Interdisziplinäre Forschung und Forschungsdaten in der Plasmatechnologie

Vortragende: Sybille Hasse

Leibniz Institute for Plasma Science and Technology (INP Greifswald), Germany

VON DER IDEE ZUM PROTOTYP

Our Organization

LEIBNIZ-INSTITUT FÜR PLASMAFORSCHUNG UND TECHNOLOGIE E.V.

INP FROM IDEA TO PROTOTYPE

Rostock | Greifswald | Karlsburg

Mitgliederversammlung
Vorsitzender: Dr. Blank

Wissenschaftlicher Beirat
Vorsitzender: Dr. Kaltenborn

Kuratorium
Vorsitzender: Herr Venohr

Vorstand
Vorstandsvorsitzender und Wissenschaftlicher Direktor: Prof. Weltmann & Kaufmännischer Direktor: Herr Berger
Wissenschaftliches Vorstandsmitglied: Prof. Uhrlandt & Vorstandsmitglied: Frau Dahlhaus

Forschungsbereiche und Forschungsschwerpunkte

Materialien & Energie
Prof. Uhrlandt

Umwelt & Gesundheit
Prof. Weltmann

Materialien/Ober… (MOF)
Dr. Foest

…ntamination (DKO)
…rof. Kolb

Strategische Ausrichtung, Themenfindung, Projektanträge….

Wissenschaftliche Abteilungen

Plasmabiotechnik (PT)
Dr. Ehlbeck

…trahlungstechnik (PST)
…Gortschakow

Mitarbeitende nach Expertise, Projektbearbeitung….

Nachwuchsforschergruppen

Biosensorische Oberflächen (BSO) Dr. Fricke	Plasma-Flüssigkeits-Effekte (PFE) Dr. Wende	Plasma-Redox-Effekte (PRE) Dr. Bekeschus

Forschergruppen

Plasmaquellen-Konzepte (PQK) Dr. Gerling	Plasmawundheilung (PWH) Dr. Masur

Administrative und unterstützende Abteilungen

Stab
Dr. Sawade

Verwaltung & Infrastruktur
Herr Berger

Forschungsbereich
Plasmen für Materialien & Energie

Plasmaforschung für energieeffiziente(re), ressourcenschonende und intelligente Technologien in der Produktions- und Energietechnik

- **Erneuerbare Energien und Plasmagestützte Oberflächentechnologien**
  - Materialien für Brennstoffzellen, Solare Energieerzeugung, Funktionale Schichten, Optische Technologien
- **Energieeffiziente Prozesse**
  - Lichtbogenschweißen, Schaltlichtbögen, Lichtquellen
- **Plasmaprozessdiagnostik und –monitoring**
  - Plasmachemische Prozesse, Spurengasanalytik

Forschungsbereich
Plasmen für Umwelt & Gesundheit

Forschungsbereich Umwelt & Gesundheit

Grundlagen zur Anwendung von Plasmen im Bereich der Umwelt und Gesundheit

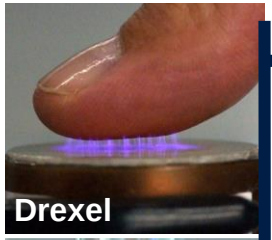
- **Biomaterialien und Oberflächen**
  - Implantate, therapeutische Geräte, Einwegartikel
- **Plasmamedizin**
  - Wundheilung, Hauterkrankungen, Zahnmedizin
- **Dekontamination**
  - Plasmen und Flüssigkeiten, Lebensmittelhygiene und –verarbeitung, Abluft

Was ist Plasma?

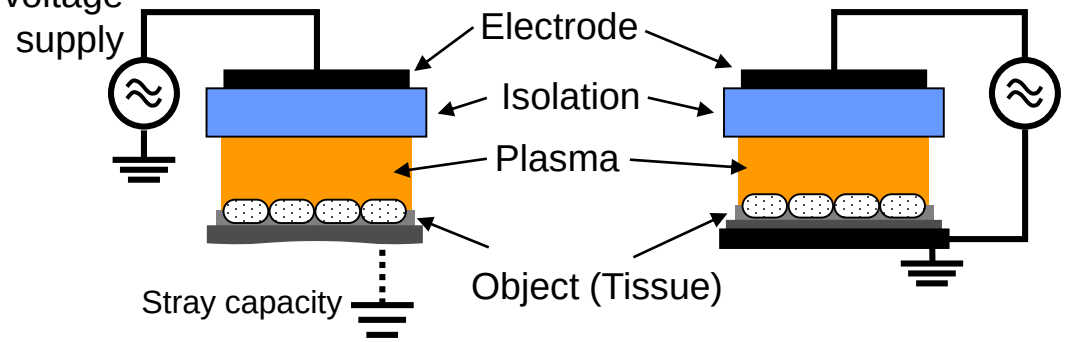
fest flüssig gasförmig Plasma

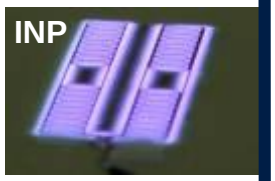
99 % der sichtbaren Materie bestehen aus Plasma – höchste Zeit, es zu nutzen

