SDBD plasma jet for skin disinfection

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Résumé

A consortium consisting of the research institute TNO, the medical university and hospital St Radboud and two industrial enterprises is working on a non-thermal plasma treatment method for skin and wound disinfection. The group is seeking for cooperation, in particular in the field validation methods and potential standardization for plasma based disinfection procedures. The present paper briefly presents the technical progress in plasma source development together with initial microbiological data obtained.

Introduction

Hand hygiene is an important topic in hospitals and medical practices as it reduces transmission of infectious diseases. Frequently applied disinfection of hands and underarms by available alcohol based disinfectants is time demanding, results in a too dry skin and often causes skin irritation. This research project is aimed at a standardized plasma-based hand disinfection procedure in accordance with basic disinfection requirements, without drawbacks of current methods, to be safely applicable and available at affordable cost.

Plasma produced in ambient or nitrogen enriched humid air produces a variety of reactive oxygen- and nitrogen species (ROS, RNS) such as the superoxide anion O_2^- and nitric oxide NO. Directed to a wet surface, transferred plasma species create secondary reactive products in solution such as peroxides. One must be aware of the fact that in the biomedical research field those chemical reactive species are not only known from other types of sources (UV, ionizing radiation) but even more that many of them are produced by cells themselves. Enzymatic production of reactive oxygen species naturally occurs in cells and cell membranes. Selected ROS and RNS may be subject to transmission through cell membranes, and may have functions in cellular signaling essential for the proper development and proliferation of cells, wound response and healing.

Different types of plasma sources which are under investigation for medical application can be classified according various criteria such as electric energy coupling modes (microwave, dielectric barrier and arc discharges), gas composition and flow as well as 'location' of the ionizing high electric field region either in vicinity of the skin/wound, at remote distance from it or a combination of both. Though plasma generation at the skin surface is possible even at low voltage potential, the remote generation of reactive plasma species is preferable for reasons of increased safety and reduced dependence of skin conductivity and morphology. In plasma jets fast transport of neutral and charged reactive species to the substrate is achieved with a forced flow. There is growing recognition that at least for N_2-O_2 mixtures, transport of ROS and RNS is of critical importance while UV radiation and electric field induced electroporation play a minor role in microbial inactivation at the remote surface [1]. However, influence of composition, temperature and flow of the plasma produced gas on skin/wound disinfection still needs further investigation in order to standardize the treatment.

Plasma source characterisation

A plasma jet source has been constructed which uses an alumina ceramic tube having an inner temperature conditioned high voltage conductor and is positioned at adjustable distance from the surface to be treated. Two parallel flattened surfaces of this tube form a thin gas space with the adjacent exterior electrode. The exterior electrodes have protruding ribs touching the ceramic and serving as starting points for a large number density of discharges on the ceramic surface. The surface discharges are created in volume spaces of 5x5xd mm^3. Different structures allow selecting the thickness d as 100, 200 or 500 micron. Figure 1 shows different aspects of the system which includes a movable substrate table which can be moved as adjustable speeds below the plasma jet source and a liquid spray unit.

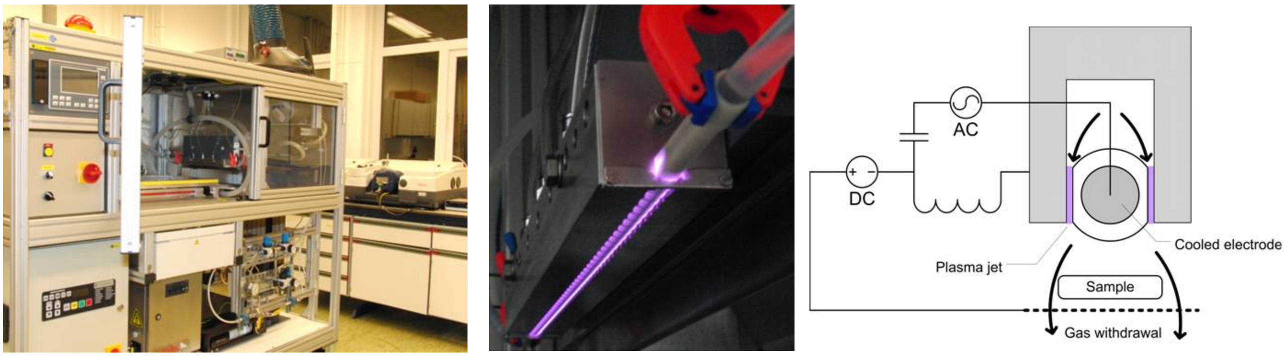

Fig. 1: (left) Test unit with movable substrate table, spray and gas withdrawal systems, (centre) tubular cooled SDBD plasma jet source, (right) electrode cross section with unipolar charging circuit.

