Microwave Plasma Torch for Bacterial Sterilization

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An atmospheric low-gas temperature plasma torch using microwave (2.45 GHz) has been developed and applied to sterilization of Escherichia coli and other bacteria. The plasma torch consists of an Al cylinder and 6 electrodes. Ar gas of 3 slm is applied from the base of the torch and microwave power of 100 W is applied to the electrodes. Plasma discharges are produced between the tip of each electrode and the inner surface of the cylinder. At a position 28 mm away from the torch, the gas temperature is 40 degrees, sufficiently cool so that the plasma doesn’t harm living organisms. When the e-coli culture (on an agar plate) is placed at this position for 3 minutes, the bacteria are almost completely sterilized in a 40 mm diameter circle.

1. Introduction

Research in atmospheric plasma sources has been quite active, because they 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 sterilization, a fact that has been recognized 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 [1-8]. Moreover a contact-free treatment can be achieved without any heating and painful sensation.

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. In this proceeding, basic device characteristics and measurements of plasma effects on bacteria cultures are discussed.

2. Experimental apparatus

The microwave plasma torch was specially designed for the purpose of high efficiency plasma output for a given power input under low gas temperature. All the functional units, including the torch, a power supply, etc., are incorporated in a trolley. The torch is placed on a counterweighted arm in order to use it flexibly. Moreover the torch can be used vertically and at angles.

In fig. 1, a detailed view of the plasma torch is shown. The plasma torch consists of 6 Al electrodes placed inside an Al 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 diameter of the electrodes and the distance between the electrodes and the surface of the cylinder are 4 mm. The tips of the electrodes are at 20 mm from the opening of the torch. Usually the torch is placed with the principal axis perpendicular to the ground. In this study, only Ar gas (purity 99.998%) is used in order to minimize the production of toxic gases. 3-5 slm is applied from the base of the electrodes through a Teflon shower plate which regulates gas flow around the electrodes. Microwave power of 2.45 GHz is applied to the electrodes through coaxial cables via a 2 stub tuner. The input power is 90-100 W. 6 small plasmas are produced between each of the electrode's tips and the inner surface of the cylinder as shown in fig. 1.

Both the gas temperature in the plasma and the surface temperature of the agar plates are measured by a thermocouple. To obtain plasma profiles below the torch, a mesh grid electrode (20 lpi), which covers the whole opening of the torch, is used to measure floating potential.

Escherichia coli (e-coli) bacteria (and others), cultured on agar plates, are used for this study. The plasma sterilization is observed following a 16 hour incubation of the culture.

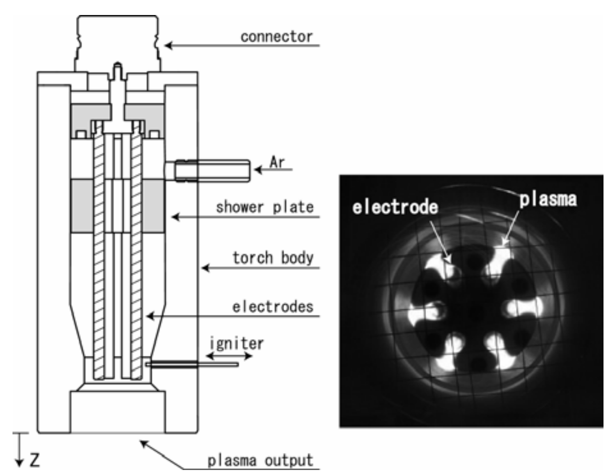

Fig. 1: Plasma torch and plasma (from plasma output).

3. Experimental results

First, we have investigated the axial profile of the gas temperature and the floating potential of the grid. In this experiment, 100 W of microwave power and 3 slm of Ar gas flow are used. The room temperature was 25 degrees. Figure 2 shows the *z*-profiles (*z*: distance from the torch) of the measured temperature at the torch axis and the floating potential of the grid electrode. In the vicinity of the torch, the gas temperature is relatively high (95 degrees). However, at z = 15 mm, the gas temperature has decreased drastically. As z increases further, the temperature decreases more gradually. At z = 28 mm, the temperature is 40 degrees, low enough so that the plasma does not harm human skin.

Inside the plasma torch the (bright) plasma production region (between the electrodes and the cylinder) is visible (fig. 1). However, the plasma flow exiting the torch is not visible. In order to determine how the plasma is distributed below the torch, the floating potential of the grid is measured. The potential also decreases as z increases, almost in the same way as the gas temperature (fig. 2).

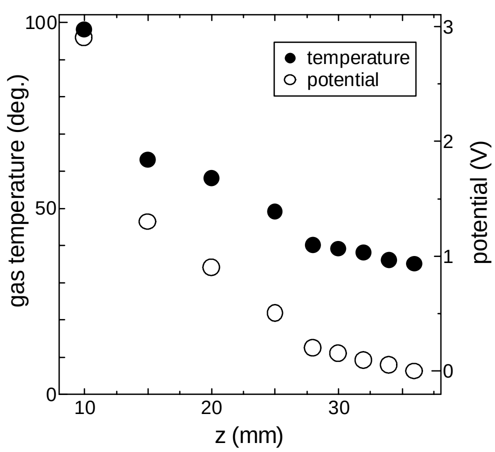

Fig. 2: Gas temperature and floating potential as a function of distance *z*.

Second, we observed the plasma exposure effect on bacteria. For example, when an e-coli culture is placed 28 mm away from the output of the torch for 3 minutes, a sterilizing effect on the bacteria can be observed as shown in fig. 3. In a circle of 40 mm diameter, a high level of sterilization has been achieved. The boundary of the sterilized area is a little fuzzy and the sterilized area is slightly larger than the opening of the torch. We measured the surface temperature of the agar plate during the treatment. In 3 minutes, the temperature increased 5.7 degrees and reached 28 degrees. Sterilization can be due to a number of effects, which are all present –charging in the plasma, radicals which are produced in the air and UV light. We are still investigating which factor is the most important for bacterial sterilization in our system.

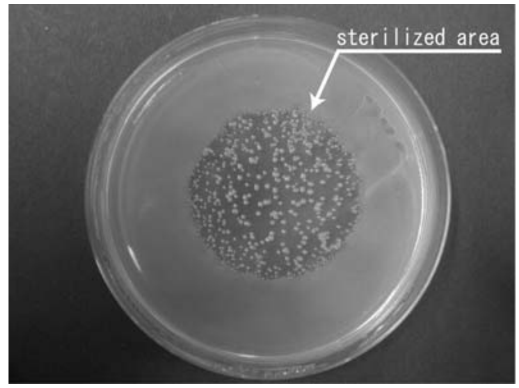

Fig. 3: E-coli culture on an agar plate after plasma treatment for 3 minutes.

4. Summary

A microwave plasma torch has been developed for the purpose of “in vivo” bacterial sterilization. Using 3 slm of Ar gas flow and 100 W of microwave power at atmospheric pressure, we obtain a plasma with suitable characteristics for medical applications and treatment. Tests with e-coli cultures (and others) have shown that bacterial sterilization occurs. We consider that this technique can be applied to the medical field, such as wound healing.

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