Low temperature plasma and medicine

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Plasma
Plasma
Plasma
Plasma is an ionized gas composed of freely movable atomic, ionic, free electron and neutral particles.
What is plasma?

• 4th state of matter
• contains free electrical charge carriers
• plasma displays collective behaviour
• plasma is quasi-neutral
Characteristics of plasma

• Degree of ionization
  • partially ionized
  • fully ionized

• Energy of the particles
  • High-temperature plasma
  • Low-temperature plasma

• Thermodynamic equilibrium / non-equilibrium
How the plasma is created?

• Heating of the gas at high temperature

• The use of electric discharge

• The use of intensive laser radiation
Electric discharge
Electric discharge

-the original free electron
-ionization collision with neutral particle
-free electron

another ionization collisions
-produced electron-ion pair
-secondary electron emission
Types of discharge

Corona discharge

Dielectric Bariere Discharge

Plasma Jet
Plasma in medicine

- Sterilization, biodecontamination
  - surfaces
  - medical instruments
  - water
  - food
- Application at the live cells and tissue without heating effect
Basic method of sterilization
Basic method of sterilization

- Heat
- Gases
- Radiation
- Low temperature plasma
Sterilization by heat

• Moist heat
  • saturated steam, (autoclave)
  • the destruction of microorganisms by denaturation of macromolecules
  • $T: 120 - 135 \, ^\circ\text{C}$
  • 3 – 15 min

• Dry heat
  • High temperature
  • Long time
  • Infrared radiation, incineration
  • $T > 160 \, ^\circ\text{C}$,
  • 60 min
  • Liquids, solids matters, powders, glass
Sterilization by gasses

- Ethylene oxide
  - Heat sensitive materials
  - Alkylation
- Formaldehyde
- Ozone
Sterilization by radiation

- Electromagnetic radiation
- Particle radiation
- Ultraviolet radiation

Ionizing radiation (X rays, γ radiation)
  - Short wavelength \( \rightarrow \) high-intensity radiation

Non-ionizing radiation
  - longer wavelength \( \rightarrow \) lower energy
Why plasma?

• High decontamination efficiency in short exposure time
• No environmental pollution
• Usable for heat sensitivity materials
• Usable on tissues without their damage
• No temperature increasing
• No surface contamination with chemical aggressive matters
• No problem with storage
• Generation of the plasma in the air
• Low cost
Sterilization of Contaminated Matter with an Atmospheric Pressure Plasma

Mounir Laroussi, Member, IEEE

Abstract—The primary methods now used to sterilize contaminated media (infectious waste, tools, liquids, ...) are exposure to UV radiation, incineration, or autoclaving. These methods have recently raised public controversies concerning their environmental effects and other health issues. In an attempt to eliminate these drawbacks, new approaches based on different technologies are being investigated. Irradiation by electron beam is an example.

II. METHODS OF STERILIZATION

Sterilization is the process of destroying the life of unwanted organisms. Generally, it also damages the medium where those organisms live. The agents which cause sterilization range from heat to lethal chemicals to physical processes [4], [5].
Plasma sterilization

- UV photons
- Chemical radicals
- Two types of sterilization
  - Atmospheric pressure
  - Low pressure
Plasma sterilization

• UV photons
• Chemical radicals

• Two types of sterilization
  • Atmospheric pressure
  • Low pressure
Basic principles of plasma sterilization

- Heat effect
- Charged particle effect
- UV radiation
- Effect of reactive species
- Inactivation curve
UV radiation
UV radiation

Absorbed by water $\rightarrow$ OH
UV radiation

Low energy of photons
UV radiation

The most important for sterilization
Thymine dimerization
Effect of reactive species

Plasma generated in atmosphere

• Electron disociation
• Inozation
• Excitation
• Deexcitation

Reactive oxygene species (ROS)

Reactive nitrogeen species (RNOS)
Effect of reactive species

ROS
- Superoxide anion radical – $O_2^{\cdot-}$
- Hydrogen peroxide – $H_2O_2$
- Hydroperoxyl radical - $H_2^{\cdot}$
- Hydroxyl radical - $^{\cdot}OH$
- Ozone – $O_3$
- Singlet oxygen – $^{1}O_2$

RNS
- Nitric oxide – $^{\cdot}NO$
- Nitrogen dioxide – $^{\cdot}NO_2$

RONS
Inactivation curve
Application of low temperature plasma
In vitro application

- Sterilization
- Antimicrobial effect

In vivo application

- Wound healing
- Treatment ulcers and skin diseases
- Caries removal
- Teeth whitening
FAST TRACK COMMUNICATION

Plasma agents in bio-decontamination by dc discharges in atmospheric air

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In vivo study of non-invasive effects of non-thermal plasma in pressure ulcer treatment

Maedeh Chatraie, Giti Torkaman, Mohammadreza Khani, Hossein Salehi & Babak Shokri

Scientific Reports 8, Article number: 5621 (2018) | Download Citation
Schematic of experimental set-up and side view of plasma jet.
Macroscopic observation of wound healing on different days of healing period.
Non-thermal air plasma promotes the healing of acute skin wounds in rats

S. Kubinova, K. Zaviskova, L. Uherkova, V. Zablotskii, O. Churpita, O. Lunov & A. Dejneka

Scientific Reports 7, Article number: 45183 (2017)
Model of wound healing

Bacterias
- E. Coli
- Isolated
  - Hand
  - Saliva

Incubation
- 0 h, 3 h, 6 h, 24 h

Exposure time
- 1 min, 2 min, 5 min, 10 min
In vitro experiment

Bacteria isolated from hands, a) incubation – 0 h, plasma exposure time – 5 min, b) incubation – 0 h, plasma exposure time – 5 min
Gene transformation

• Transfer of genetic information
  • Heat shock transformation
  • Electroporation
  • Low temperature plasma transformation
Gene transformation

Chemical transformation

1. Incubation
2. Heat shock (e.g., 42°C, 30 sec)
3. Recovery

Chemically competent cell

Electroporation

1. Incubation
2. Electric shock (e.g., 15 kV/cm, 5 μsec pulses)
3. Recovery

Electrocompetent cell
Gene transformation

Heat shock transformation

- 100 µl of bacteria
- 35 – 40 min incubation on the ice
- Heating 60 °C, 60 – 90 s
- Cooling 2 min on the ice
- Incubation – 37 °C, 45min

Plasma transformation

- 100 µl of bacteria
- 35 – 40 min incubation on the ice
- 2 x 10 s plasma treatment
- Incubation – 37 °C, 45min
Gene transformation

Heat shock transformation

Plasma transformation
Plasma activated water (PAW)

1 - High Voltage Source
2 Syringe pump (Q = 0.5 ml / min)
3 Faraday's cage
4 High-voltage probe
5 Injection needle serving as an electrode
6 Metal grip
7 Oscilloscope
Antimicrobial effect of PAW

100 µl E.coli added to the PAW or CTRL water

Three time points –
• 60s, 8 min, 20 min

Different dilutions seeded on the Petri dish
Antimicrobial effect of PAW

60 s

Control

PAW
Antimicrobial effect of PAW

8 min

Control

PAW
Antimicrobial effect of PAW

20 min

Control

PAW
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