

Fast Plasma Assisted Hand Sterilization System



Greg Fridman, BioMed; Richard Hamilton, Emergency Medicine; Suresh Joshi, Surgery; Mark Ingerman, Infectious Diseases

Plasma-Medicine Lab
Drexel Plasma Institute

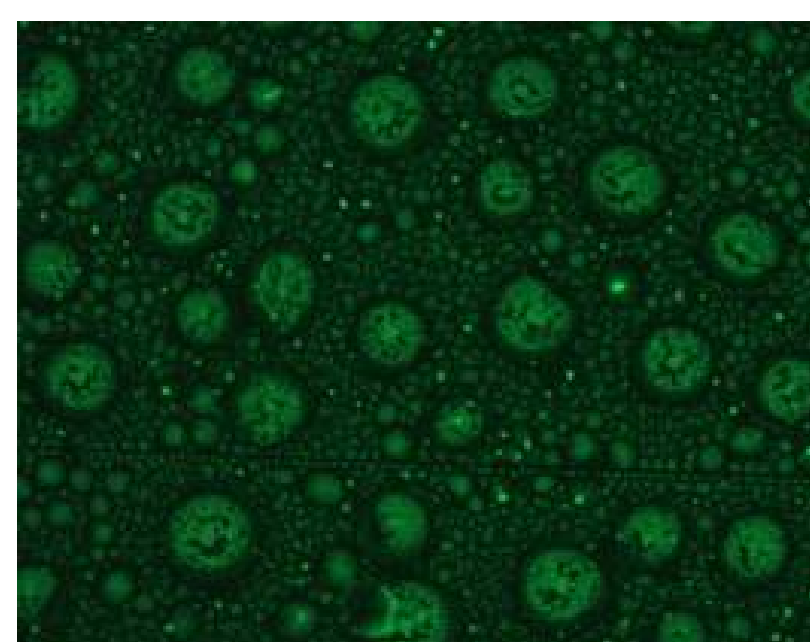
Target market: ICU, ER, Nursing homes, ...

- ICU, ER, Surgery, ...
- All hospital areas
- Nursing homes
- Butcher shops and produce handling

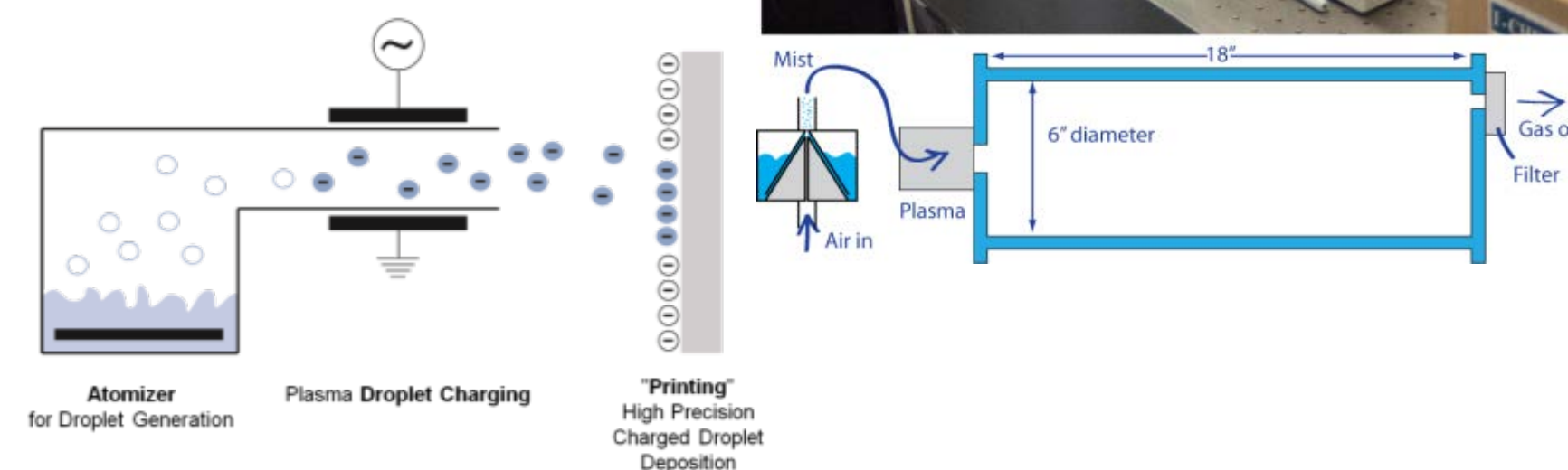


Plasma-charging and uniform deposition of water droplets

- Plasma charges liquid droplets
- Droplets deposit at the same rate, independent of their size
- Uniform coverage in fraction of a sec
- Large liquid throughput

