

# Ambient Gas Plasma

## *A Sustainable Disinfectant Made From Electricity and Air*

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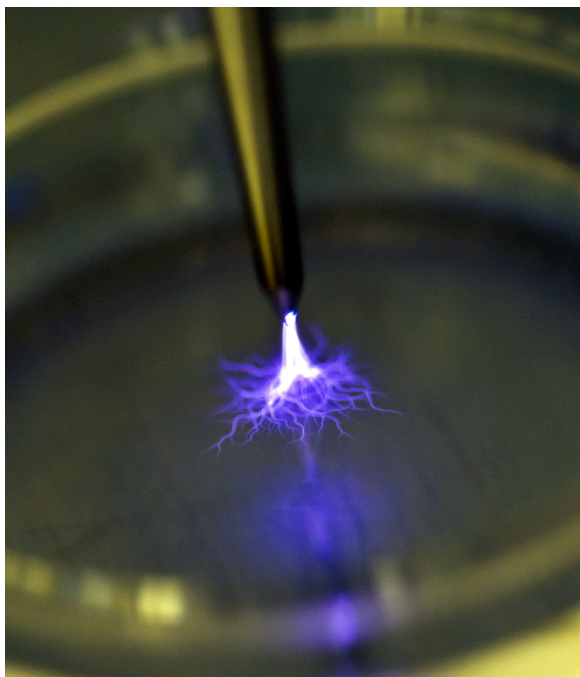
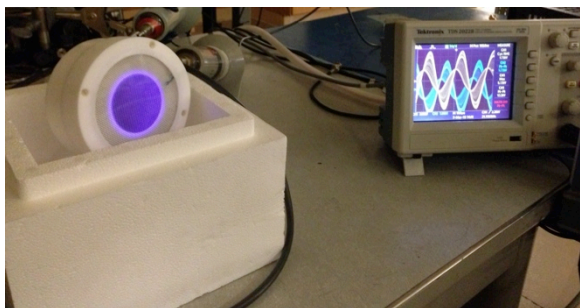
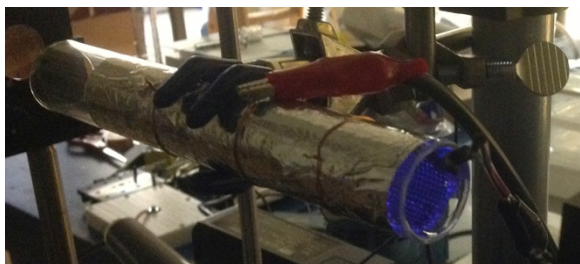
<http://graves-lab.cchem.berkeley.edu/agp>

### Building a Prototype

In a laboratory setting, it is easy to obtain high levels of disinfection with plasma devices. We now hope to develop a prototype that is suitable for use in third world countries. Although there are many variations of plasma devices that can be built (see "One Stop Plasma Shop"), our first device will be a medical instrument sterilization device.

### Designed for Low Resource Settings

Plasma sterilization is perfectly suited for low resource settings. Our prototype will be built out of cheap, robust materials that can be replaced locally. The device can operate in two distinct modes (i.e. high and low power) that add variety to the device's capabilities. Perhaps the greatest benefit of plasma technology is that it only requires two inputs, electricity and air. Remote locations no longer have to depend on shipments of supplies (e.g. antiseptics). This makes communities independent and empowers the men and women living in them.

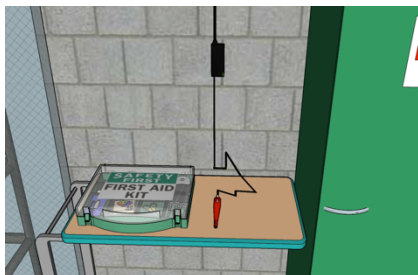


### One Stop Plasma Shop



Sanitized tanks could be used to store plasma-disinfected water prior to drinking. Drinking water would be disinfected using low power mode since ozone quickly breaks down in water. Water treated in high power mode has potential to act as a plant fertilizer.

Plasma might be used to disinfect linens, medical instruments, drinking water, or water for hand washing. Plasma activated water could also be bottled for use as an antiseptic.