Plasmaquellen

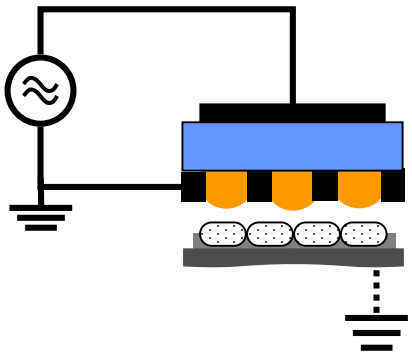


Volume Barrier Discharge

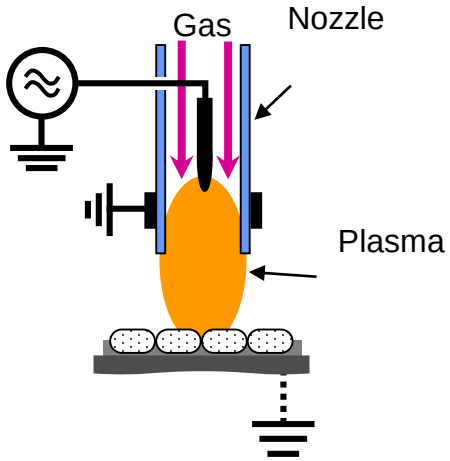


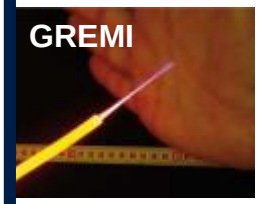


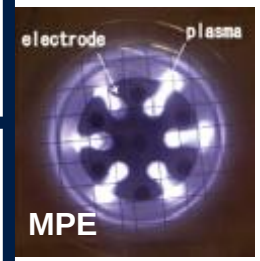
Surface Discharge



Plasma jet



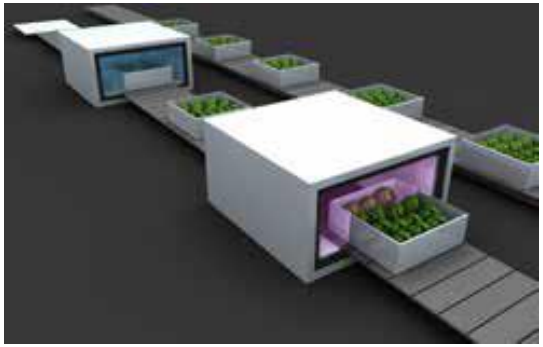




K.-D. Weltmann, E. Kindel, Th. von Woedtke, M. Hähnel, M. Stieber, R. Brandenburg, Pure Appl. Chem. 82 (2010) 1223-1237

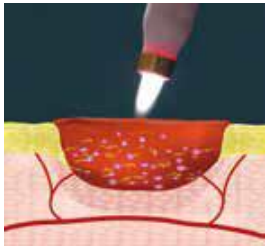
Plasma for biomedizinische Anwendungen

Biological Decontamination	Surface modification	Therapeutic applications



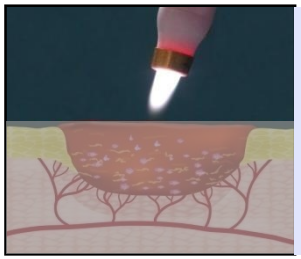
food
- fresh produce
- dry goods (nuts, corn)

Implants
- Prothesis (joints, dental implants)
- Sinews and ligaments
- Vascular grafts
- Stents
- Heart valves



Plasma medicine

From basic research to clinical proof

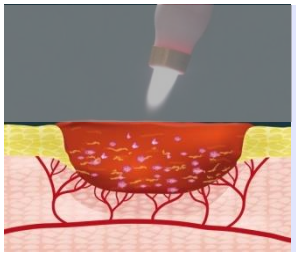


Plasma sources

- Development
- Adaptation
- Diagnostics
- Optimization, control, monitoring
- Experimental applications

in vitro

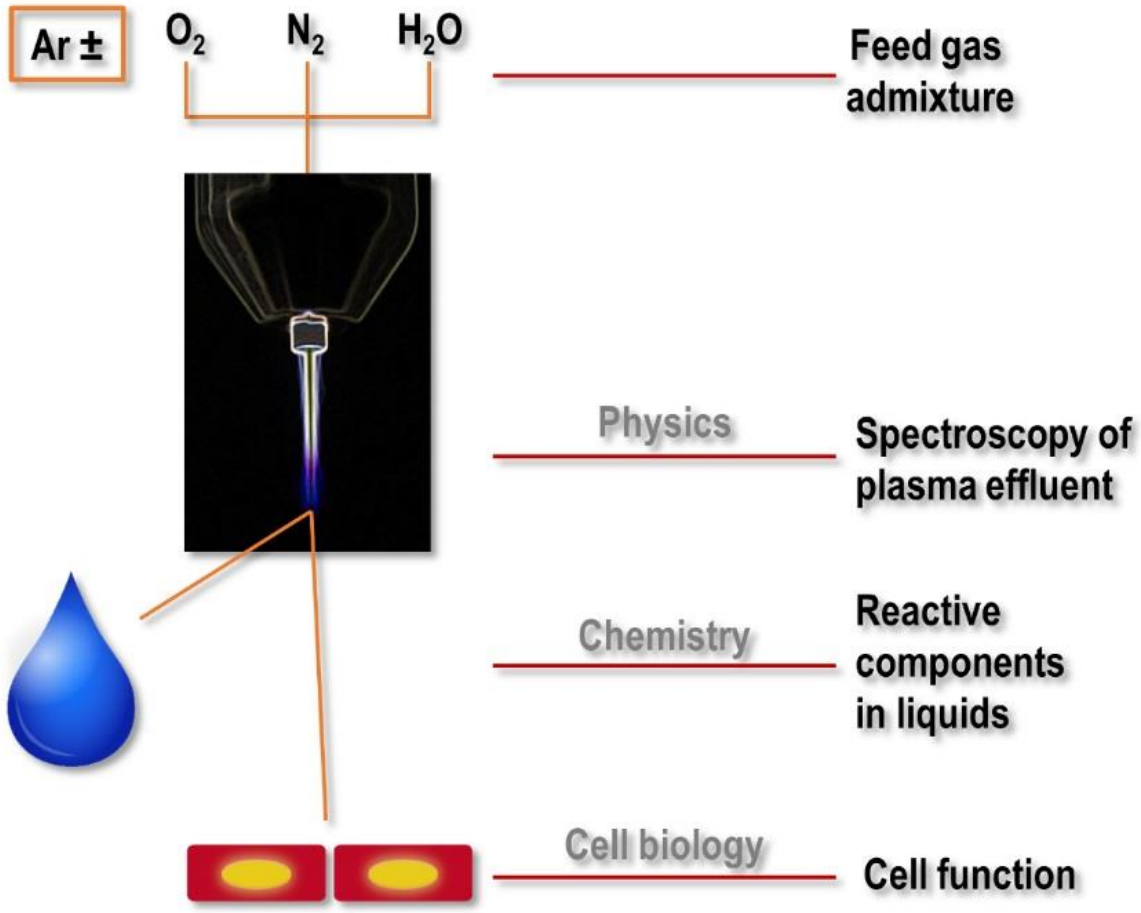
in vivo



Biological effects

- Physiological liquids
- Cells:
  - microorganisms
  - mammalian cells
- Cell and tissue cultures:
  - not contaminated
  - contaminated/infected
- Isolated tissues/organs
- Organisms:
  - animal experiments
  - clinical investigations

