RUHR-UNIVERSITÄT BOCHUM

The role of humidity and UV-C emission in the inactivation of *B. subtilis* spores during atmospheric-pressure DBD treatment

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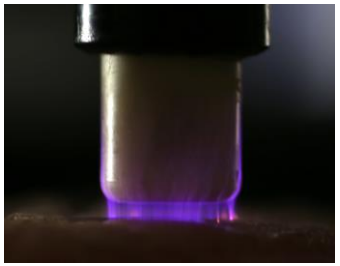
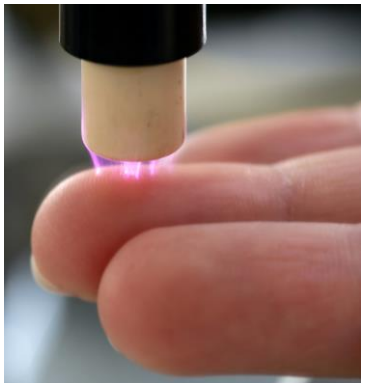
Plasma Medicine

- Plasma medicine: application of plasma devices for therapeutical usage

- Possible applications:
  - Supplement to standard wound care
  - Therapy of skin diseases (psoriasis, acne, etc.)
  - Coagulation of tissue
  - Resection of tissue (tumores, etc.)





- Focus of research: study of the impact of plasma on biological cells and tissue

  → Does plasma medicine offer an alternative to conventional medicine?

Plasma vs. Conventional Medicine?

[1]

Effects induced by treatment with non-thermal atmospheric-pressure plasmas:

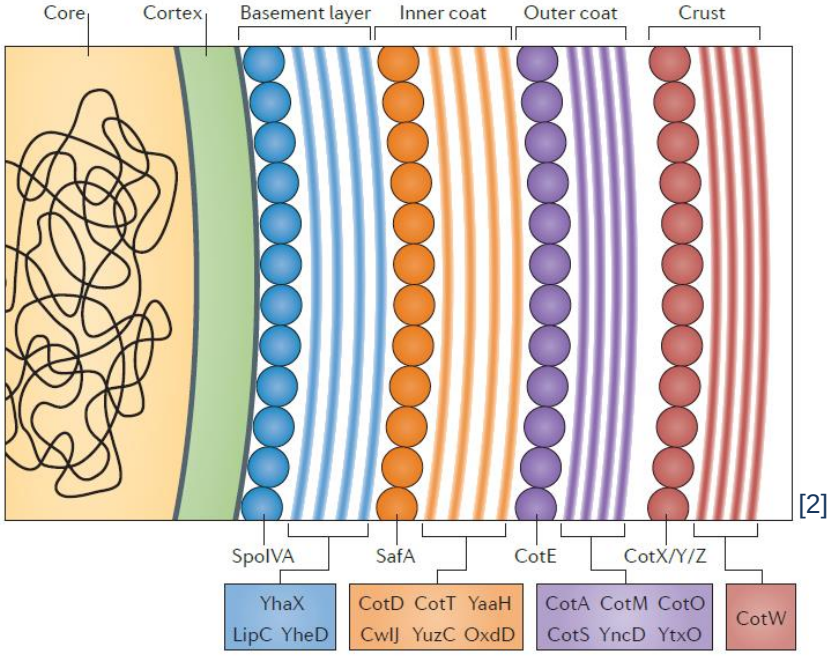
- Reduction in number of microorganisms in human wounds
- Reduction in wound size
- Enhanced proliferation

Meta-analysis of Assadian *et al.* claims:

- “Use of AP in wound care is safe, but the retrieved evidence and meta-analysis show that there is no clinical benefit of AP in chronic open wounds using currently available AP device settings.“