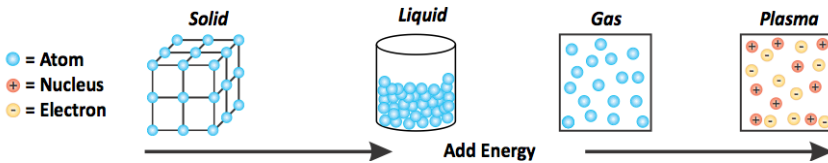
Another advantage of plasma disinfection is the possibility of making plasma devices in many different geometries or configurations, such as a "pen" device for disinfecting finely detailed instruments or wounds.

Our collaborators at WE CARE Solar have developed a portable energy source to provide lighting, communication, and medical support in low-resource areas. Excess solar energy can be used to power plasma-producing devices.



## What is Plasma?

Plasma is commonly known as the fourth state of matter. This state occurs when gas molecules are given enough energy to break apart into smaller particles that may be positively or negatively charged. These particles often recombine to form new molecules that were not present before. Our plasma devices have two modes, "high power" ( $>0.25 \frac{W}{cm^2}$ ) and "low power" ( $<0.15 \frac{W}{cm^2}$ ), that produce different chemicals. High power mode favors production of nitrogen oxides, while low power mode favors production of ozone.



## How Do We Measure Disinfection?

We measure disinfection by calculating the log reduction in bacteria. This is calculated using the following expression:

$$\log_{10} \frac{N_0}{N}$$

Where  $N_0$  is the number of colonies in an untreated sample, and  $N$  is the number of colonies in a treated sample.

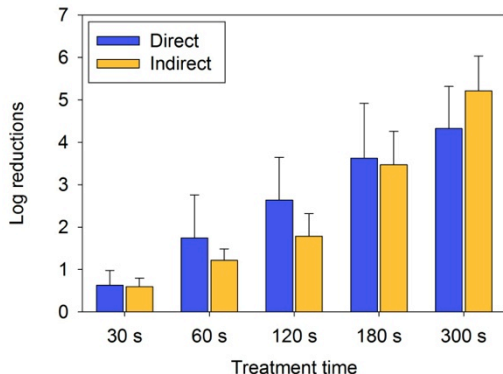
This gets shortened to "logs". 1-log means that 90% of the sample (e.g. bacteria) was inactivated. 2-log corresponds to 99%, 3-log to 99.9% and so on.

*If hand sanitizer kills 99.9% of bacteria, that is 3 log reduction*



## Plasma Treatment Disinfects Dry Surfaces

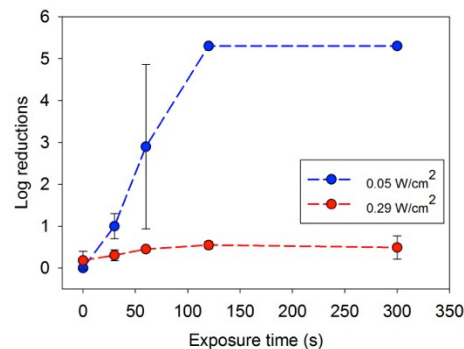
Experiments have been performed showing that stainless steel experiences at least a 5-log reduction of E.coli bacteria after 5 minutes of plasma treatment in high power mode. A 5-log reduction in bacteria is 100 times more effective than a 3-log reduction (e.g. hand sanitizer). Direct treatment involved having the plasma touch the steel. Indirect treatment simply allowed the chemicals produced by the plasma to interact with the steel. [1]



## Plasma Activated Water is Antimicrobial

Experiments have shown that treatment in both high and low power mode inactivate bacteria present in water. Low power mode achieves at least a 5-log reduction in bacteria after two minutes of plasma treatment. [2]

High power mode is only effective under longer treatment times. One benefit of plasma activated water (PAW) generated in high power mode, is that it remains antimicrobial for days after treatment. After being plasma treated for 20 minutes, the PAW was allowed to "age" for varying amounts of time before bacteria was introduced. Even after 4 days, the PAW was able to achieve more than a 3-log reduction in bacteria. [3]



## Acknowledgments and References

The laboratory science behind our technology was performed in the labs of Professor David B. Graves and Professor Douglas Clark (UC Berkeley). Other team members and collaborators include Pritha Hait, Luis Gonzalez, and Leo Kao (UC Berkeley) and Professor Zdenko Machala (on leave from Comenius University, Slovakia).

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References: [1] Pavlovich et al., Plasma Processes and Polymers 10 (2013), 69-76; [2] Pavlovich et al., J. Phys. D: Applied Physics 46 (2013), 145202; [3] T aylor et al., J. Phys. D: Applied Physics 44 (2011), 472001