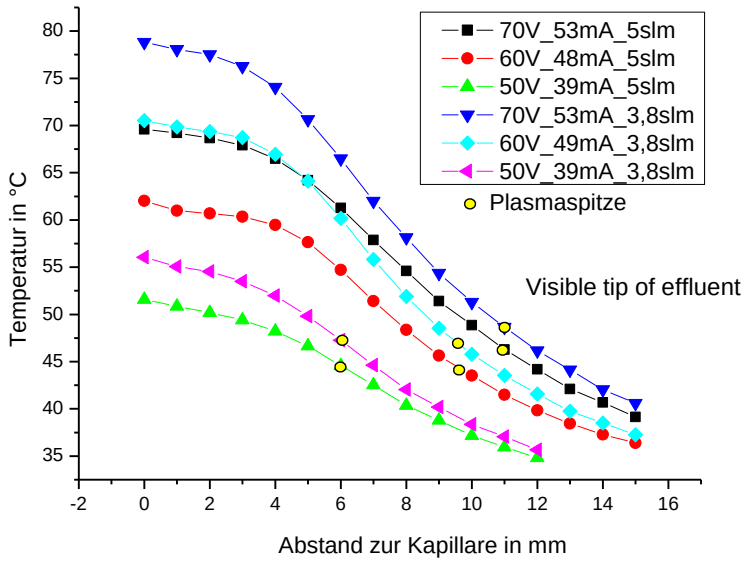
Therapeutic Applications

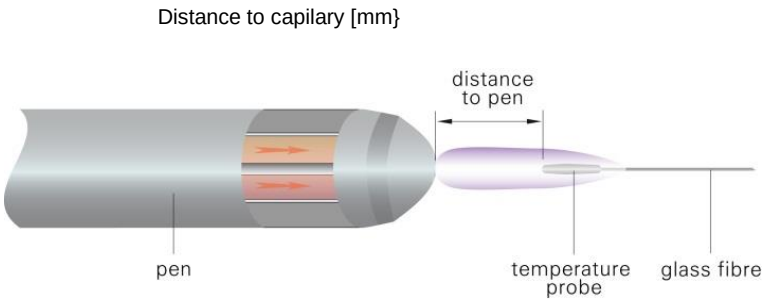


Bekeschus, S., Schmidt, A., Niessner, F., Gerling, T., Weltmann, K. D., Wende, K. Basic Research in Plasma Medicine - A Throughput Approach from Liquids to Cells. *J. Vis. Exp.* (129), e56331, doi:10.3791/56331 (2017).

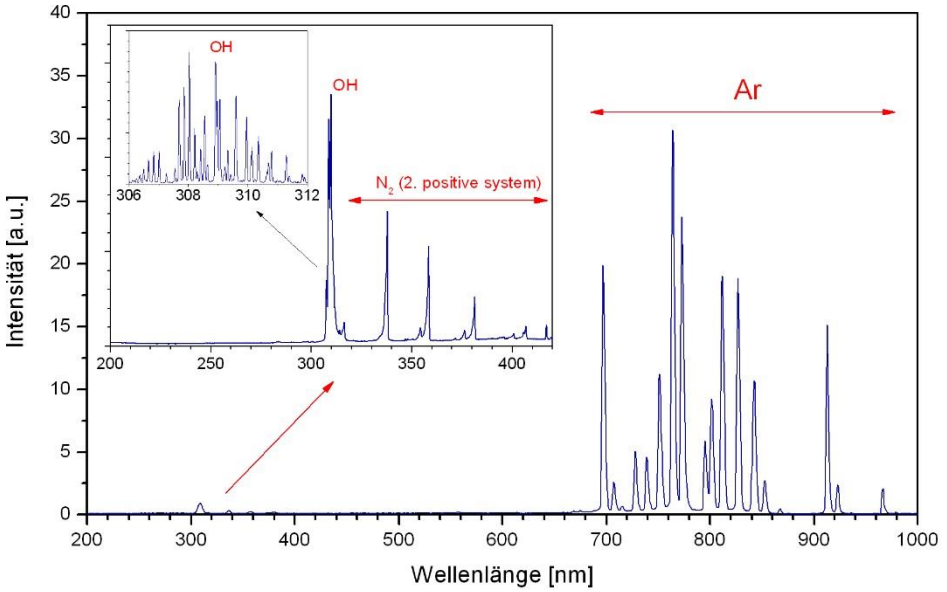
Physics – i.e. spectroscopy of plasma effluent

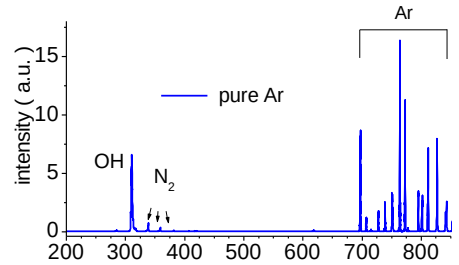
Temperature

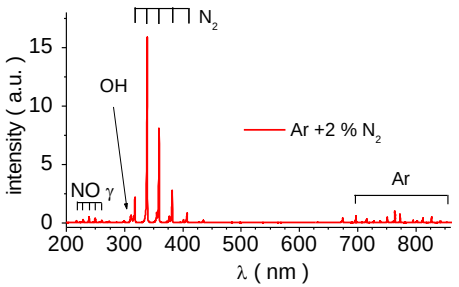




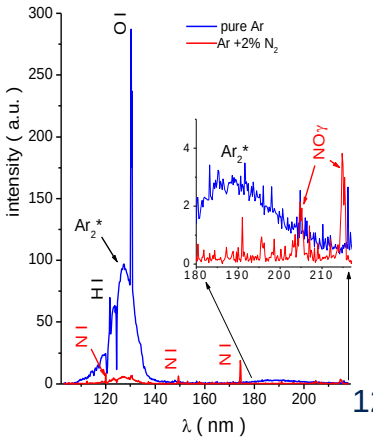
Optical Emission Spectroscopy







(V)UV radiation



K.-D. Weltmann, E. Kindel, R. Brandenburg, C. Meyer, R. Bussiahn, C. Wilke, Th. v. Woedtke, Contrib. Plasma Phys. 49 (2009) 631–640