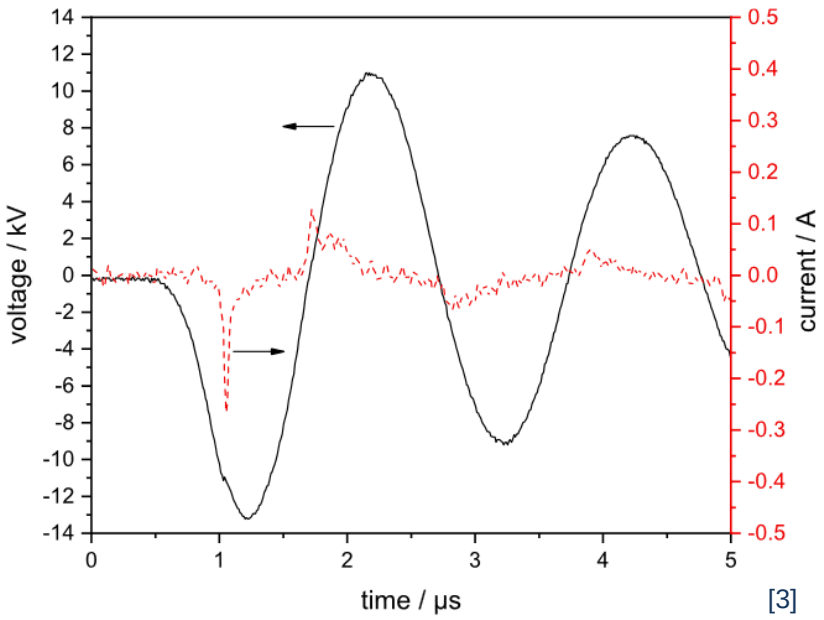
Bacterial Spores

- Spores are formed in times of nutrient depletion
- Dormant, long-living form to preserve the genetic information of the cell
- Spore coat gives protection to reactive species, predators and UV-radiation
- *B. subtilis* as a common used bioindicator for sterility due to high resistance to outer stressors



[2]

Experimental Setup



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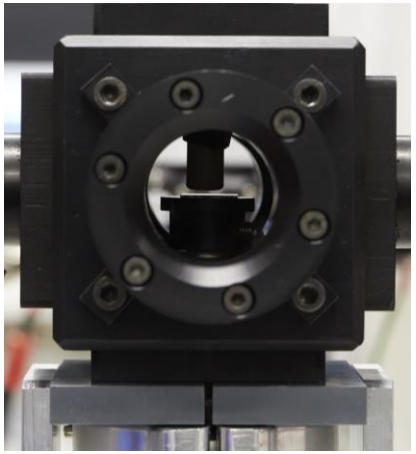


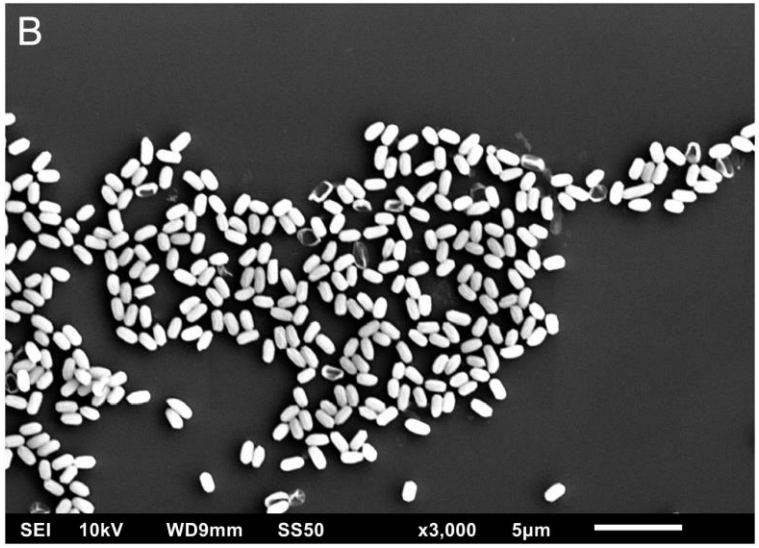
Treatment conditions:

- f = 1000 Hz, V_{pp} = 24 kV_{pp}
- Process gas:
  - Ambient air
  - N_2/O_2 mixtures
  - Synthetic air with relative humidity
- Counter electrode: glass slide with sprayed spores on grounded aluminum plate

