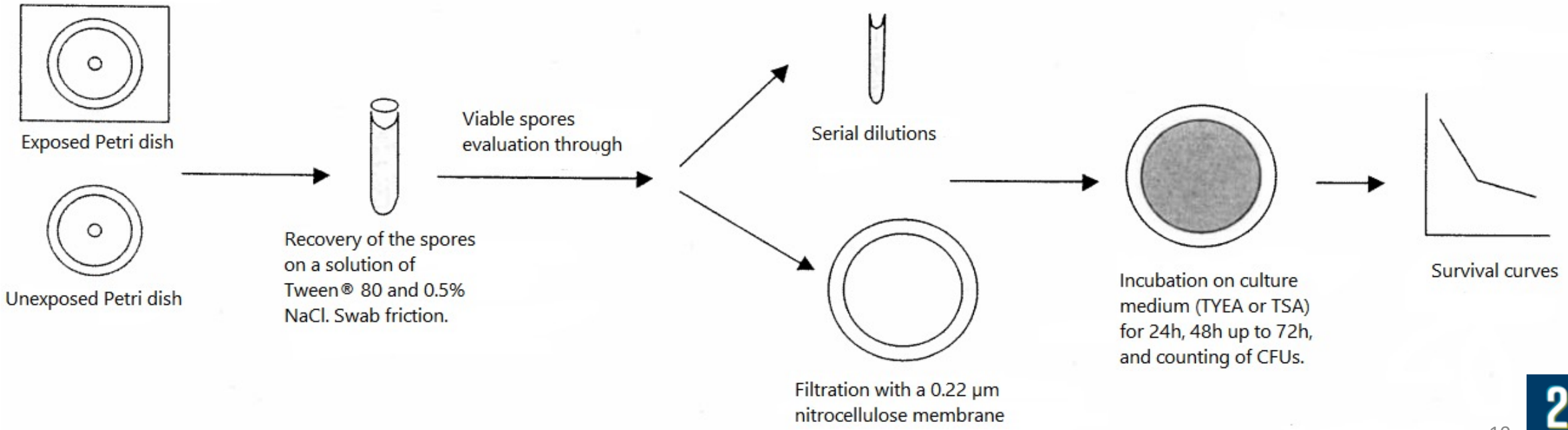


Characteristics of our plasma source

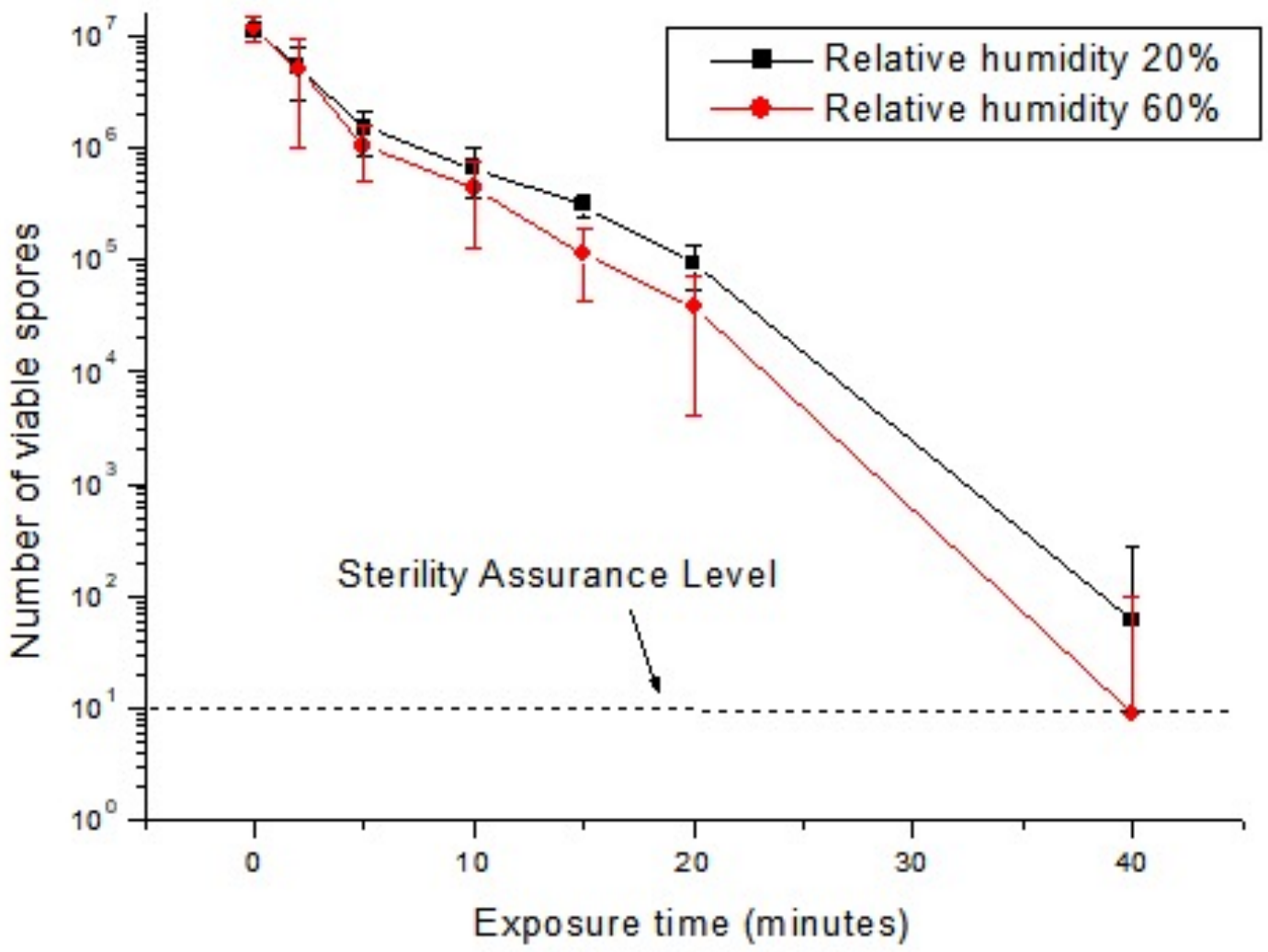
Discharge	Single Dielectric Barrier Discharge
Stability	Diffuse and temporally stable discharge
Power	Low power consumption: below 20W
Electric current	Low electric current: below 1mA
Heat exchange	The surrounding environment was enough for the heat exchanging
Macroscopic temperature	Below 50°C

The microbiological validation method