Physics Performances

- **Gasous formation: ozone**

Odour threshold: 40 µg/m³ or **0.02 ppm**

According to EU directives (2002/3/EG), there is no health risk at concentrations <110 µg/m³ or < 0.055 ppm

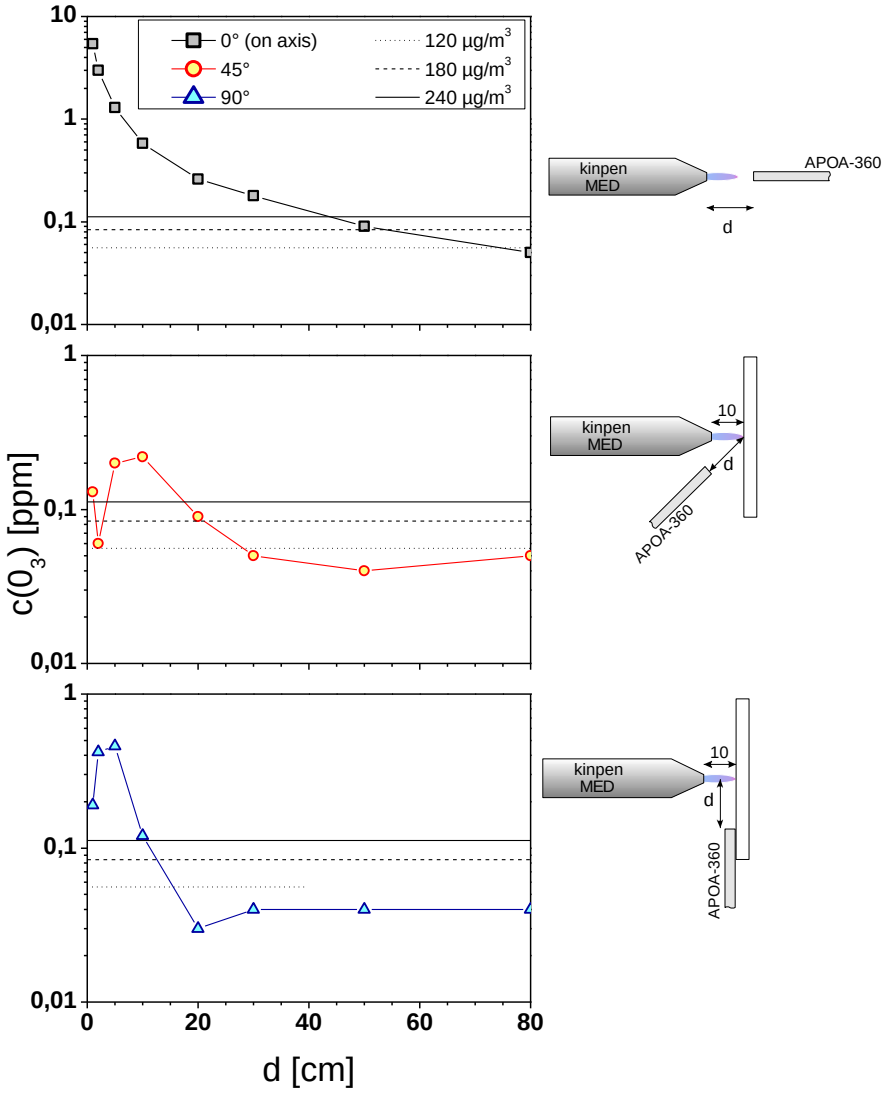
Concentrations 2-10 mg/m³ or 1-5 ppm: even after short exposure times - acute health irritations

Ozone formation under atmospheric conditions:

$e + O_2 \rightarrow O + O + e$

$O + O_2 + M \rightarrow \mathbf{O_3} + M$

[M – third diluent (N_2 or O_2)]



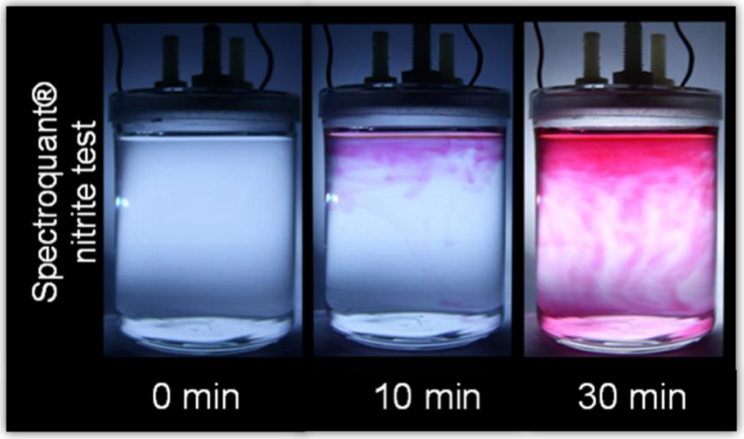
R. Bussiahn, N. Lembke, R. Gesche, Th. von Woedtke, K.-D. Weltmann, Hyg. Med. 38 (2013) 212-216

Chemistry – reactive compounds in liquids

- **chemical composition of plasma-treated liquid**
  - *Photometric assays or ion chromatography*

detection of:

NO_2^-: according to	DIN EN 26777
NO_3^-: according to	DIN 38405-9
H_2O_2: according to	DIN 38409-15
pH: according to	DIN EN ISO 10523

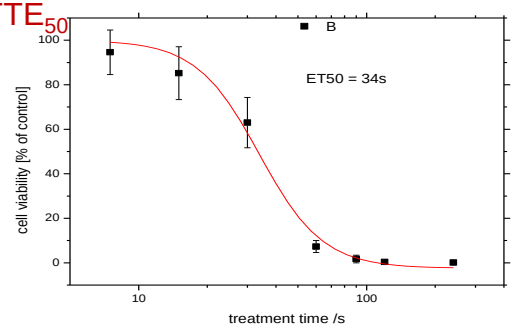


Oehmigen *et al*., 2011 (modified)

→ stable parameters representative for complex reaction chains
→ main reactive processes in plasma-liquid interaction