Plasma Treatment

Sample Preparation

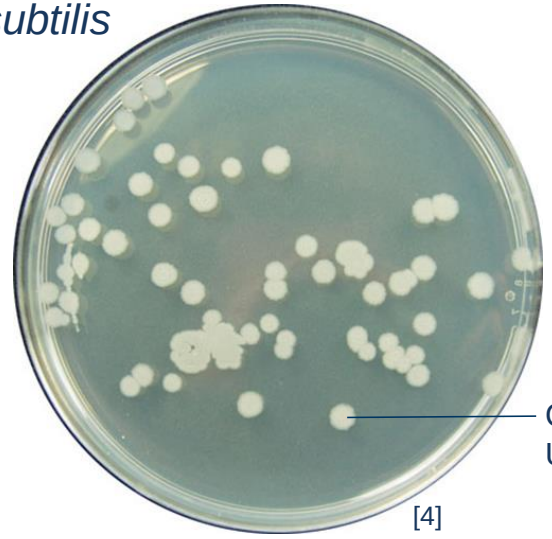
- *B. subtilis* wild type PY79



- Sprayed in a monolayer on glass slides to avoid shielding

Evaluation

- Cultivated on Agar plates – outgrowth of *B. subtilis*



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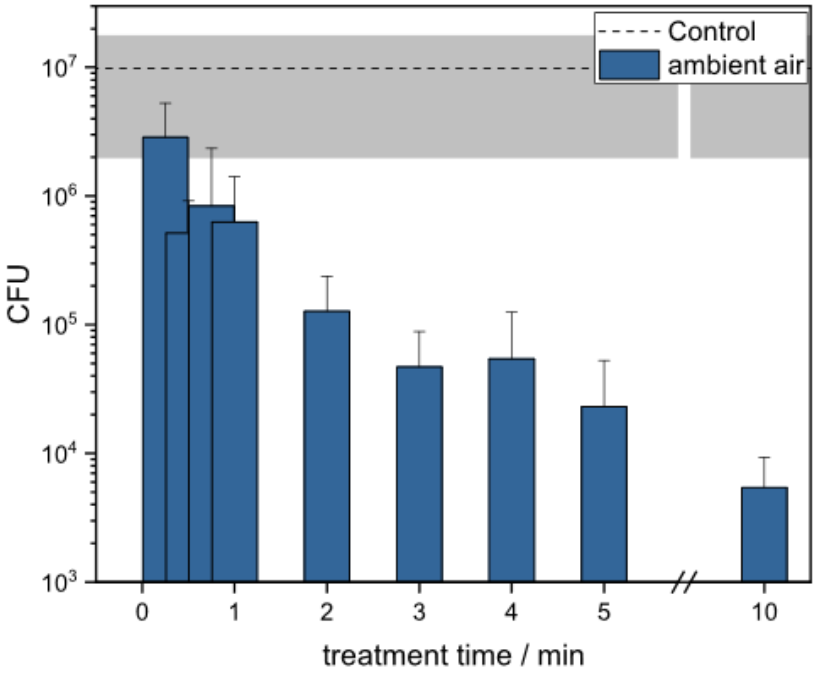
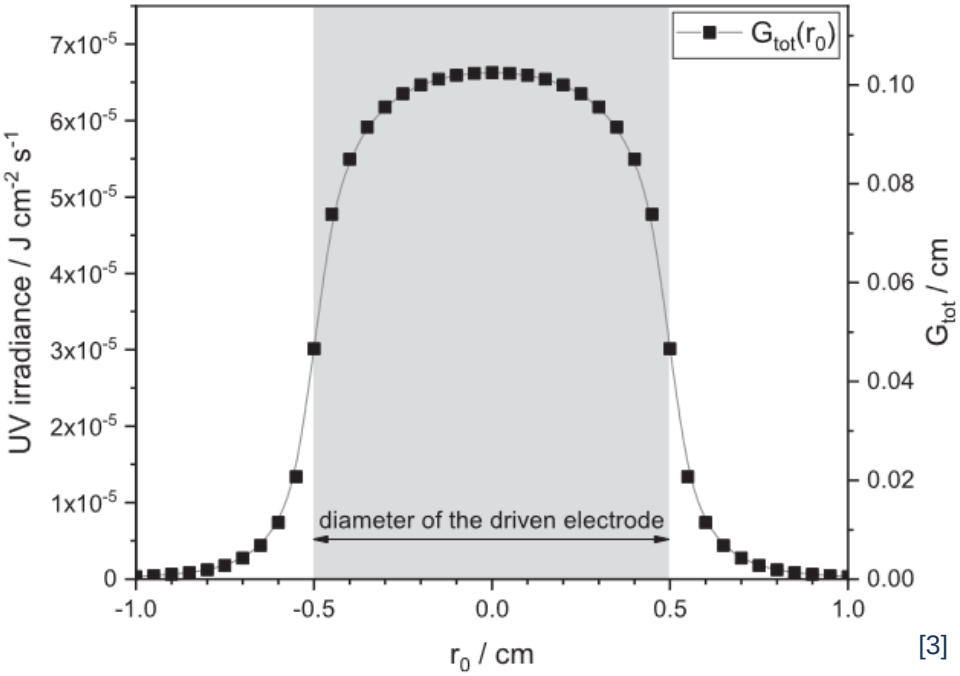
- Number of colonies represents number of surviving spores

