Plasma medicine, application of plasma for wound sterilization

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Research in the field of atmospheric plasma sources has been quite active, because the atmospheric plasma combine many advantages, such as low cost, simple design and easy handling. Ever since such non-thermal atmospheric discharge sources were established, various medical applications have been investigated with growing interest. Even in a room-temperature plasma at atmospheric pressure, many chemical reactions are expected due to the high energy electrons that are produced. This can be utilized for the cleaning of medical equipment. In addition, with atmospheric plasmas it is possible to treat substances which are not resistant to vacuum, such as living organisms. A contact-free treatment can be achieved without any heating and painful sensation. Moreover, plasma treatment is different from antibiotics since bacteria don’t look to acquire drug resistance.

For hospitalisation of dermatological patients infectious skin diseases caused by bacteria are one of the main reasons. Standard treatments for these wounds, i.e. topical and systemic antibacterial regimens, are often limited by the development of resistance of germs to antibiotics and allergic reactions.

In our group, a new plasma device (a microwave plasma torch) at atmospheric pressure has been developed and tested with a view to applying this new technique to the therapy of chronic foot and leg ulcers.

Our plasma torch consists of 6 stainless steel electrodes placed inside an aluminum cylinder of 135 mm in length. The centers of the 6 electrodes, whose surfaces are serrated, are distributed equally at a distance of 6 mm from the inner surface of the cylinder. The size of the torch’s opening is 35 mm in diameter. Ar of 2.2 slm is applied from the base of the electrodes through a shower plate which regulates gas flow around the electrodes. Microwave power at 2.45 GHz is applied to the electrodes through coaxial cables via a 2 stub tuner. The input power is 80 W. Six plasmas are produced between each of the electrode's tips and the inner surface of the cylinder.

We have investigated the axial profile of the gas temperature and the floating potential of the mesh grid electrode as well as the UV light power. In the vicinity of the torch, the gas temperature is relatively high (over 500 K). However, around 8 mm away from the torch, the gas temperature decreases drastically. As the distance from the torch increases further, the temperature decreases more gradually. At the position of 17 mm away from the torch, the temperature is 301 K, low enough for ‘in-vivo’ application. There are charged particles at this position because the floating potential of the electrode is not 0. The UV light intensity at the position is measured by a UV power meter which has sensitivity between 160 and 380 nm. From the plasma, the UV power density is 90 $\mu W/cm^2$ which is not much because this light intensity is in the same order of that from the sun. On the other hand, we need more discussion because the plasma spectrum has many peaks while the sun light has a continuous spectrum.

When an *Escherichia coli* (and other bacteria relevant to wound healing) culture is placed at a position 17 mm below the torch, where the gas temperature is sufficiently cool (301 K), for 2 minutes, the bacteria are almost completely killed in a 40 mm diameter circle. We consider that this technique could be used for different medical applications. Therefore we have started a clinical study for the therapy of chronic foot and leg ulcers. In the talk, the plasma property as well as the results from the clinical study are discussed.