Cell biology - Plasmawirkung auf Zellvitalität

Calculation of treatment time equivalents TTE_{50}



3500 cells/well for proliferation
>24h pre-incubation in 96 well plates

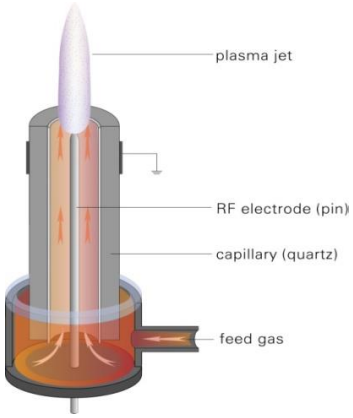
Cell incubation, seeding

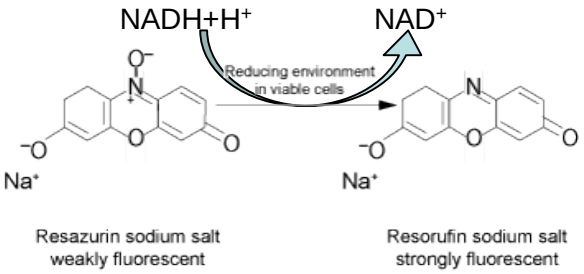
Stimulation (plasma, controls)

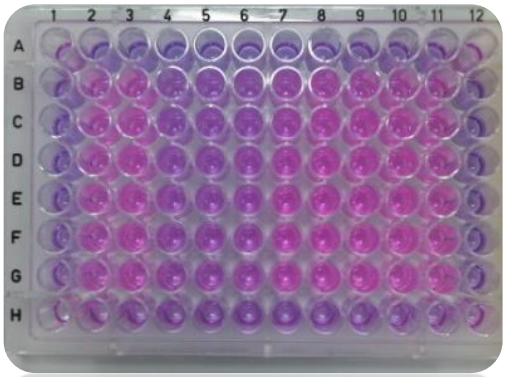
Incubation

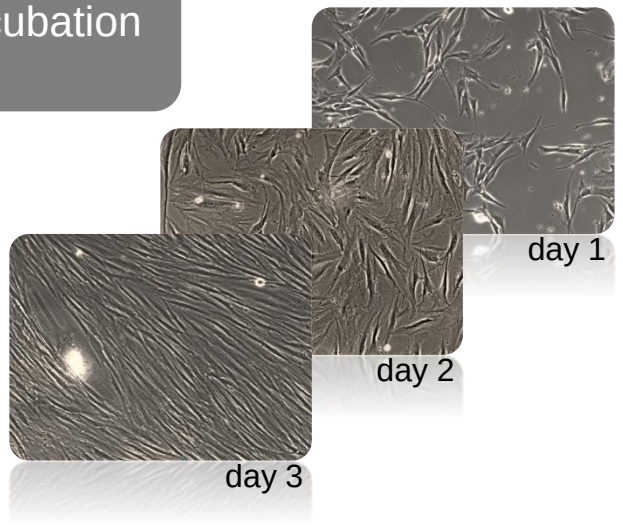
Staining, readout

erpretion, planning

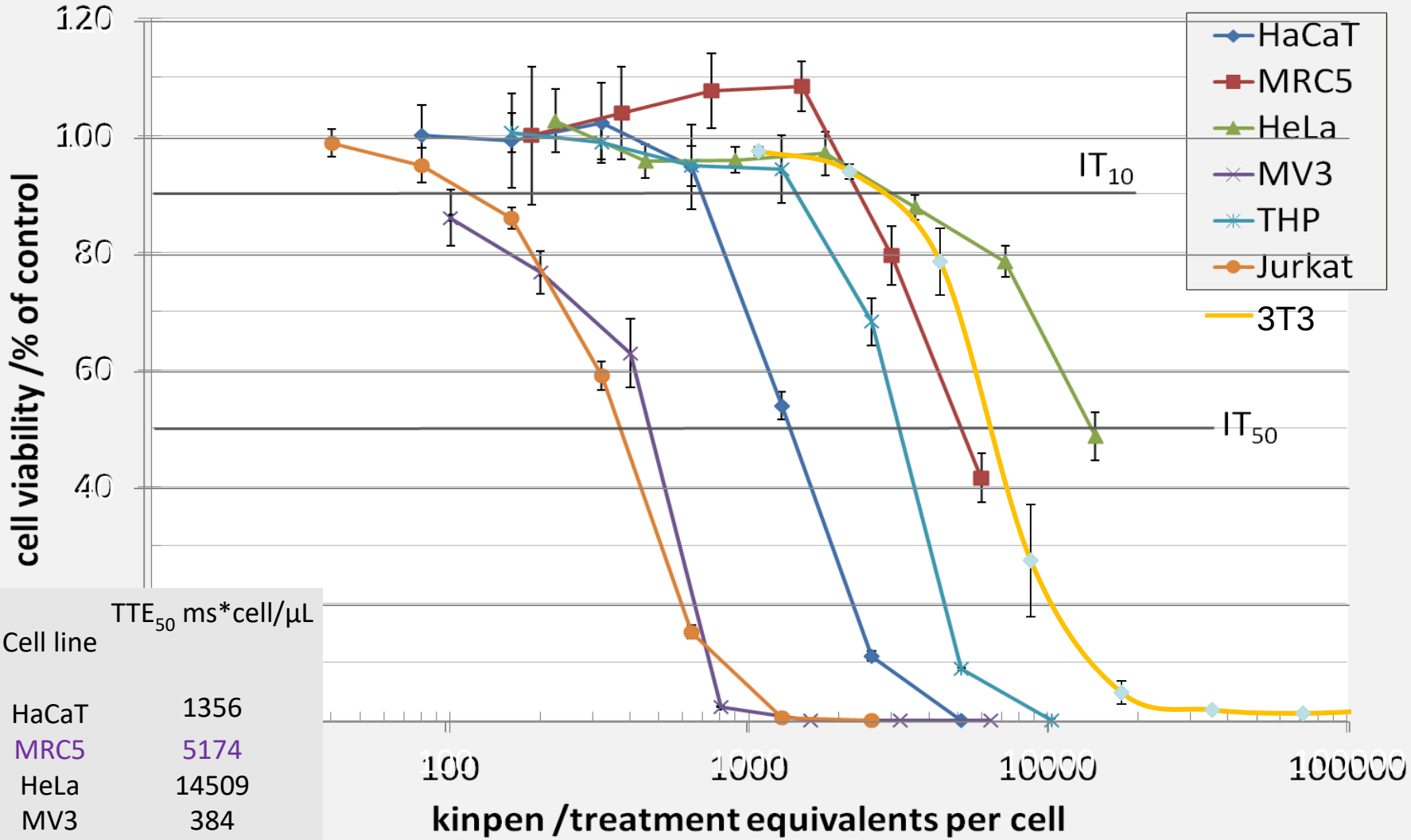






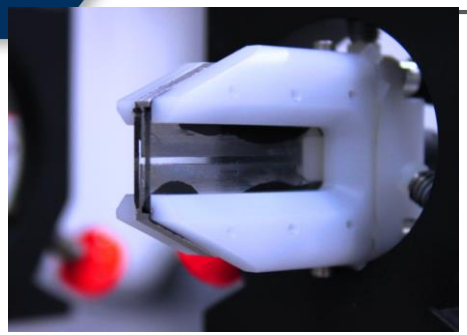


Cell biology - Vergleich verschiedener Zelllinien

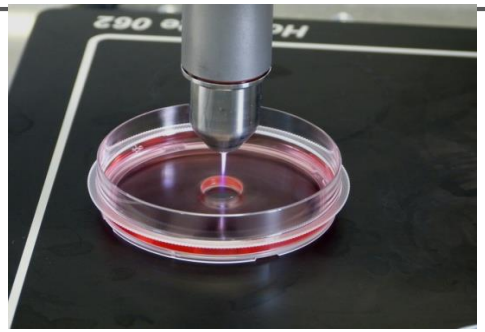


Cell line	TTE_{50} ms*cell/µL
HaCaT	1356
MRC5	5174
HeLa	14509
MV3	384
THP	2868
Jurkat	343
3T3 Fibr	6958

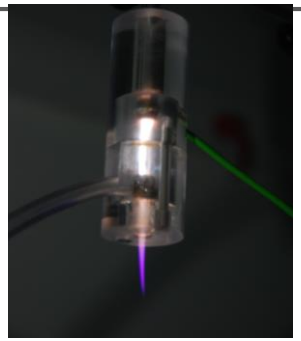
Vergleich der biologischen Wirksamkeit von **Plasmaquellen**



µAPPJ 0.3% 0_2, 25W



kINPenMed 0.3% 0_2



kHz-Jet 0.3% 0_2, 15%

µAPPJ is a capacitive coupled rf-plasma jet

- operating at **13.56 MHz**.
- gas flux of **1 slm helium** with small molecular admixtures.

The operating power of the plasma jet is **up to 30 W RF** power.