Inactivation of spores in ambient air

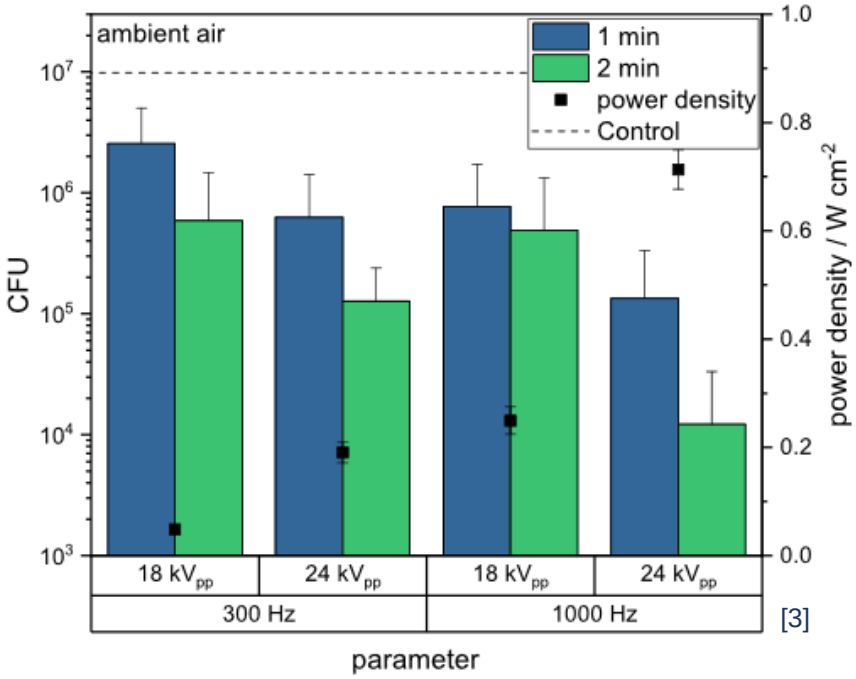




[3]

