Non-thermal plasma for microbial decontamination

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What is plasma?

- 4th state of matter
- Ionized gas – mixture of charged and neutral particles
- Approximately the same number of positive and negative particles (quasi-neutrality)
- Collective behavior – the state of plasma depends on local conditions as well as on the state of the plasma in remote areas.

Thermal plasma

Thermal ionisation

Over 10 000 K

(Sun, tokamak, ...)

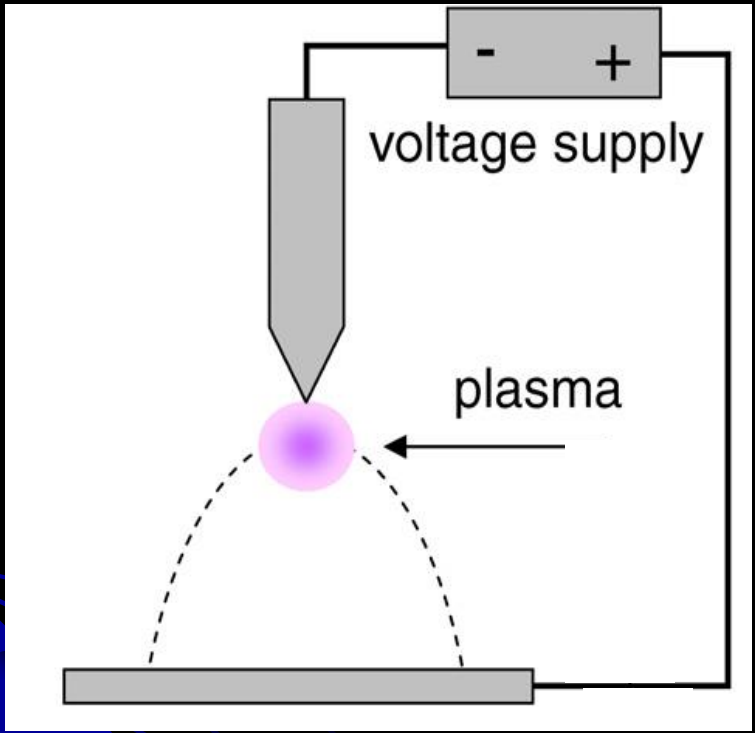
Non-thermal plasma

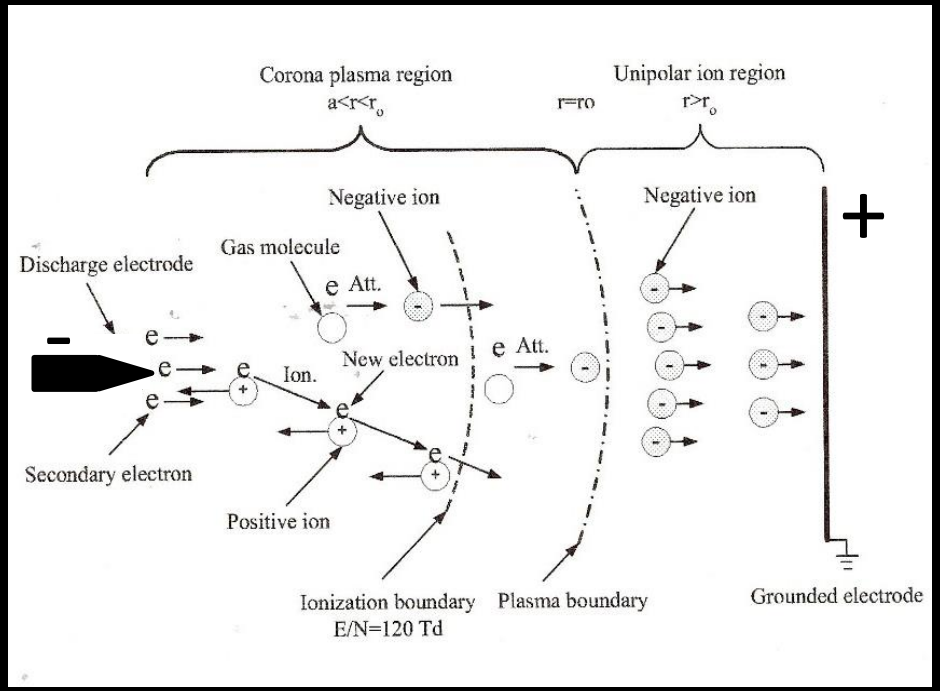
Energy is supplied only to electrons

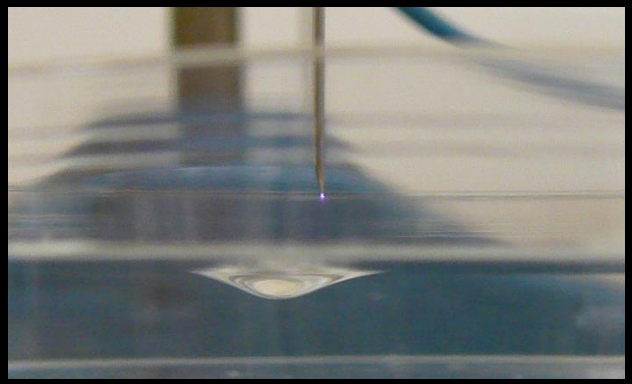
(Electrical discharges)

