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Non-Thermal Atmospheric Plasma for Use in Medical and Hygiene Application

Tetsuji Shimizu, Julia L. Zimmermann and Gregor E. Morfill

Max-Planck Institute for extraterrestrial physics, Giessenbachstr., 85748 Garching,Germany

Non-thermal atmospheric plasma is a potential tool for biomedical applications because it can produce active agents, e.g. reactive oxygen species, and the treatments without thermal damage can be achieved. By tuning the produced agents, there are many applications. In this paper, we discuss the current status of our clinical study for wound care and wound healing. And a possible application for hygiene is also discussed, in particular, hand sanitation.

1. Introduction

A research field of biomedical applications using cold atmospheric plasma is receiving a growing attention [1-4]. Cold atmospheric plasma can play an important role in medicine and hygiene since it has been found to have bactericidal/fungicidal property and regulation effect of cellular process [5]. It can be applied to living tissues without a thermal damage and be treated a rough surface in micrometer range. Such atmospheric plasma contains charged particles, reactive species, heat and photons and they can react simultaneously on tissues.

In general, plasma has an ability to permeabilize cell walls. When hot plasmas are applied, the cell walls are chemically and physically sputtered. Interestingly, even in cold plasmas this permeabilization process may take place in a different manner. There are three processes under investigation. The first is due to charging [6]. The charging results to make the cell walls spherical and introduces the surface stress. The second is due to de-excitation of excited molecules recombination of charged particles on the cell wall surface. This gives a local heating and this heat is located in a very small volume since the thermal conductivity of the cell membrane is low. This local heat can result in opening of the membrane temporarily. The third in lipid peroxidation caused by reactive species [7]. There are some reports of the cell wall opening up to possibly 5 nm in size [8].

This temporal permiabilization process allows us to introduce reactive species into the cells. Since these reactive species produced by the plasma have a high mobility, a faster process of molecular application is expected than that using fluid or ointments. For instance, a bacteria reduction (plated on agar) of 10^5 is possible in 10-20 seconds [9].

In this paper, our study in medicine and hygiene using cold atmospheric plasmas is briefly described. For medical application the current status of our clinical study in chronic wound care is discussed. For hygiene application, we demonstrate an atmospheric plasma dispenser for large area disinfection, e.g. hands.

2. Medical application: wound care

A clinical study has been carried out in collaboration with Department of Dermatology, Allergology and Environmental Medicine, Hospital Munich Schwabing, Department of Dermatology, University Hospital Regensburg, and Adtec Plasma Technology Co. Ltd. [10] Fig. 1 shows the clinical device using in the clinics for wound care. At the end of the flexible arm, an argon plasma torch is placed and the plasma is applied onto wound of

Figure 1. Clinical device for wound treatment. At the end of flexible arm, the plasma torch is placed.

patients. The plasma discharge is produced with ~80 W of microwave power at 2.45 GHz and ~2 l/min if argon flow inside the plasma torch. The produced plasma is pushed out with the argon flow toward the wounds.

Patients received standard wound care besides a two to five minutes argon plasma treatment on randomized wound(s) (add-on therapy). The bacterial load was detected by nitrocellulosis filters, which give us the germ load as well as spatial distribution of bacteria on wounds. It was found that there was a highly significant reduction of bacteria counts (~34 %, $P < 10^{-6}$) in plasma-treated area compared with control area. This reduction was observed in all kinds of bacteria including resistant bacteria, e.g. MRSA.

3. Hygiene application

A large area scalable and robust electrode design for plasma production in the ambient air has been developed and tested [9]. The electrode has an insulator plate sandwiched by a metal plate and a metal mesh electrode. By applying a high AC voltage between two metal electrodes, an air plasma discharge is formed on the mesh electrode as shown in fig. 2. In our study typically 0.5 W/cm^2 of power is applied to the electrode.

By the plasma dispenser shown in fig. 2, it was shown that a bacterial load reduction of more than five orders of magnitude was obtained in about 10 seconds for many kinds of bacteria including anti-biotic resistant bacteria. From the plasma there are many produced agents relevant to biological effects, e.g. charged particles, reactive oxygen and nitrogen species (O, O_3, NO, etc.), UV photons, etc. Our measurements showed that UV photons alone didn't have a bactericidal property. So the reactive species and charged particles paly an important role.

Figure 2. Plasma device for sanitation. Two plasma electrodes are equipped.

We are investigating a parameter window in plasma production in order to have a maximum effect in bactericidal property and a minimum effect on human cells.

There are already many researches in the usage of cold atmospheric plasmas for biomedical applications. Still a large comprehensive study involving biology, chemistry, physics, medicine, etc. is necessary and important to achieve the full potential of the technology using the cold atmospheric plasma.

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