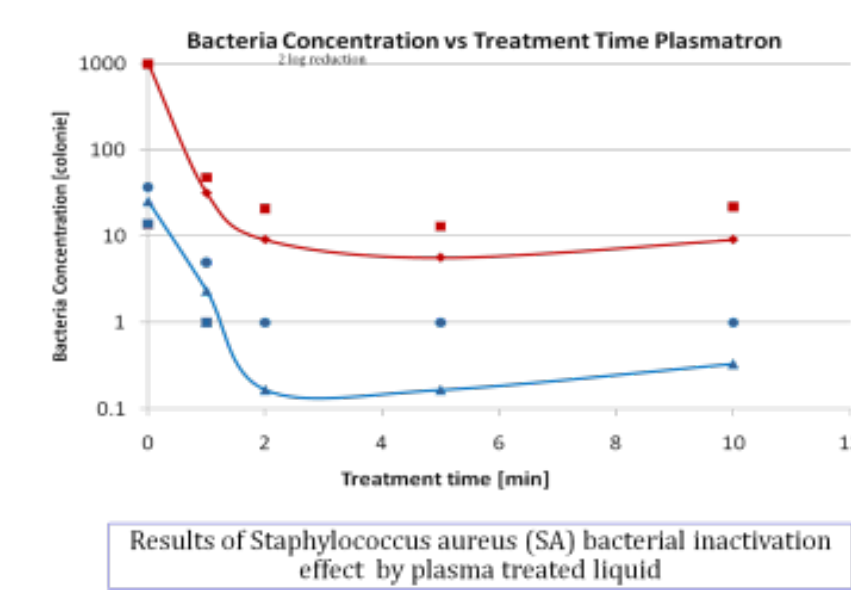
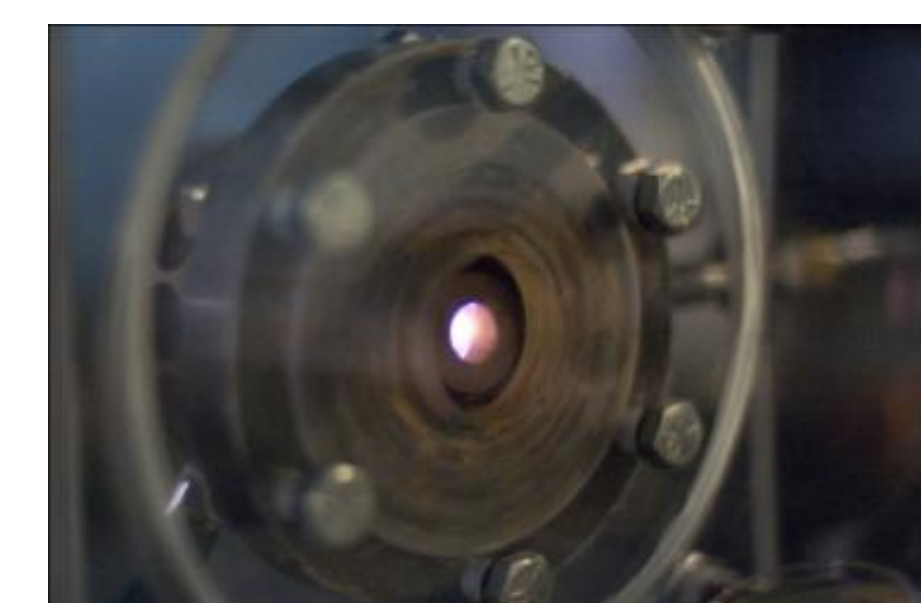
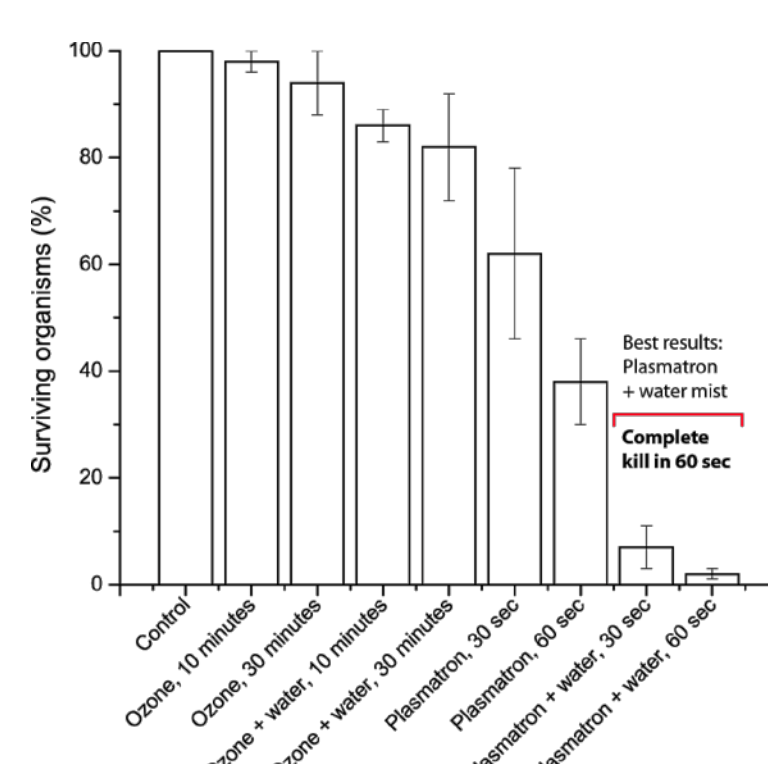