Sources of non-thermal plasma

DC corona discharge

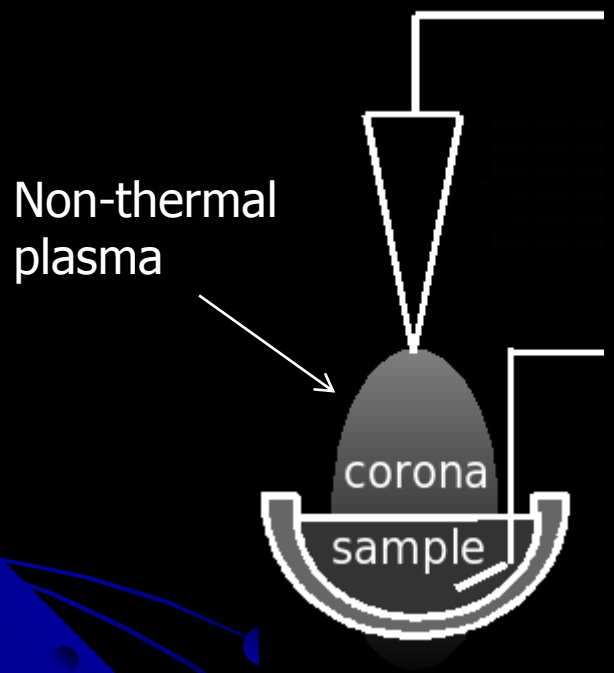


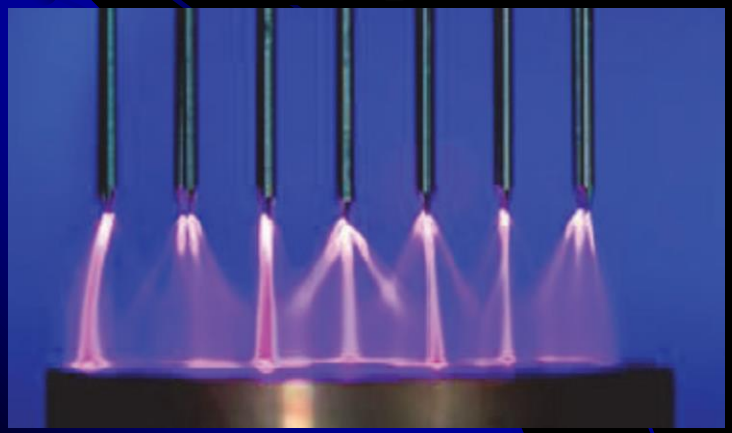


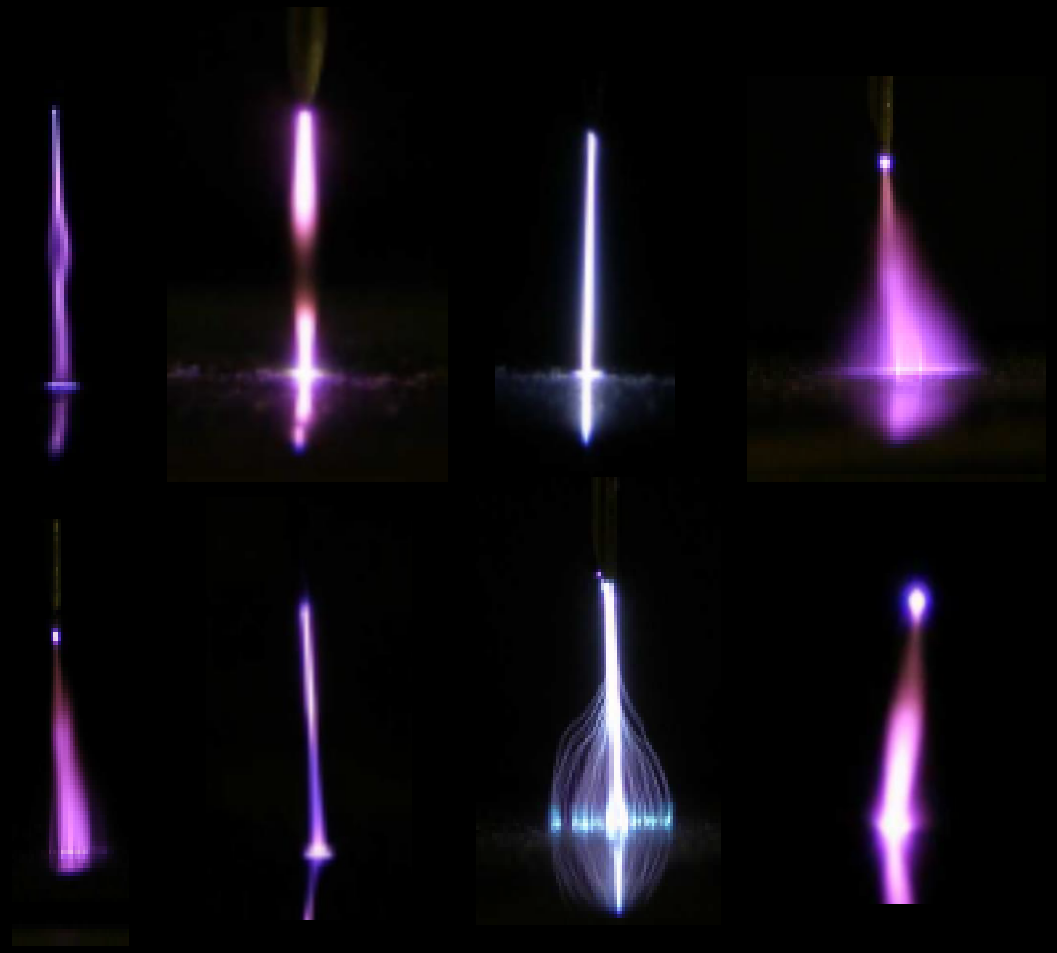


Sources of non-thermal plasma

DC corona discharges – different types



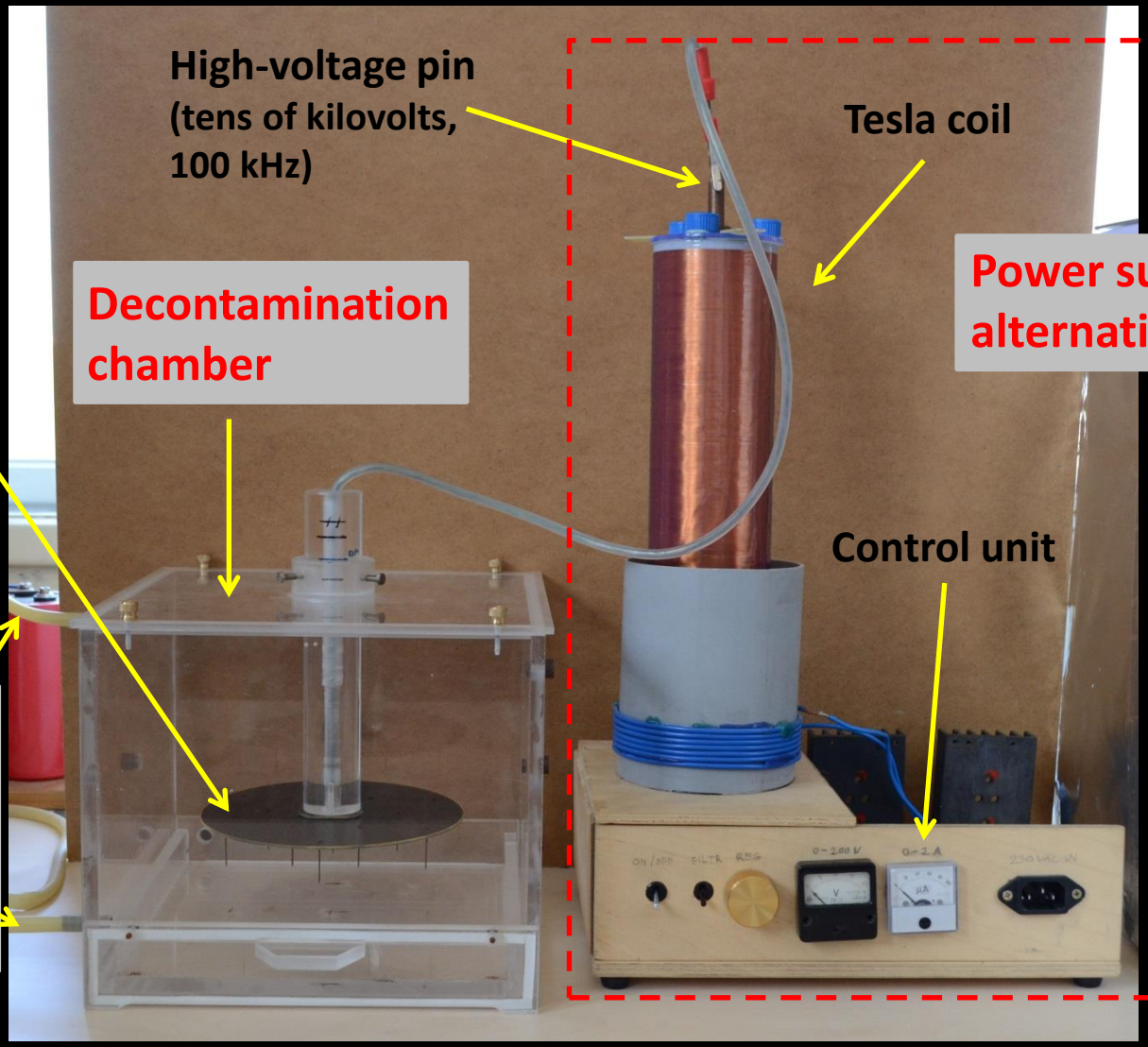




Sources of non-thermal plasma

AC corona discharge,

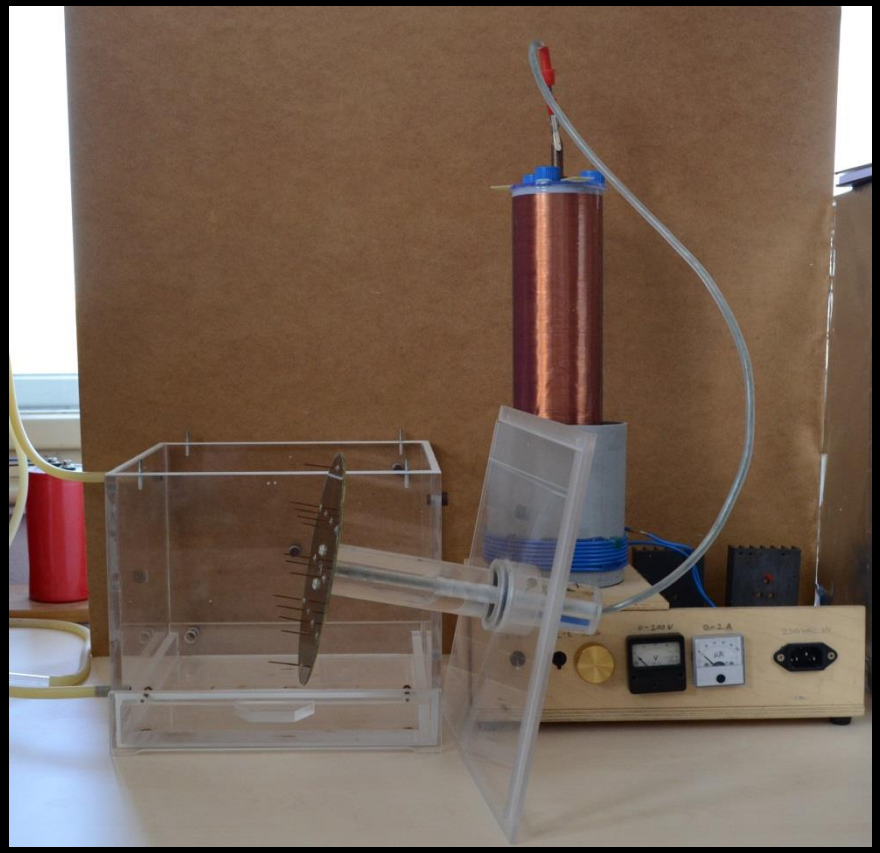
(apparatus created in our working group, author: BC. Pavel Hozák)