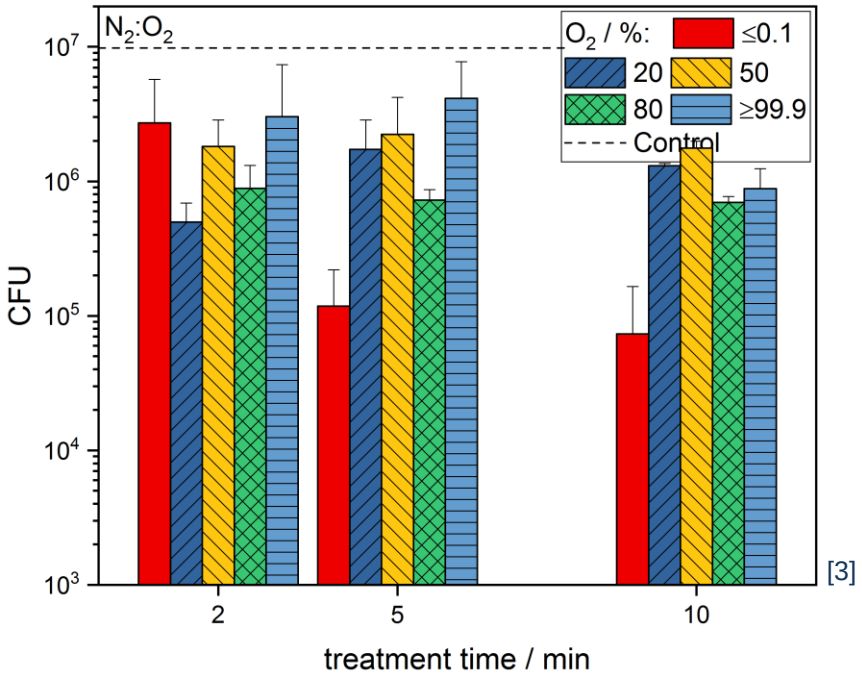
- Within 3 min: number of surviving spores reduced by two orders of magnitude
- Decrease in inactivation for longer treatment times due to spatial profile

Inactivation of spores in ambient air



- Reduction of CFU correlates with power density

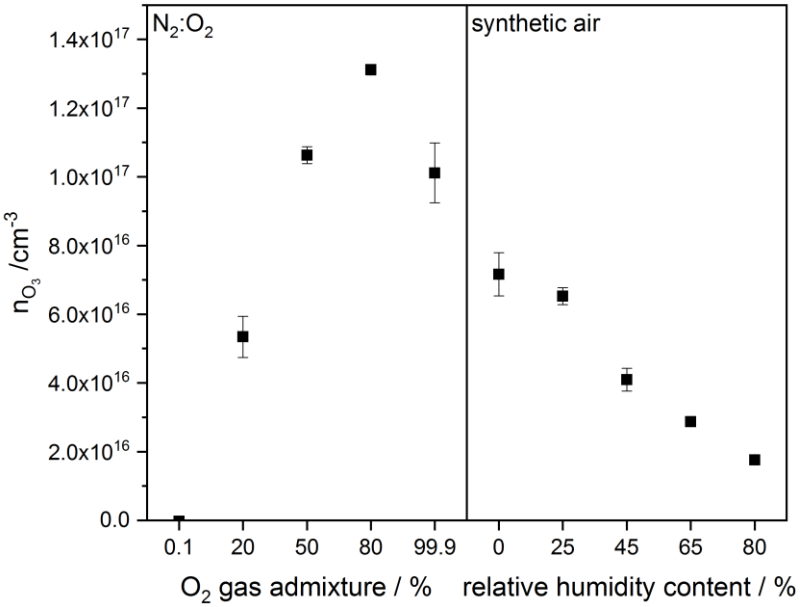
Inactivation of spores in N_2/O_2 atmosphere

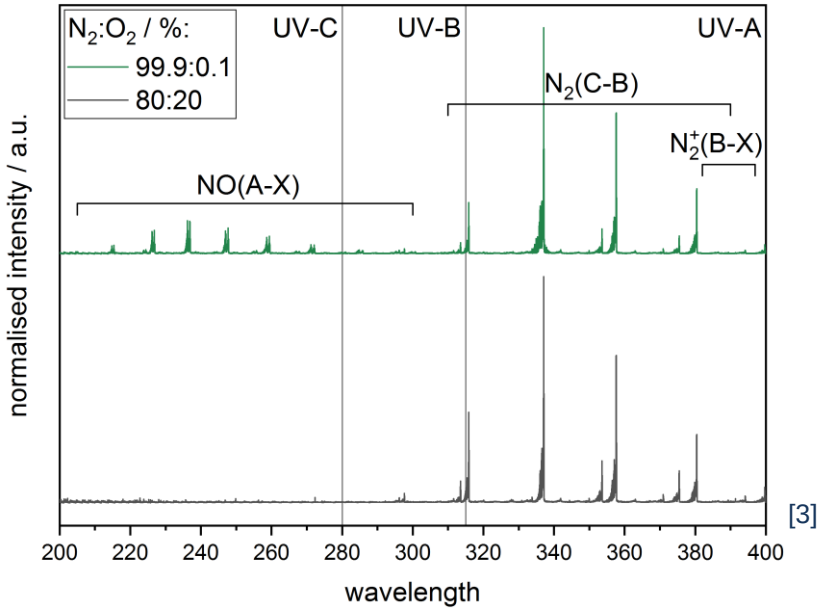


[3]