Uniform deposition (fluorescent ink)

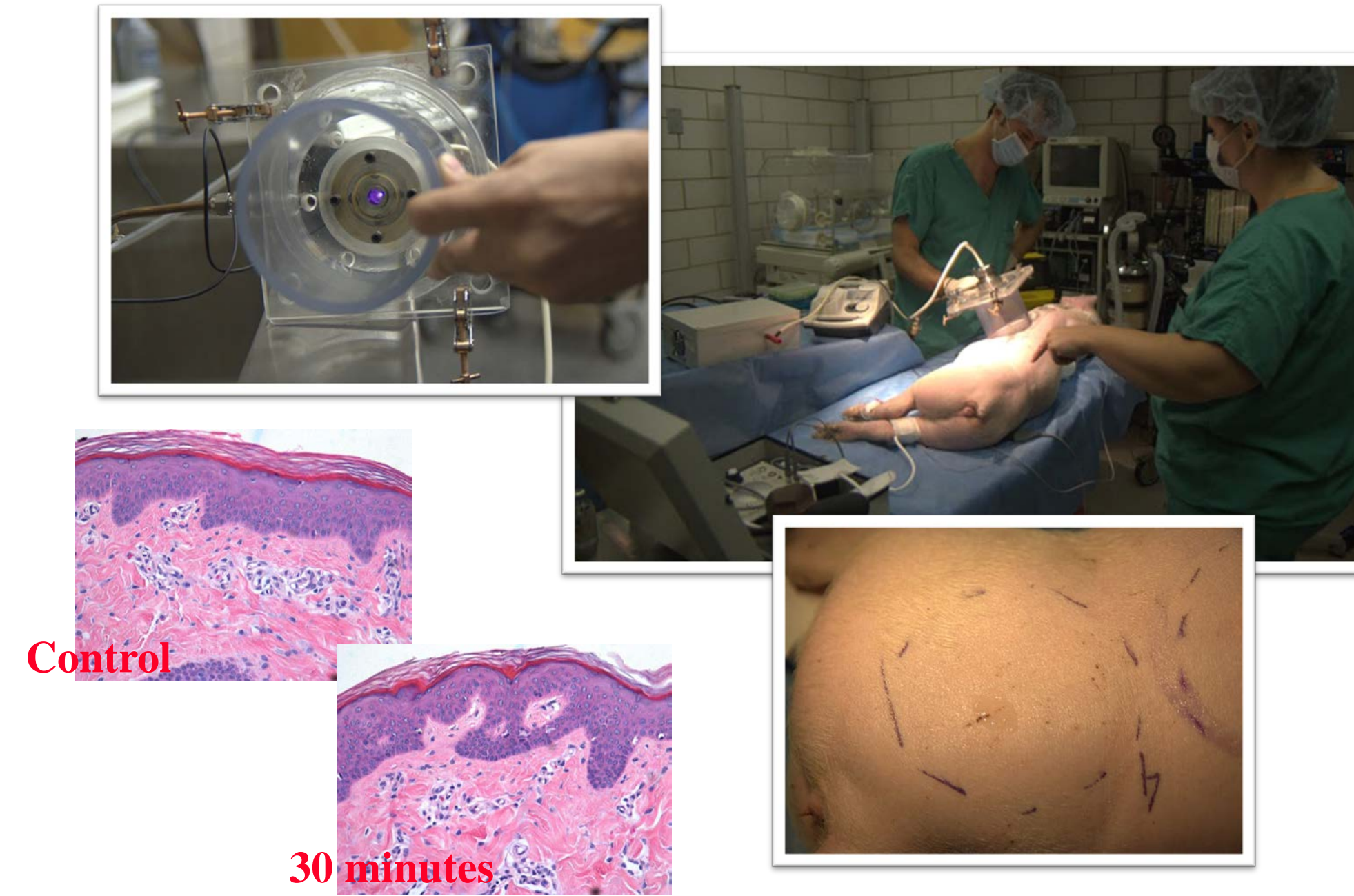


Fast and effective sterilization

- Effective against *E. coli* and *S. aureus*
- Complete kill in 60 seconds (on agar dishes in simulated setup)
- More effective than plasma afterglow, ozone, H₂O₂, or alcohol