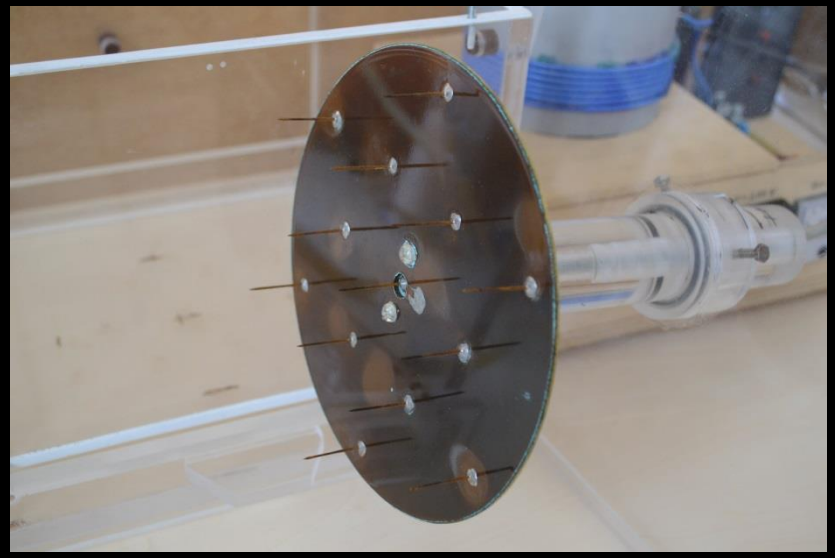


Sources of non-thermal plasma

AC Corona discharge, apparatus used in our group

Detail of multi-pin electrode system

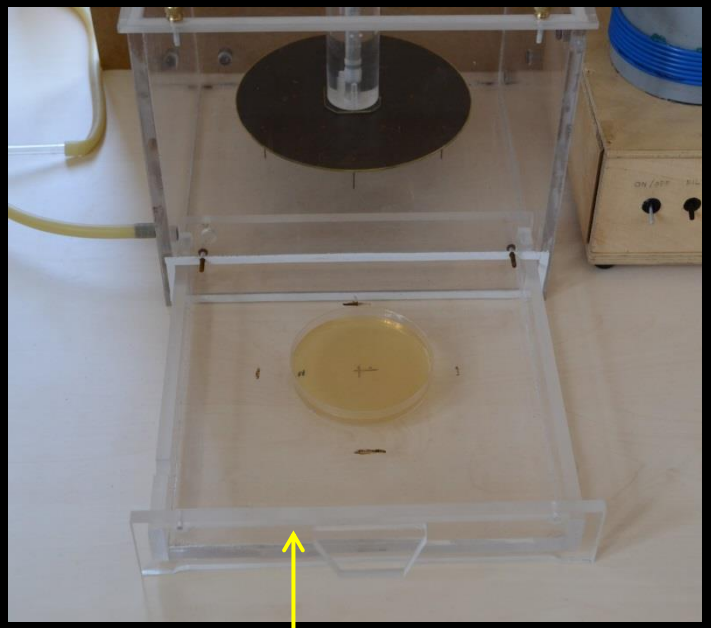




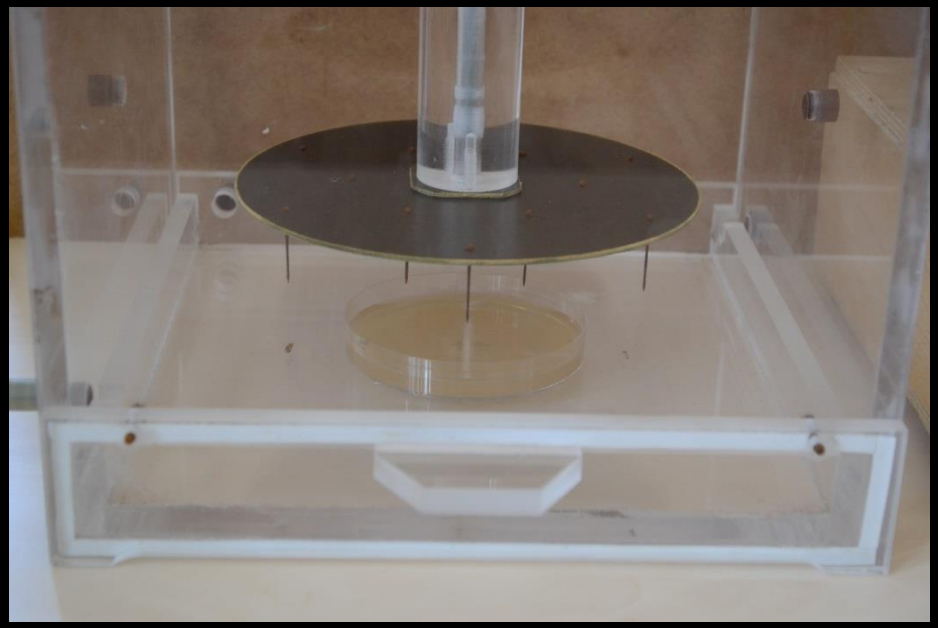
Sources of non-thermal plasma

AC Corona discharge, apparatus used in our group

Decontamination chamber



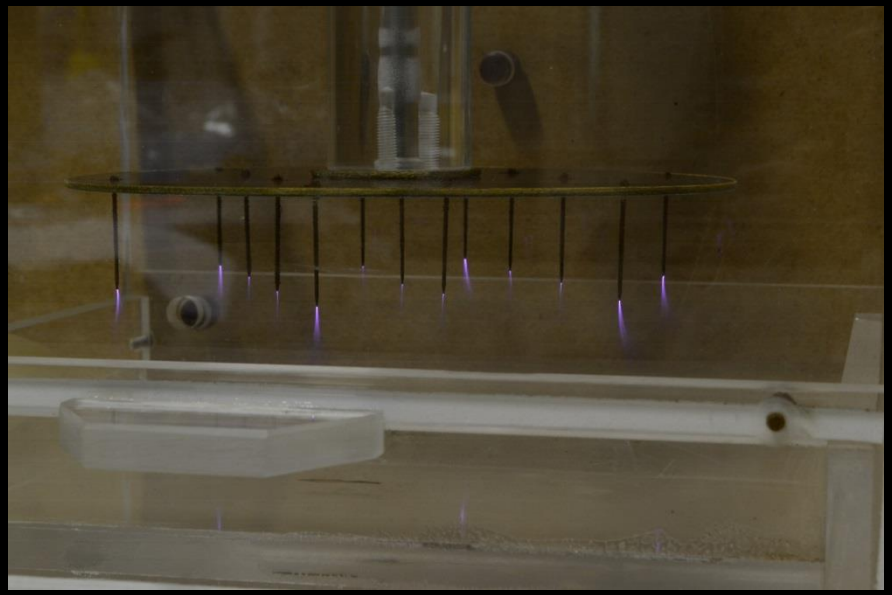
movable drawer
for sample to decontamination

