Reaching beyond the surface in plasma treatments

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Cold atmospheric pressure plasmas have been shown to possess bactericidal potential. Many research groups are looking into developing biomedical applications for plasma; however some big questions still remain. There are several main hurdles that need to be jumped before plasma has a chance to break through into the medical treatments market, one of these is penetration. Can plasma penetrate beyond the surface and reach cells beyond those on the surface? Can we make plasma treatments to penetrate, for example, through skin?

This research looks into whether a 'plasma injection system' can be developed to fire droplets of water through plasma and penetrate skin. Previous research has shown that penetration of water jets (2.5-6µL of fluid) into the skin is possible. We are looking at much lower volumes of fluid to be injected in a repetitive droplet firing system as opposed to a jet. Our current system uses a piezo-electric actuator that drives a syringe plunge to fire water droplets out of an orifice with a diameter that ranges between 50µm and 200µm.

These droplets travel between two plasma electrodes that are used to generate an RF plasma. The plasma is modulated as a means to control the gas temperature of the discharge, and the injection system and the RF generator are synchronised to control that the injected water droplets transit between the electrodes when the plasma is active. At high input power, the droplets can be fully evaporated and with large droplets the discharge gets quenched. At lower input power, however, droplets can transit the plasma without evaporating and undergo reactions with the background plasma, up-taking reactive species such as H_2O_2.The droplet then carries on to the surface of the skin model where they have enough momentum to penetrate and reach beyond the outer surface.

Preliminary results show that penetration of the droplets into artificial skin (agar)[1,2] is possible and that fired droplets of low concentrations of hydrogen peroxide can kill bacteria, such as *Escherichia coli*, embedded in it.

Future work entails developing a stronger firing mechanism to deliver droplets with even higher velocity, therefore being able to penetrate targets with even smaller droplets and measurements of the concentration of hydrogen peroxide in the droplets after passing through the plasma.

1. J. Li et al., J. Biomech. Eng. **132**, 101005-1 (2010)
2. J Stachowiak et al., J Control. Release **135**, 104 (2009)