- Controlled changes in the plasma chemistry
- Strong inactivation in an atmosphere of N_2 with oxygen residuals (≤0.1%)

O_3 density and UV emission in controlled N_2/O_2 atmosphere

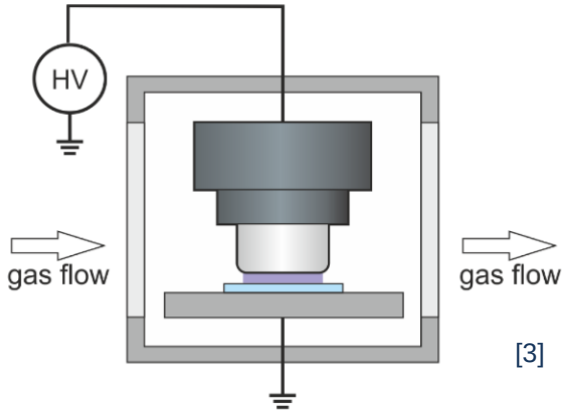




[3]

- Ozone, O_3: powerful oxidant
- UV emission: potentially damaging for cells (DNA-damages) due to high energies

Is it all about the flux profile?



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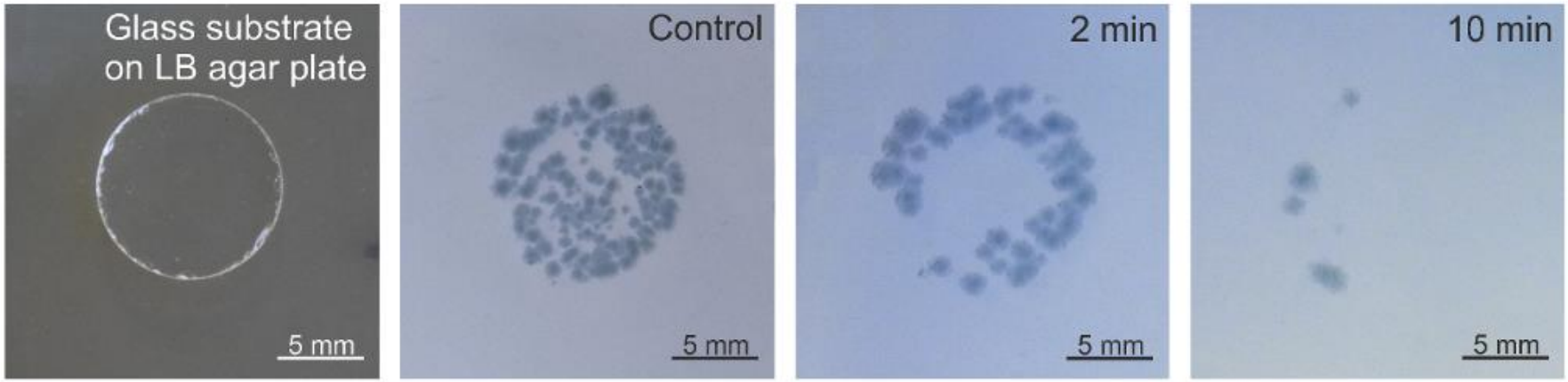
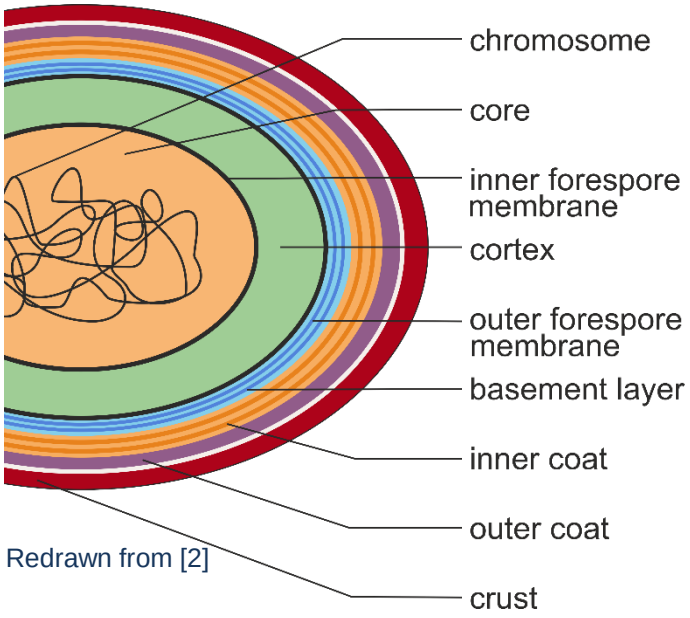