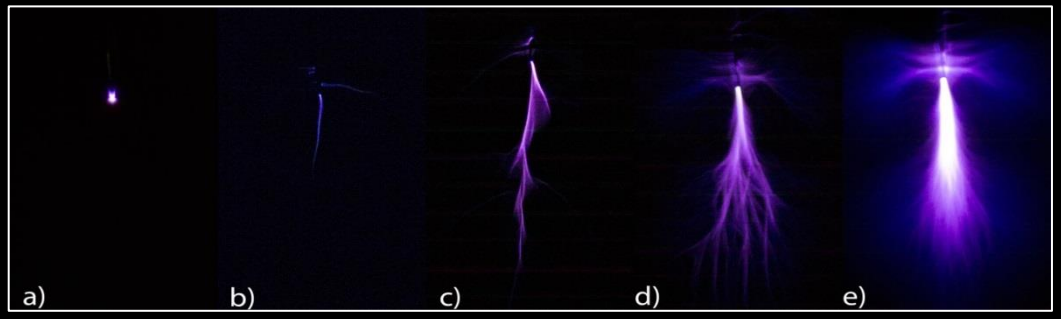


Sources of non-thermal plasma

AC Corona discharge, apparatus used in our group

AC corona discharges

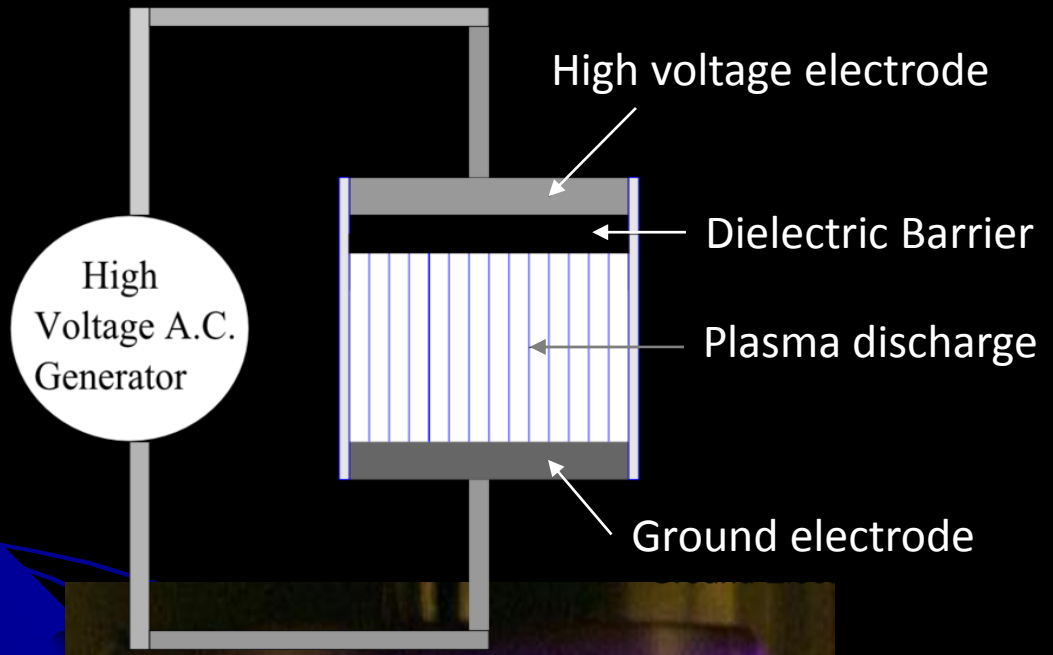


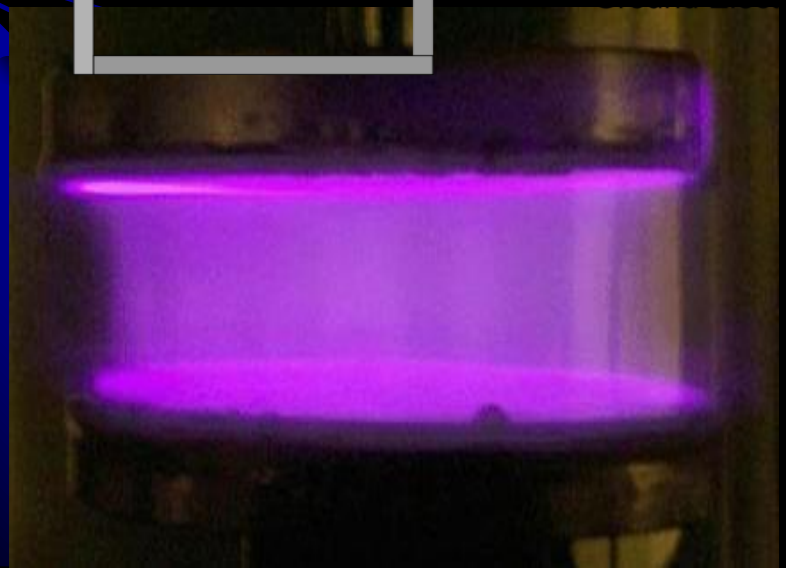


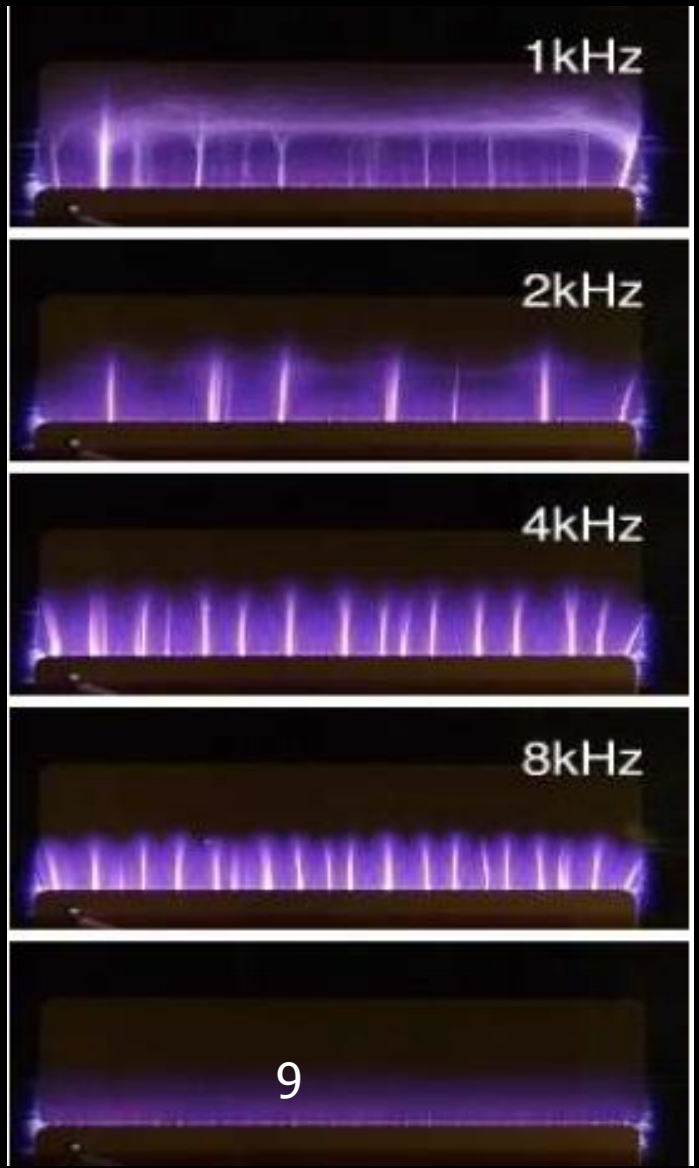
Detail of AC corona discharge generated from single pin (different exposition times)

Sources of non-thermal plasma

Dielectric barrier discharge







Microbicidal agents in plasma

- Microbicidal active particles
  - Charged particles (electrons, ions)