The electric field vector in this plasma source is perpendicular to the gas flux direction. Therefore, only few charged species are expected outside the discharge region. The ozone production at small oxygen admixtures lies within the range of that of the kINPen.

The plasma jet's

- operating frequency is **1 MHz**, **pulsed mode at a frequency of 2,5 kHz.**
- gas flux of **3-5 slm argon** with small (in the order of a few %) molecular feed gas admixture possible.

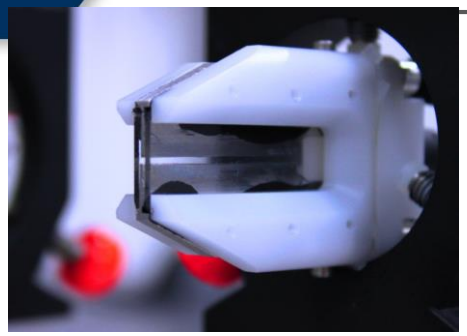
The plasma jet consists of a pin type inner electrode within a dielectric tube. The dielectric is surrounded by a circular grounded electrode. The jet emits so called plasma bullets, which are typical for dielectric barrier jets albeit usually observed in KHz jets.

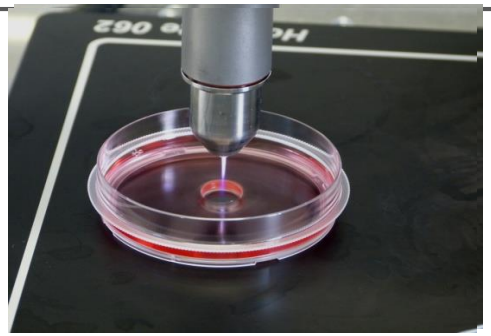
The lower frequency kilohertz-driven dielectric barrier discharge jet is

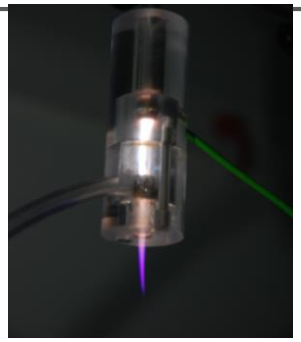
- driven at a **pulse excitation frequency of tens of kHz** and a high voltage (1 to 10 kV)
- operated in **helium.**

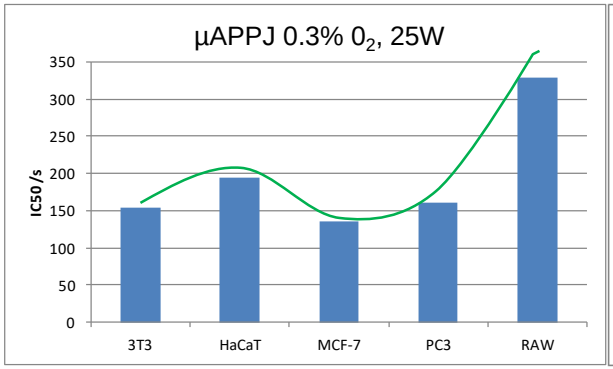
Two external, 2 mm wide, tubular copper electrodes are assembled around the tube, forming a dielectric barrier discharge type configuration. The distance between electrodes can be varied. The electrode separation is typically a few cm.