- Biological indicator: Petri dishes with at least 10^7 G. *stearothermophilus* spores (ATCC 12977);
- Exposures to the plasma for 2, 5, 10, 15, 20 and 40 minutes under 20% and 60% relative humidity (RH) of the air;
- Evaluation of the viable spores through the spread plate technique (5 Petri dishes for each exposure time and RH) and counting in triplicata.

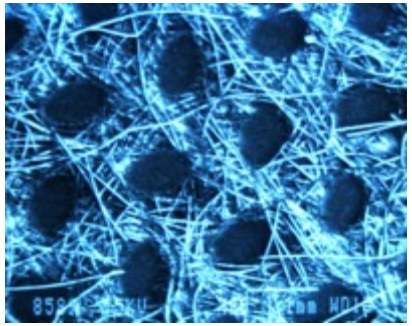


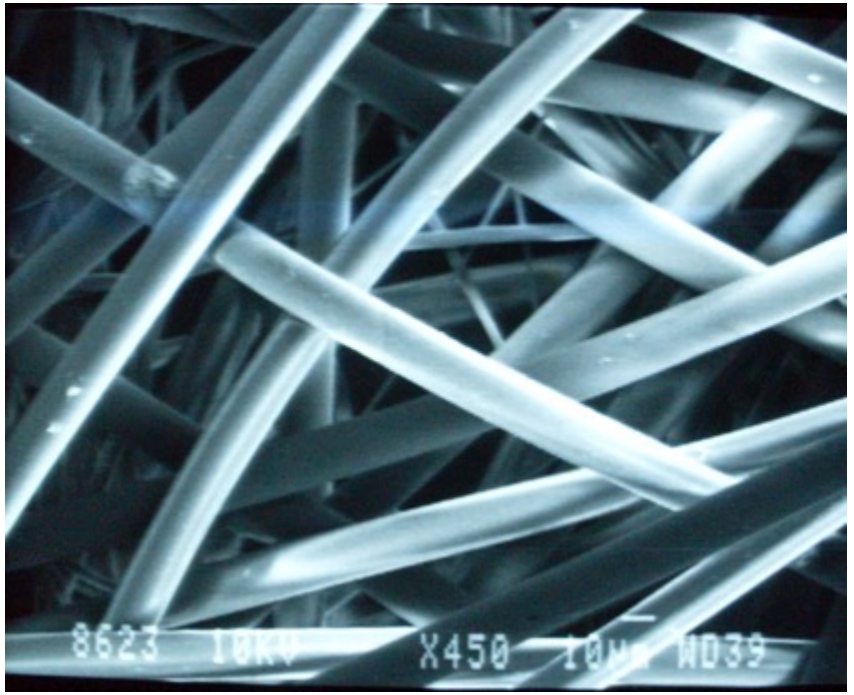
Number of viable spores after the plasma exposure