  - Reactive particles (OH radicals, NO_x, atomic oxygen, ozone)
  - Excited molecules
- UV radiation
- Combination of agents

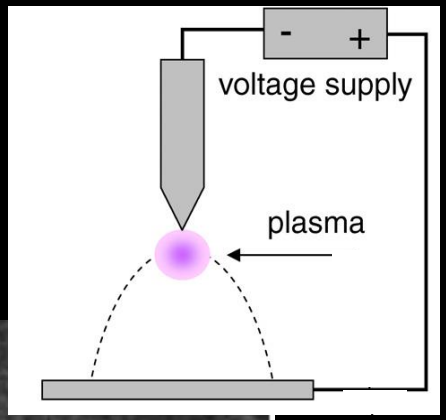
- High energy have electrons only, rest of gas remains at ambient temperature.

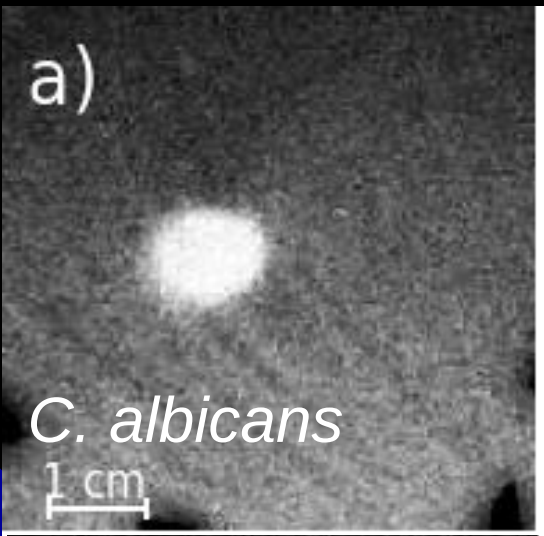
Application

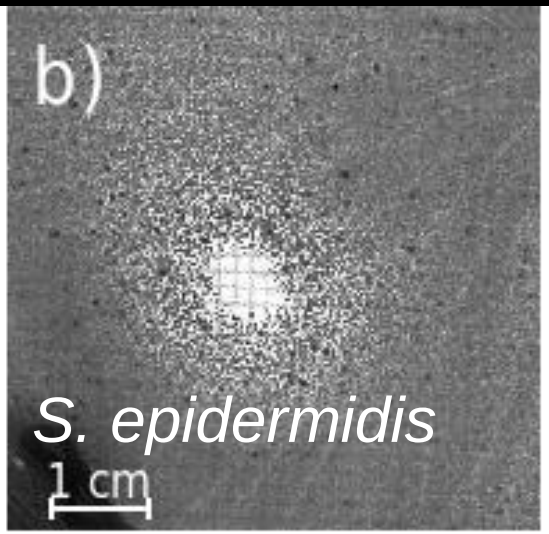
- Biodecontamination
- Medical applications
- And new – decontamination of cultural heritage.

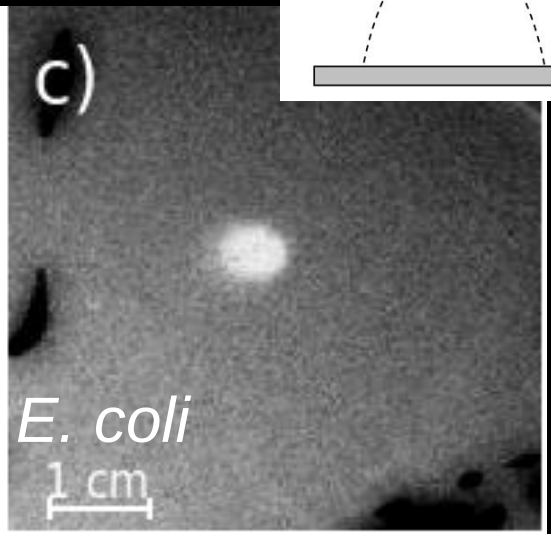
Surface decontamination

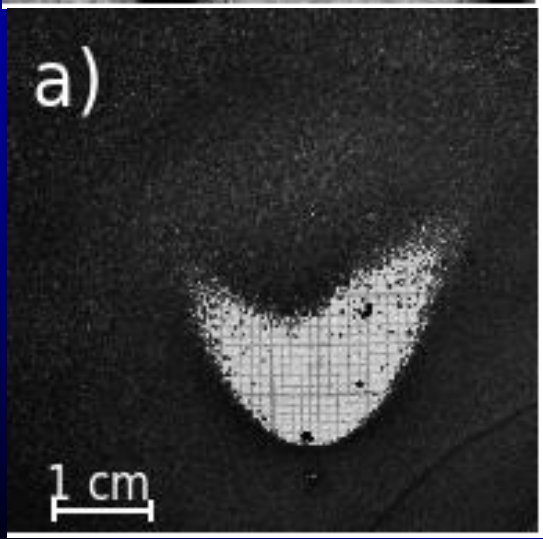
- DC corona discharge, cometary discharge