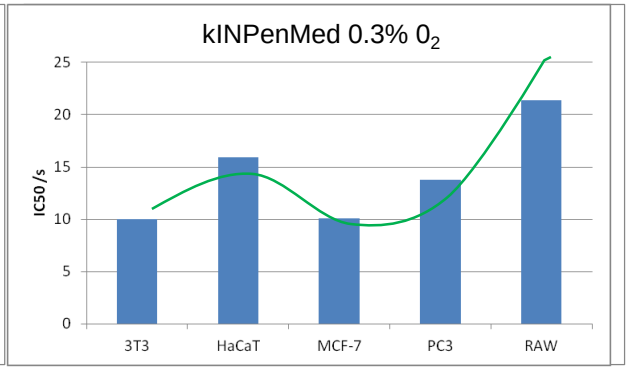
Vergleich der **biologischen Wirksamkeit** von Plasmaquellen

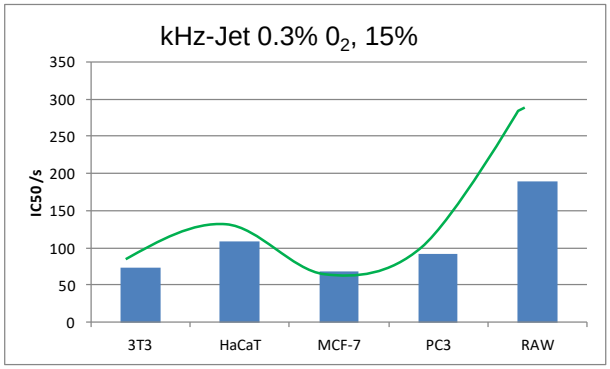








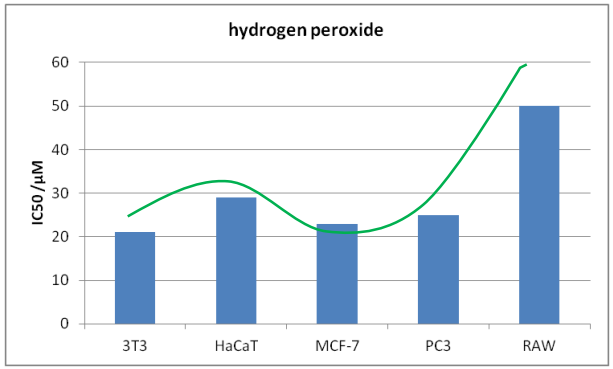




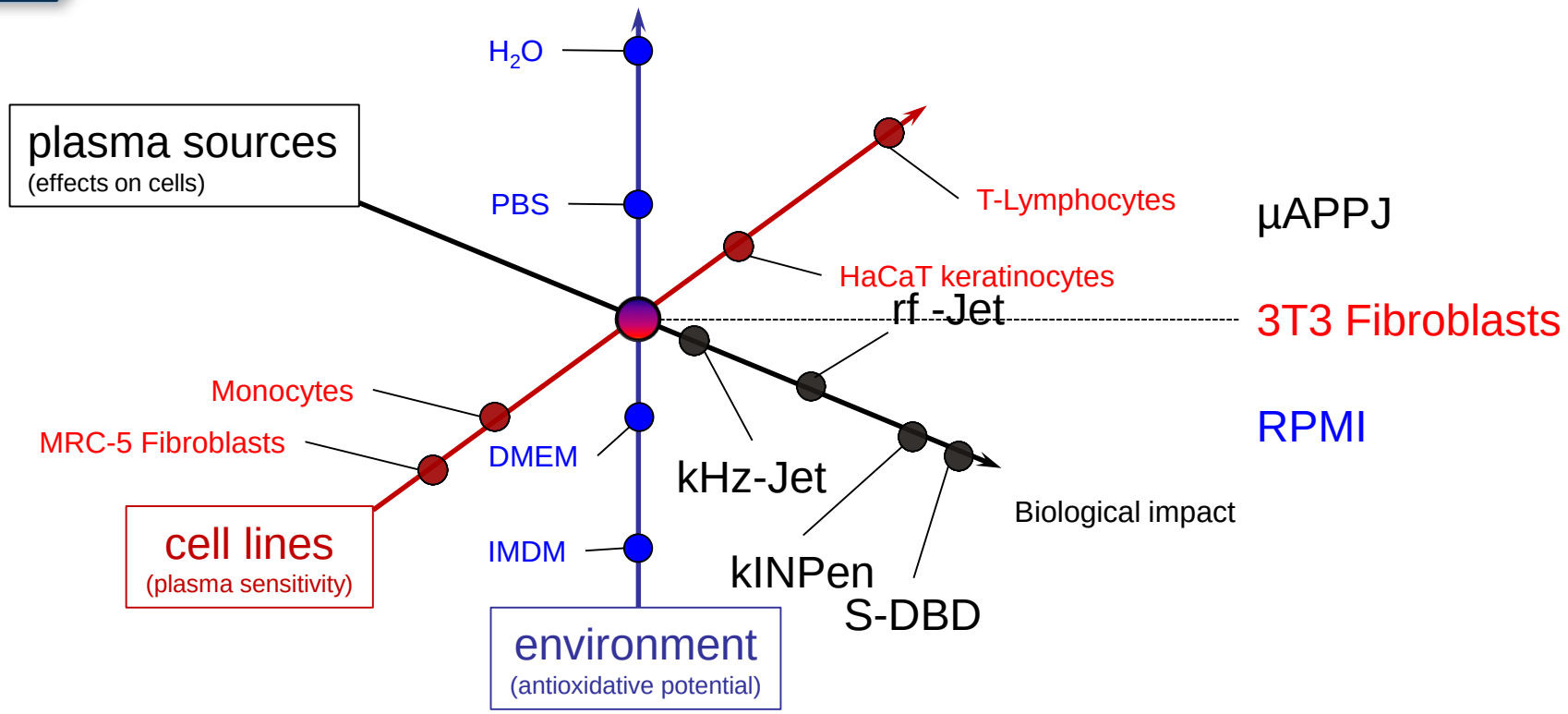
-Sensitivität der Zellen ist ähnlich trotz verschiedener Plasmaquellen ABER es gibt Zelllinen spezifische Unterschiede

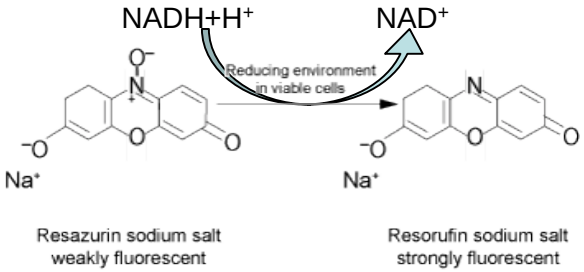
-Hohe Variabilität des biologischen Einflusses der einzelnen Quellen
->> kinpen >> kHz-jet > µAPPJ