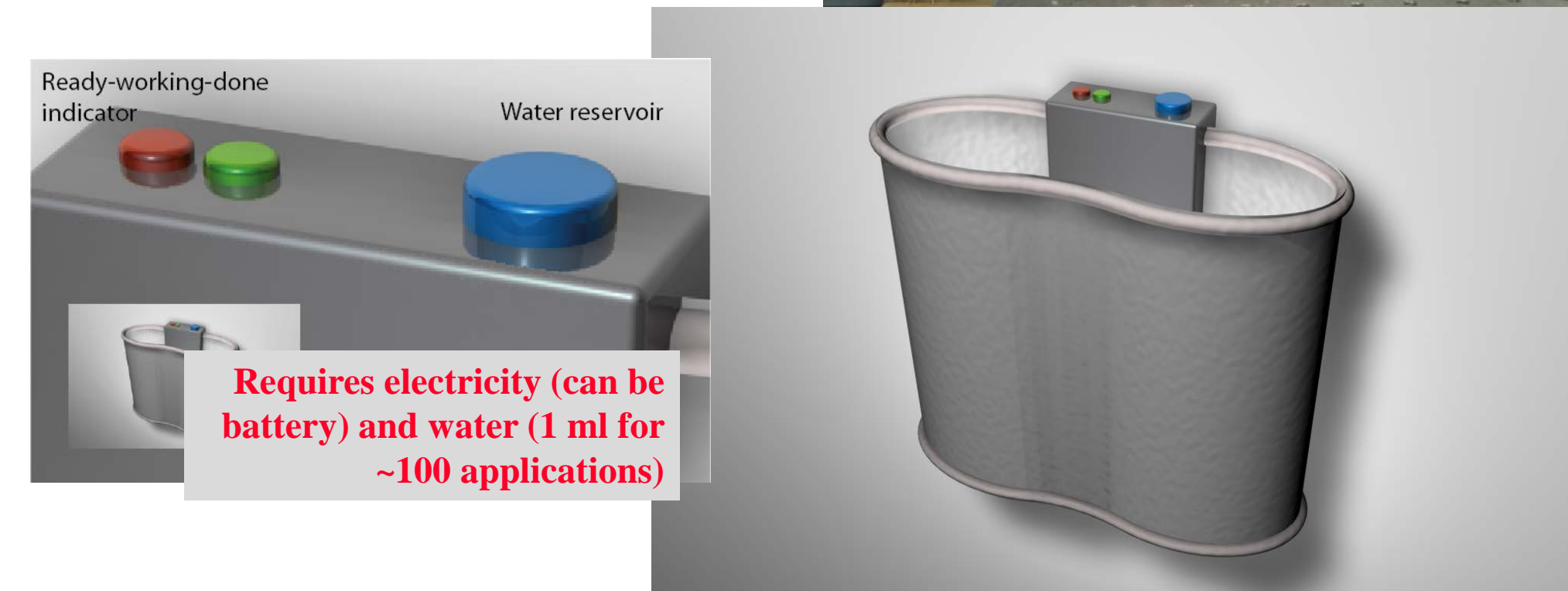


Plasma-treated liquid is non-toxic to animal skin



Envisioned Future Health Care Product: Fast Hand Sterilizer

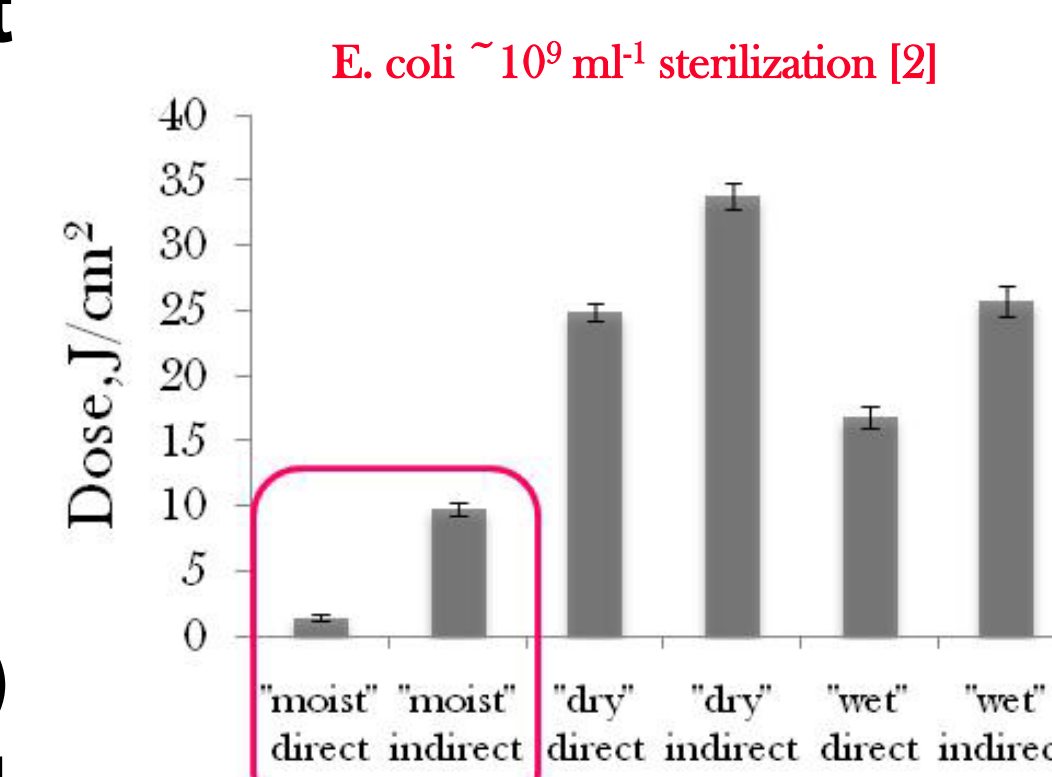
- Complete sterilization (>99.9999% kill, 6 logs)
- Below 5 seconds
- Reduce human factors
- Inexpensive



Requires electricity (can be battery) and water (1 ml for ~100 applications)

Medium is extremely important in plasma treatment

- **Medium/Environment** is important
 - Treatment Moist/Dry
 - Liquids (PBS/Water /Blood Plasma)
- **Chemical nature**
 - Reactive Oxygen Species (ROS) (form, change, convert) in liquid phase
- **Liquid Phase** is Important