This plasma jet source is characterised by fast transport of reactive plasma species in a modest gas flow, effective temperature control of the ceramic allowing a high power density (up to 1000 Watt/300 mm tube length), gas temperature controlled ratio ROS/RNS and regulated electrical charging using asymmetric pulse amplitudes or a superimposed DC+AC potential (WO2008082297, WO2010047593). Using the finite element software package Comsol the temperature and flow field have been calculated as shown in Figure 2.

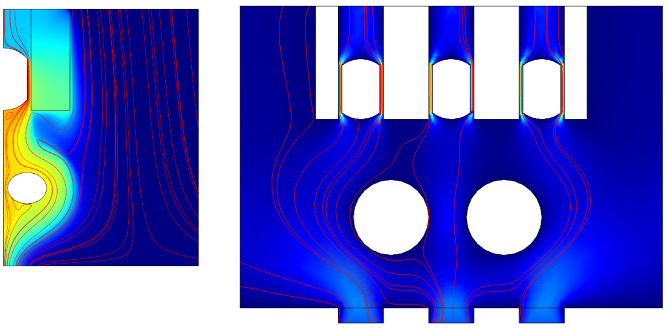

Fig. 2: Examples of FEM calculations showing the effects of gas transport around objects, (left) temperature distribution resulting from a single electrode structure (red=330K, yellow = 310K), (right) gas flow field using 3 parallel electrode structures. Applied flow conditions are 3 L/min/cm, total gas withdrawal flow is 2x the gas supply flow. The calculations show the importance of parallel jets and gas withdrawal for effective treatment of large shapes such as a human hands and underarms.

Microbiological inactivation

E. coli and *B. globigii* have been treated in dry form on glass slides (contaminated area = 20x35 mm^2). First results indicate that ~20 sec treatment at 10 mm distance from the source nozzle results in a significant reduction of colony forming units from *E. coli.* A thin film of distilled water (~0.1 mg/cm^2) causes a dramatic further increase of the inactivation efficiency. Replacing water with a 5% chloroxylenol solution is shown to cause a small but significant synergetic effect. A one log decrease of *B. globigii* spores is observed in this case as well.

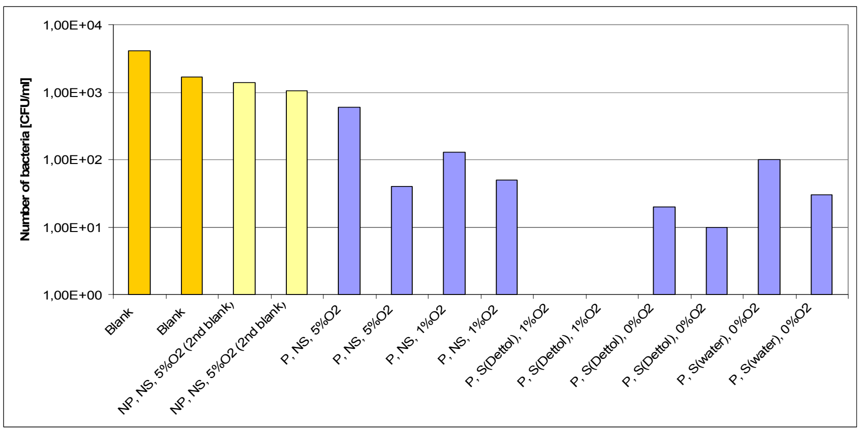

Fig. 3: Microbiological inactivation data for *E. coli* treated by a 500W plasma jet with 2 mm/s sample movement. P, NP design plasma and no plasma treatment. S, NS design spray and no spray treatment. The percentage oxygen concentration in nitrogen has been varied. Gas through the jet is heated from 25 to 40 deg ^{o}C (Neoptix optical fibre system at the nozzle outlet) while the cooling water temperature is increased from 20 to 31 ^{o}C at 25 L/h (~320 W).

References

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