Analysis of Reactive Species in a Plasma Flow for Medical Treatment

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ABSTRACT

Reactive species generated in Ar plasma flow produced by a microwave plasma torch were investigated to understand the interaction mechanism between the plasma and living tissues for medical applications. The measurements by gas detectors show that NO_2 is produced in the plasma flow through mixing between Ar plasma and the ambient air. In addition, OH radical was found also in the plasma flow by optical emission spectroscopy. These reactive nitrogen and oxygen species can play a role for disinfection.

1. Introduction

Recently, research in the field of biomedical applications using low temperature atmospheric plasma has received growing attention [1-3]. It can be used in medicine for the living tissue disinfection and regulation of cellular processes involved in the development of various pathological conditions as a source of biologically active agents, such as reactive species, charged particles, and ultraviolet light. Moreover, by such plasma it is possible to treat substances which are not resistant to vacuum. It is quite important to understand the interaction between these agents and living tissues for defining possible areas of plasma applications in medicine and optimizing plasma depending on the purpose. For example, for wound disinfection, there are requirements that the plasma should reduce bacterial density without producing any negative effect on human cell viability and genetic stability. Since the bactericidal effect of plasma irradiation relies mainly on mutagenic and oxidative properties of UV light and reactive species, the plasma treatments could give a harmful influence on human cells and tissues. It is critical to identify plasma components which have different effects on bacteria and mammalian cells.

For the first step, measurements of reactive species produced in the plasma flow were carried out in order to understand the interaction mechanism between the plasma and living tissues. These measurements were carried out by a gas detection system and optical emission spectroscopy.

2. Experimental setup

In our group, a small microwave plasma torch has been developed for the disinfection of biological tissue. The torch consists of a 24 mm long aluminum tube, a quartz glass and a titanium powered electrode of 1 mm in diameter with a sharpened tip as shown in fig. 1. The powered electrode is placed coaxially in the quartz tube covered by the aluminum tube. The plasma was produced between the tip of the powered electrode and the surface of the quartz tube by microwave power of 1.7 W at 2.45 GHz and Ar flow of 500 sccm (Ar purity 99.998 %). The plasma produced inside the torch flows out from the nozzle of 2 mm in diameter.

The concentrations of NO_2 and O_2 were measured by the Dräger Multiwarn II gas detector and the Hebesberger IM1000-2 oxygen meter, respectively. The reactive species profiles along the *z* direction (z shows the distance from the opening of the nozzle) were examined using spectroscopic measurements by the HAMAMATSU C10029 optical spectrometer. The optical fiber of the spectrometer was positioned perpendicular to the *z* axis. The distance between the axis and the fiber surface was 1 cm. In addition, photos of the plasma flow were taken using the HAMAMATSU C9299 UV camera equipped with the UV-Nikkor 105mm lens (Nikon). The wavelength sensitivity threshold of the camera system is ~200 nm.

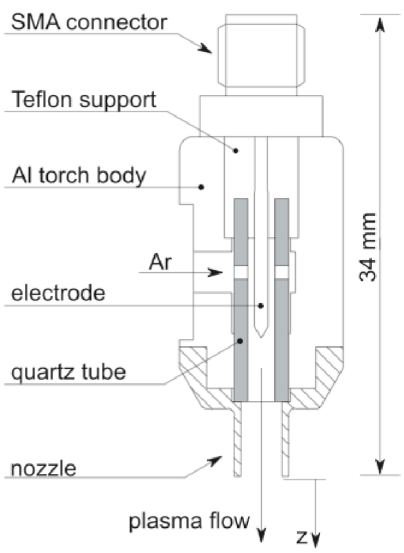

Fig. 1 Sketch of the plasma torch. Plasma is produced between the tip of the electrode and the surface of the quartz tube.