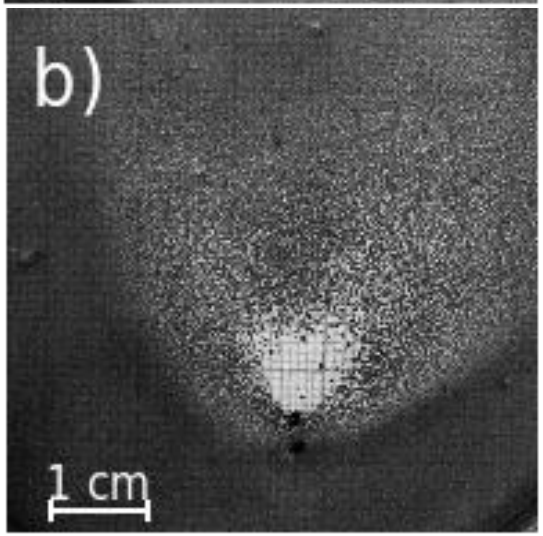


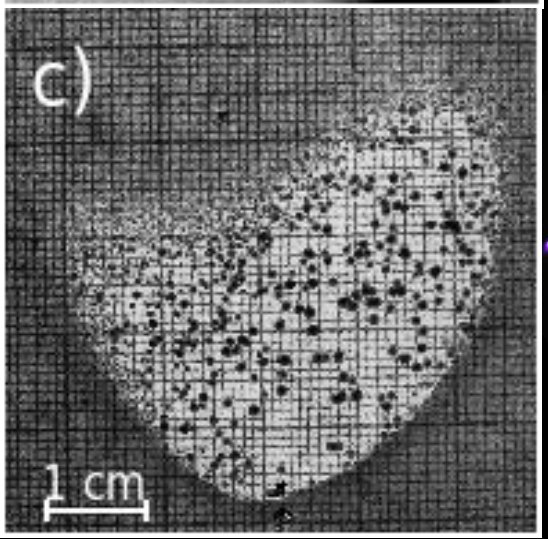






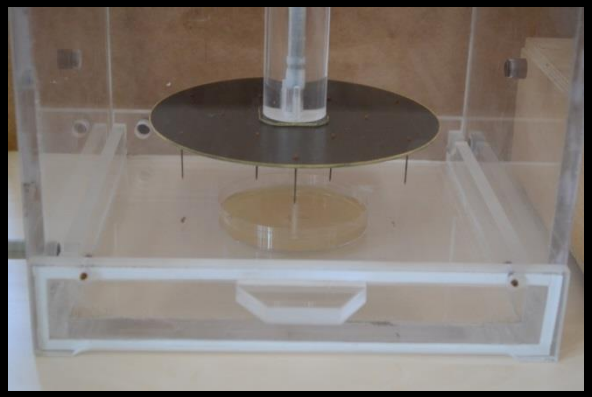


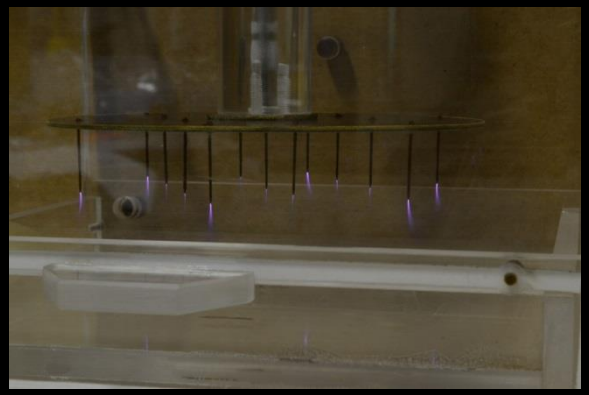


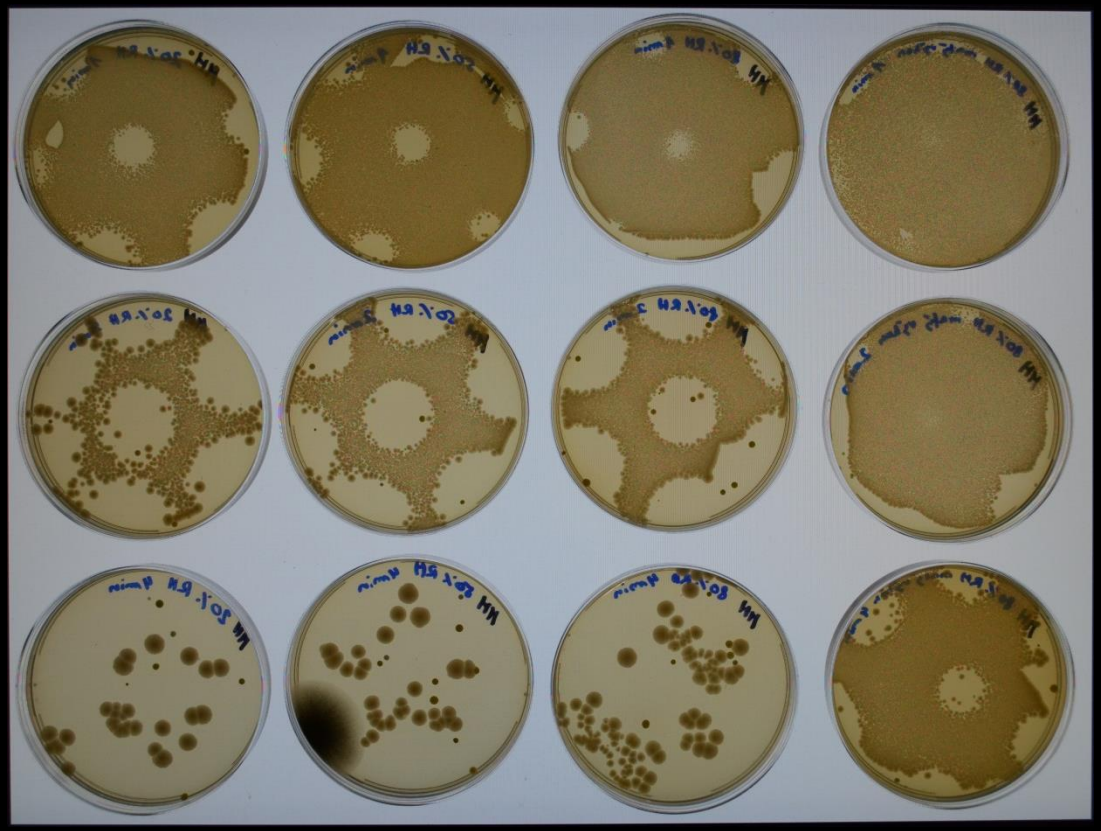


Surface decontamination

- AC corona discharge in closed chamber (preliminary results)
- atmosphere in chamber – air with different humidity