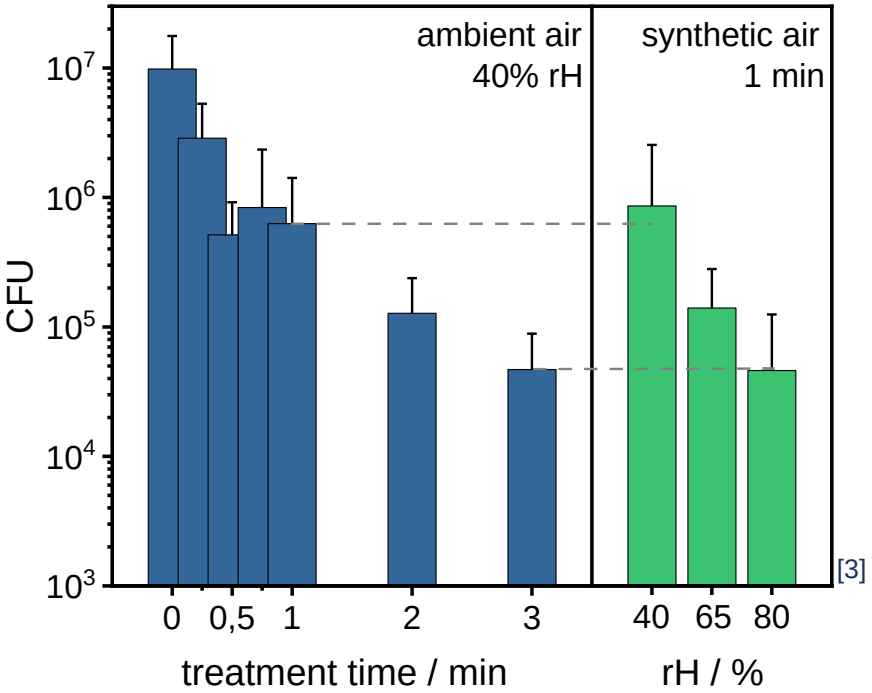
[3]

- Increase of the area of inactivated spores in the centre of the discharge
- Influence of the flux profile clearly visible

Inactivation of spores in controlled humidity content



Redrawn from [2]



[3]

- Strong impact of relative humidity
- Within 1 min: number of surviving spores reduced by two orders of magnitude

Possible inactivation mechanism

- DBD vs. spores: reduction achieved!

- No positive correlation between spore inactivation and UV-A or UV-B emission
- No positive correlation between spore inactivation and ozone
- UV-C irradiance due to NO emission might play a role
- An increase in humidity leads to less surviving spores
- Reactive water-related species, such as OH or H_2O_2 might lead to inactivation of spores
- Gas-phase acids, such as HNO_2, HNO_3 or HNO_4 might have an influence

Thank you for your attention!

Bibliography

[1] F. Brehmer *et al*., Journal of the European Academy of Dermatology and Venereology 29.1, 148-155. 2015

[2] P. T. McKenney *et al*., Nature Reviews Microbiology, 11.1, 33, 2013

[3] F. Kogelheide *et al*., Journal of Physics D: Applied Physics, 53(29), 295201, 2020

[4] PP0282 – Tryptone Soya Agar. [Online]. Available: http://www.eolabs.com/product/pp0282-tryptone-soya-agar-irradiated/