3. Results and Discussion

Figure 2 shows the profile of NO_2 and O_2 concentration. At z = 6 mm, the maximum concentration of NO_2 was observed. This indicates that the Ar plasma produced inside the torch appears to be fully mixed with the ambient air around z = 6 mm. This is supported by the measurement of oxygen concentration. In the vicinity of the nozzle, the oxygen concentration is relatively low and it increases with z. At z = 10 mm, the oxygen concentration is the same as in the ambient air.

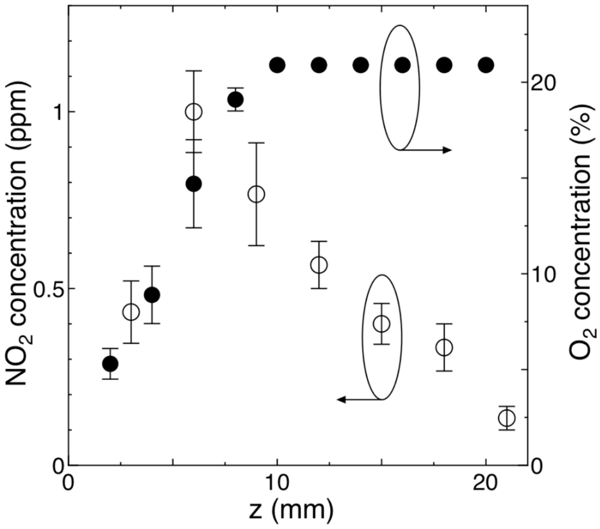

Fig. 2 NO_2 and O_2 concentrations as a function of the distance from the torch (z).

A side view of the plasma flow below the torch and optical spectra from the plasma flow are shown in fig. 3 and fig. 4, respectively. The exposure time of the photo in fig.3 was 30 s and the circles show the field of view in the spectroscopic measurements shown in fig. 4. The shape of the plasma out from the torch looks almost conical. From the spectra, Ar dominates in the vicinity of the nozzle (lines in the long wavelengths). The line at 309 nm indicates presence of OH in this region. As z increases, the light intensity decreases. The presence of reactive species is evident in the plasma flow even at z = 15 mm according to the lines in UV.

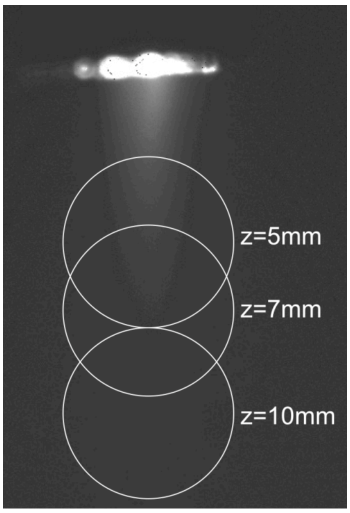

Fig. 3 Side view of the plasma flow. The exposure time was 30 s and the circles show the field of view for the optical spectroscopy measurements.

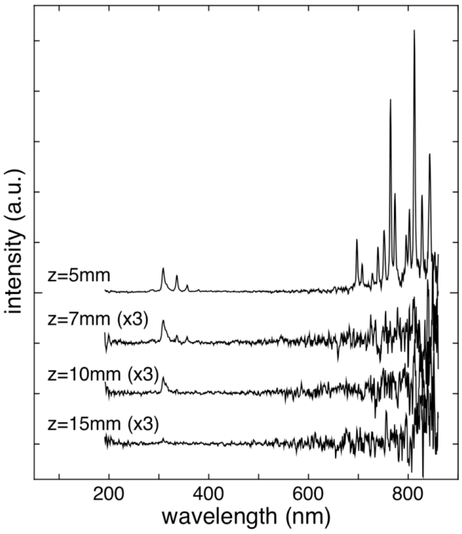

Fig. 4 Optical spectra in the plasma flow.

4. Summary

To design plasma depending on the purpose, the reactive species produced in the plasma flow were investigated. The measurements show that NO_2 was produced in the plasma flow due to the mixing of the plasma with the ambient air. The optical measurements show that OH is also produced in the plasma flow. These reactive nitrogen and oxygen species are very important for plasma applications in medicine because they have a bactericidal property.

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