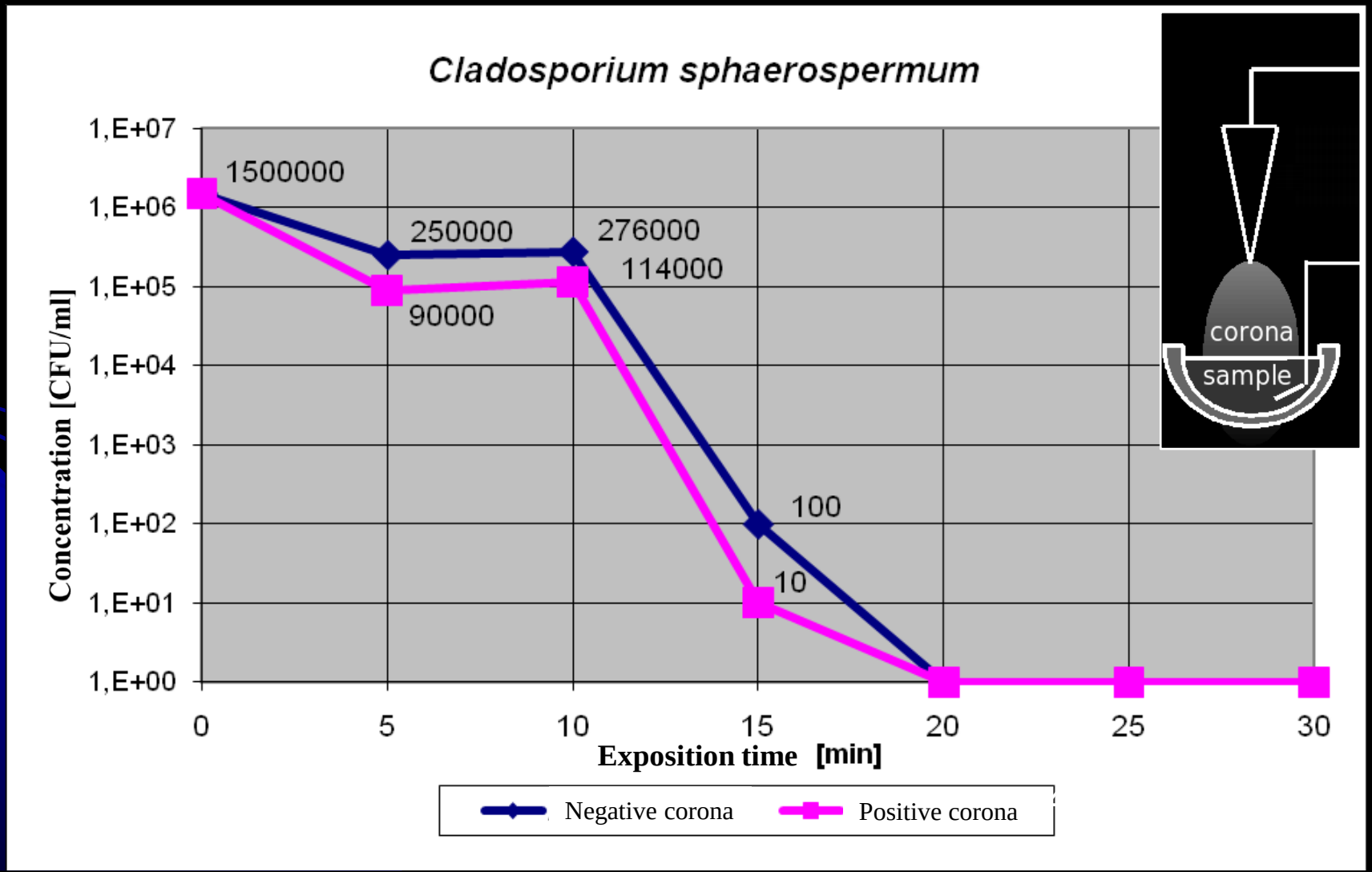




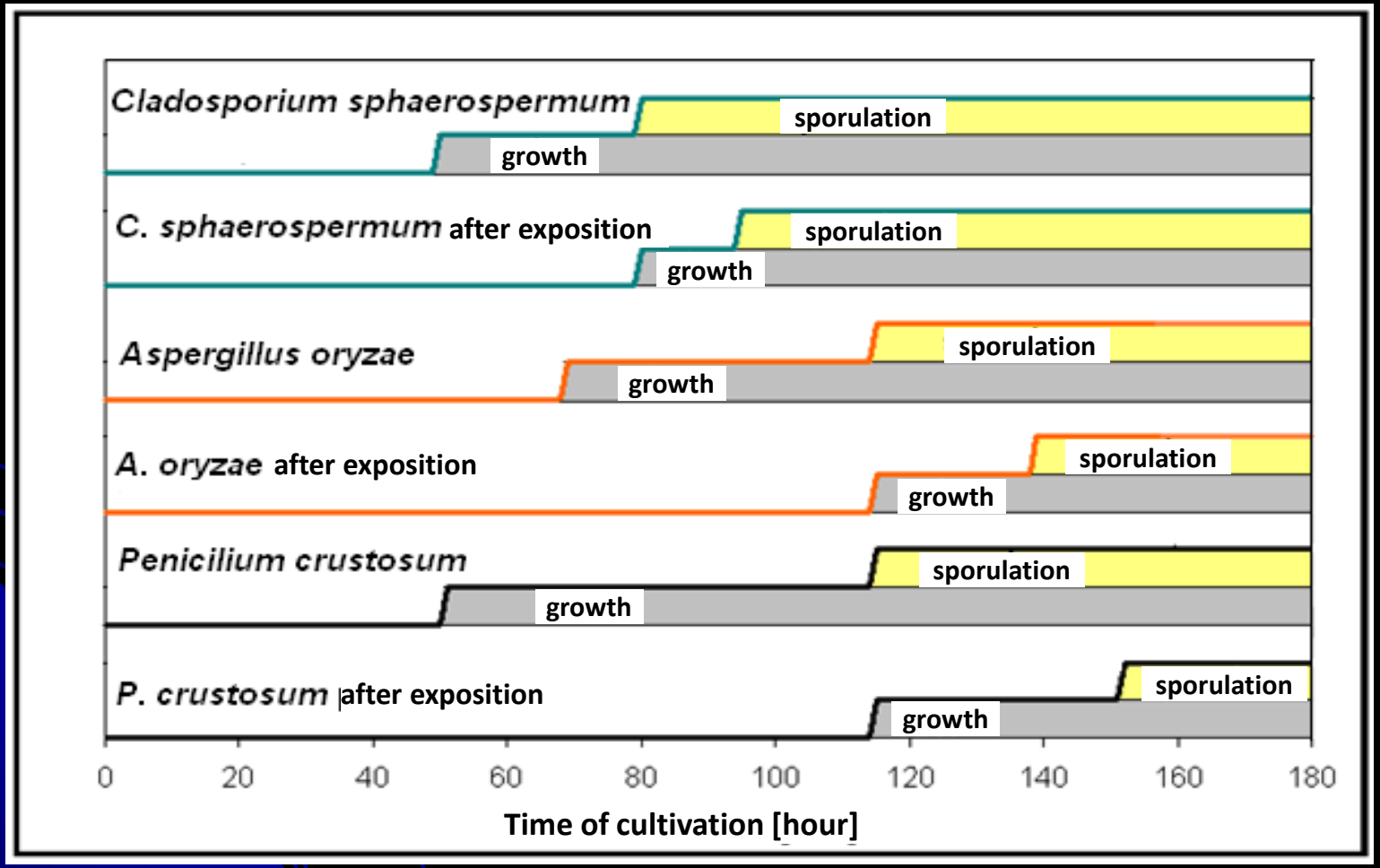
Decontamination of liquids

Inactivation of micromycetes in suspension

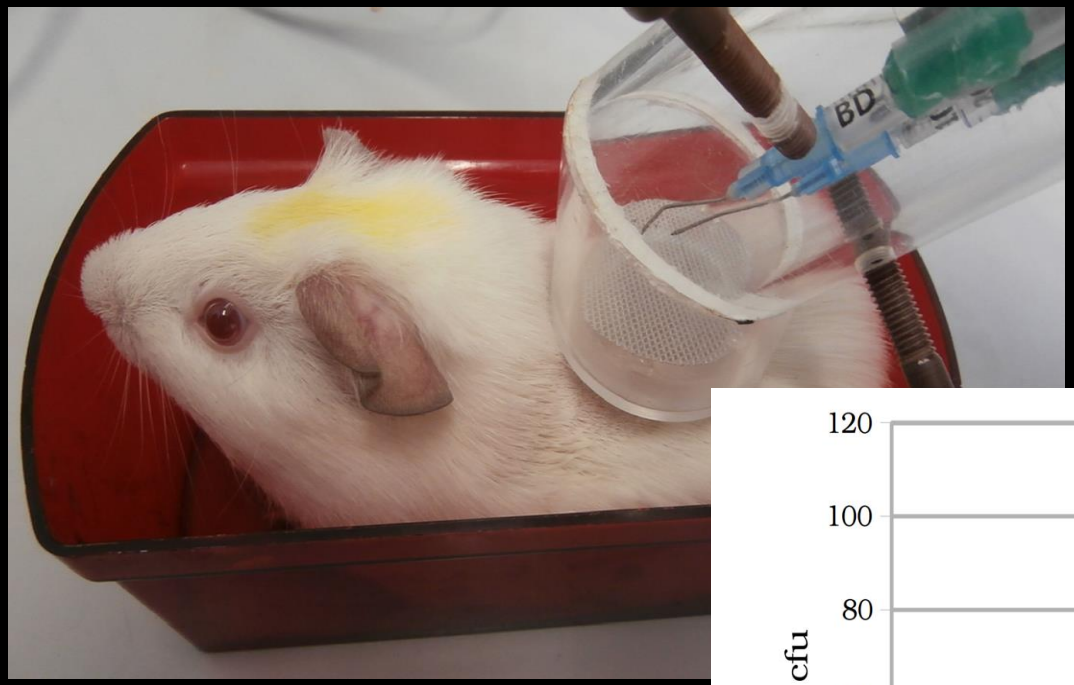
- DC positive and negative corona discharge

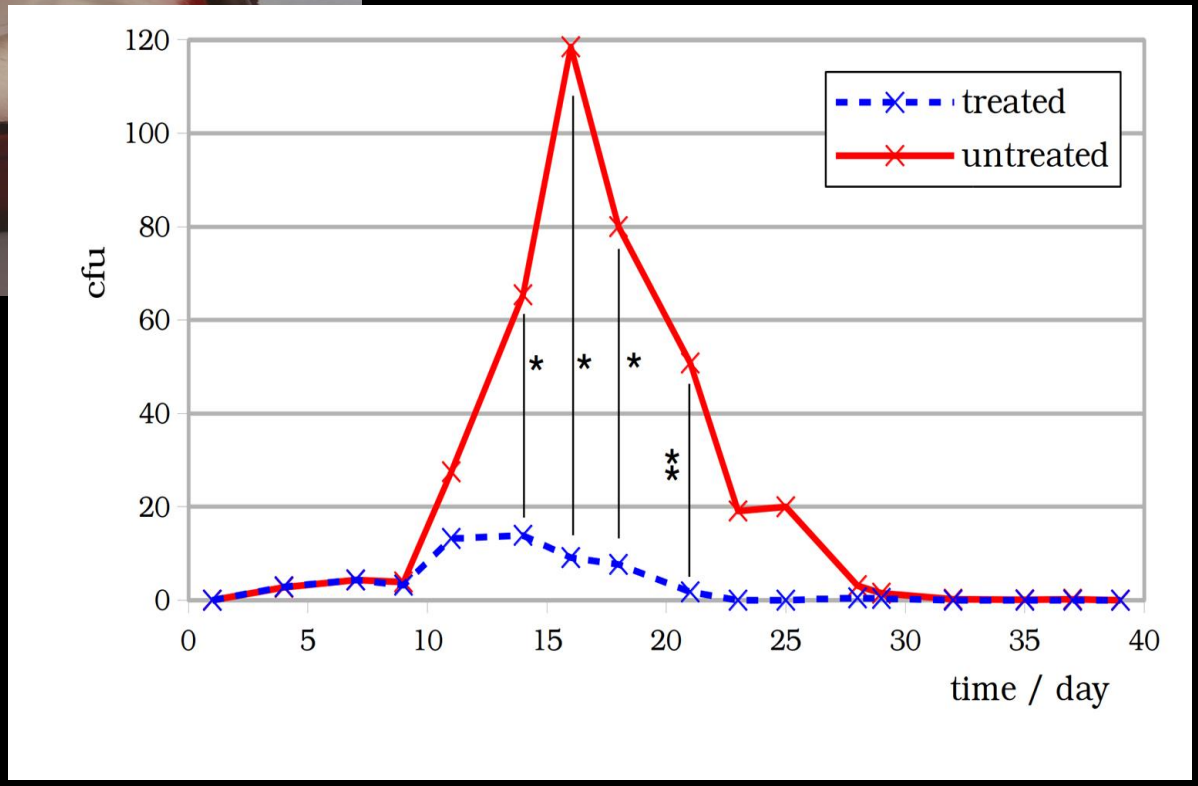


Inactivation of micromycetes in suspension



Skin mycoses treatment





Photographs decontamination

- DC corona discharge with hydrogen peroxide
- Exposition time 180 s

Treated

Untreated

Thank you for your attention

Table 1. List of various reactive oxygen, nitrogen, halogen and sulfur species [10, 22, 23].

Radical	Non-radical	Radical	Non-radical
Reactive oxygen species (ROS)		*Reactive nitrogen species (RNS)*	
Superoxide, O_2^-	H_2O_2	Nitric oxide, NO	Nitrous acid, HNO_2
Hydroxyl, OH^-	Ozone, O_3	Nitrogen dioxide, NO_2	Nitrosyl cation, NO^+
Hydroperoxyl, HO_2	Singlet oxygen (O_2 1 Dg)	Nitrate radical, NO_3	Nitroxyl anion, NO^-