-Hauptunterschiede liegen auf seiten der Plasmaquellen.
➔Nicht auf seiten der Zelllinien

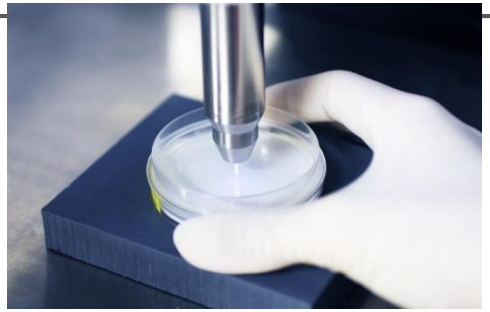


Das Bio-GPS der Plasmamedizin

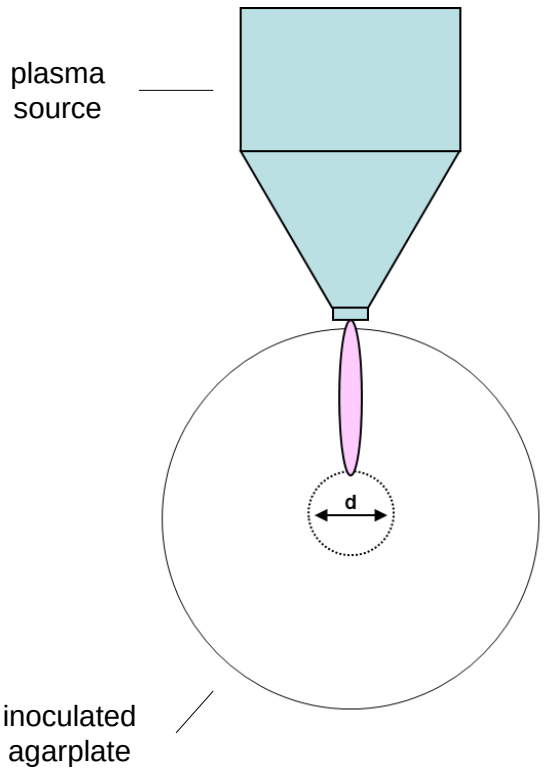


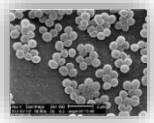


Micro-Biological Performance



- **antimicrobial acitivity**
  - *time-dependent inhibition zone assay*





S. aureus ATCC 6538

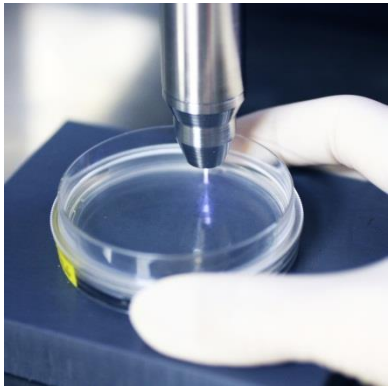
S. epidermidis ATCC 14990

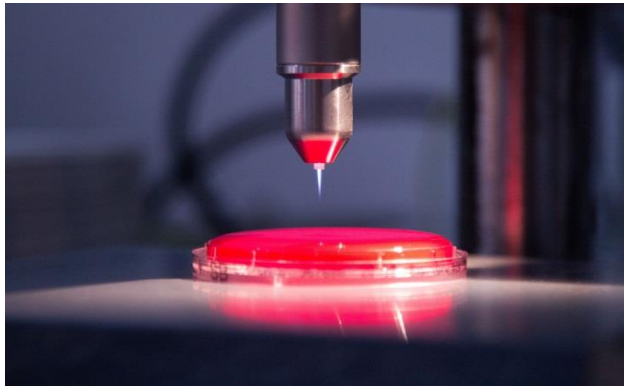
E. coli K-12 NCTC10538

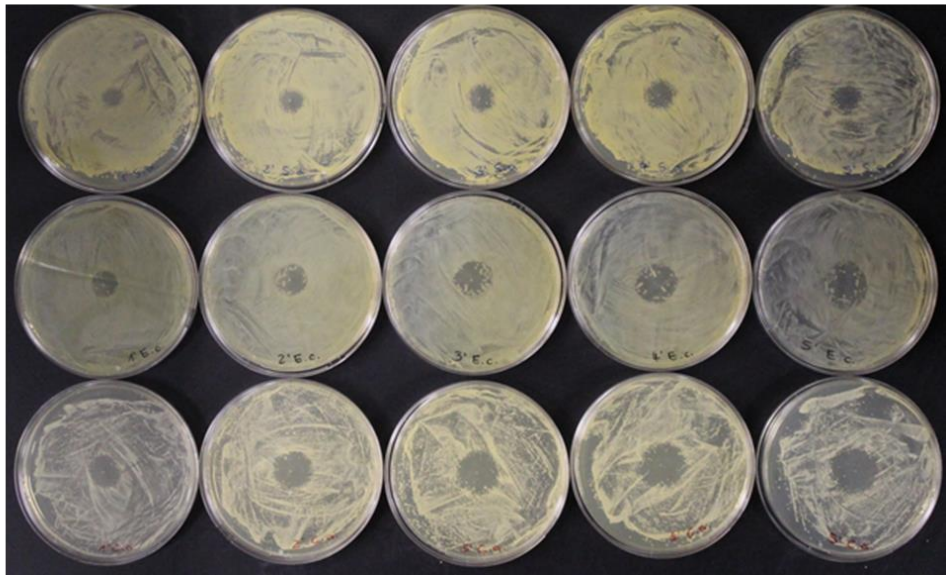
P. aeruginosa ATCC 10145

C. albicans ATCC 10321

Micro-Biological Performance







S. aureus Gram **pos**.

E. coli Gram **neg**.

C. albicans fungy

!! Cold plasma application by kINPen MED: dimension of inhibition zones is dependent on treatment time and type of microorganism

Zusammenfassung & Fazit

- Die biomedizinische Forschung auf dem Gebiet der Atmosphärendruckplasmen bietet eine große Vielfalt sowohl auf Seiten der Plasmaquellen als auch auf Seiten der biologischen Targets.

- Eine Datenbank zur Erfassung aller relevanter Daten für verschiedene Fachrichtungen (Physik, Chemie, Biologie) bietet eine nützliche Plattform zur Erfassung und Vergleichbarkeit.

Vielen Dank für Ihre Aufmerksamkeit

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