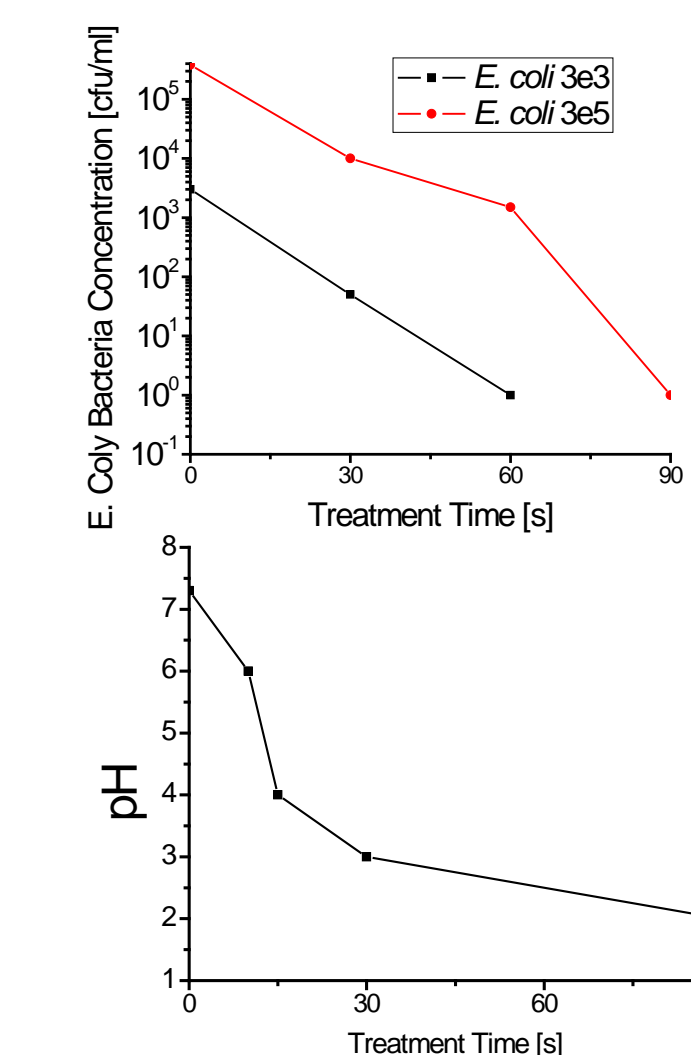
PBS = Phosphate Buffered Saline

[1] G. Fridman et al., Plasma Process. Polym. 2007, 4, 370-375
[2] D. Dobrynin et al., Interaction with living tissue", 2009 New J. Phys. 11 115020 (26pp)

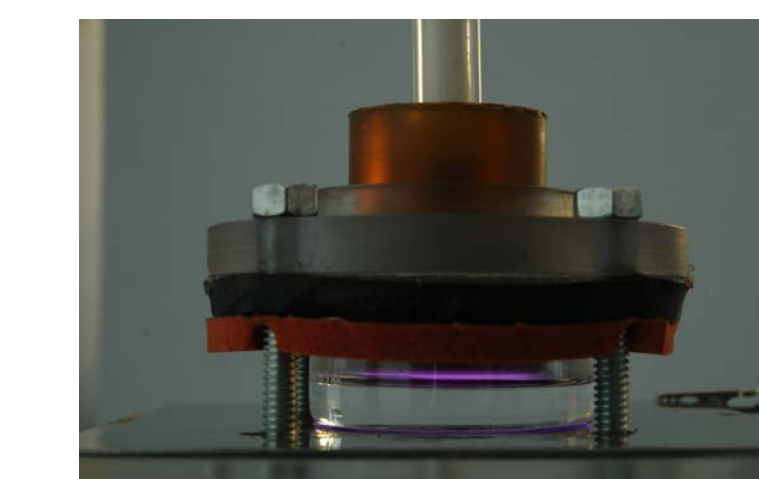
Plasma-acid sterilizes through oxidation

- H₂O₂ in acidic solution is **extremely strong oxidizer**
 $H_2O_2 + 2 H^+(aq) + 2 M(aq) \rightarrow 2 M^+(aq) + 2H_2O(l)$
 $H_2O_2 + 2 H^+(aq) + 2 Fe^{2+}(aq) \rightarrow 2 Fe^{3+}(aq) + 2H_2O(l)$
- Fenton's reaction
 $Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + OOH + H^+$
 $H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + OH^* + OH^-$
- $O_2^- + 2H^+ \rightarrow H_2O_2$ (dismutation reaction)

Effective sterilization with plasma-treated water



- DBD Plasma treated water Kills bacteria



Active factors in plasma-treated water

1. Positive Ions create acidity
 - Charge exchange mechanism:
 $N_2^+ (O_2^+) + H_2O \rightarrow H_3O^+ + N_2(O_2)$
 - $H_2O^+ + H_2O \rightarrow H^+(H_2O) + OH^-$
2. Conjugate Base (Negative Ions)
 - $e + O_2 \rightarrow O_2^-$
 - O_2^- is the primary negative ion both in gas and liquid
3. H₂O₂ is immediately created in both gas and liquid
 - $OH^+ + OH^- \rightarrow H_2O_2$