Carbonate, CO_3^-	Hypobromous acid, HOBr		Dinitrogen trioxide, N_2O_3
Peroxyl, RO_2	Hypochlorous acid, HOCl		Dinitrogen tetroxide, N_2O_4
Alkoxyl, RO			Dinitrogen pentoxide, N_2O_5
Carbon dioxide radical CO_2^-	Hypoiodous acid, HOI		Alkyl peroxynitrites, ROONO
Singlet ($^1O_2$)	Organic peroxides, ROOH		Alkyl peroxynitrates, RO_2ONO
	Peroxynitrite, ONOO−		Nitryl chloride, NO_2Cl
	Peroxynitrate, O_2NOO-		Peroxyacetyl nitrate, $CH_3C(O)OONO_2$
	Peroxynitrous acid, ONOOH		
	Peroxomonocarbonate, $HOOCO_2^-$		
	Carbon monoxide, CO		
Reactive chlorine/bromine species		*Reactive sulfur species*	
Atomic chlorine, Cl	Chloramines	Thiyl radical S.	Hydrogen sulfide, H_2S
Atomic Bromine, Br	Chlorine gas, Cl_2		Disulfide, RSSR
	Bromine gas, Br_2		Disulfide-S-monoxide, RS(O)SR
	Bromine chloride, BrCl		Disulfide-S-dixide, RS(O)2SR
	Chlorine dioxide, ClO_2		Sulfenic acid, RSOH
			Thiol/sulfide, RSR′