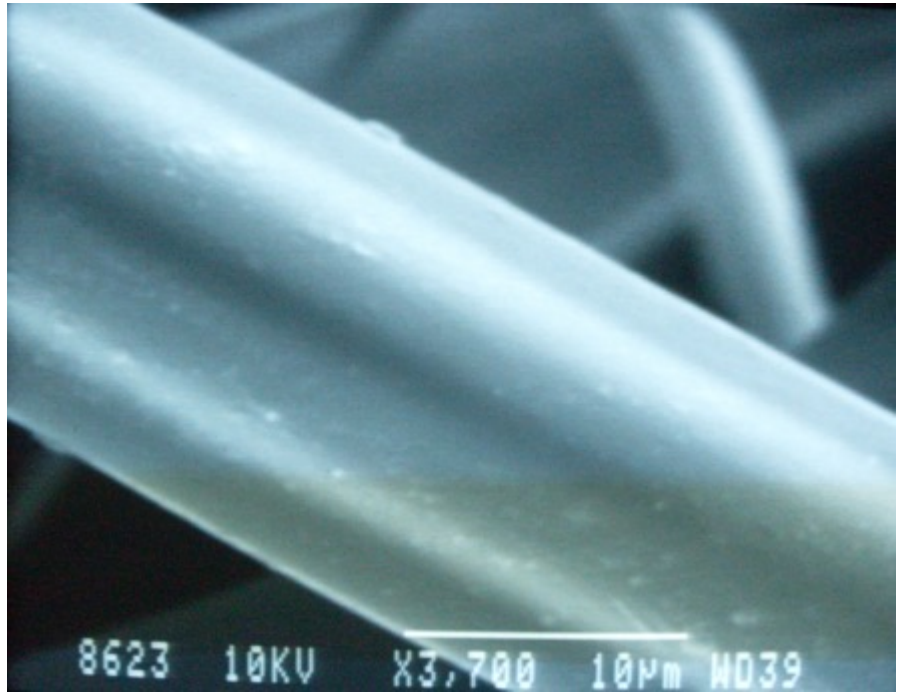


Preliminary results on packaging material compatibility

- Non-woven fabric fixed on petri dishes;
- Exposure to the plasma for 40 minutes;
- Analysis on scanning electron microscopy.







Conclusions

- We successfully developed a low-temperature plasma source for sterilization studies, where the plasma is the only sterilization agent.
- We eliminated 10^7 CFU of *G. stearothermophilus* after 40 minutes of exposure.
- We associated this result to the positioning of the biological samples in our device and the low power of our system.
- We did not find a relevant contribution of the UV radiation to the biocidal process.
- We observed an important influence of the relative humidity of our precursor gas on the microbicidal capability of the plasma, which we associated to the changes in the concentration of reactive species produced from dissociation of the water molecule in plasma, like the hydroxyl and other oxides, which raised the biocidal capability of the plasma.
- We did not identify relevant changes on the structure of the non-woven fabrics exposed to our discharge, probably due to the positioning of the samples in our device and to the low power of our system.

Future perspectives

- Ongoing experiment;
- Plasma diagnostics to quantify the sterilization agents;
- Optimization of the plasma parameters;
- Compatibility with materials and equipment: evaluation of functionality;
- Scale up the experiment;
- Cost-effectiveness studies.

Acknowledgements

UnB

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The end

Obrigado!

Merci!

Thank you!

¡Gracias!

Danke!

Grazie!