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Localized Plasma Treatment for Individual Cells

Ryutaro Shimane[1], Shinya Kumagai[1], Masaru Hori[2] and Minoru Sasaki[1]

[1] Toyota Technological Institute
2-12-1, Hisakata, Tenpaku-ku, Nagoya 468-8511, Japan
Phone: +81-52-809-1840 E-mail: mnr-sasaki@toyota-ti.ac.jp
[2] Nagoya University
Furo-cho, Chikusa-ku, Nagoya, Aichi 464-8603, Japan

Abstract

A micro nozzle device was fabricated towards plasma treatment for individual cells. The micro nozzle device had through-holes of ϕ5-20μm, which were smaller than typical size of a cell (several tens of micrometers). Through the nozzle device, atmospheric pressure plasma was irradiated onto a plant cell of *onion*. The plasma irradiation opened holes in the cell membranes. Such hole could be useful for drag administration. The obtained results are promising for achieving selective activation or apoptosis of individual cells.

1. Introduction

Plasma is now widely used in medical and biological fields. High reactivity of the plasma is used for sterilization and/or disinfection [1,2]. There is a report of selective killing cancer cells by plasma irradiation [3]. During the plasma treatment, tissues are exposed to the irradiation of reactive plasma species (Fig. 1). For the tailor-made treatments to the level of individual cell, the plasma treatment area should be smaller than the size of a cell. Considering the size of typical cells, the reduced area size should be 10–20μm [4]. The localized plasma irradiation, or plasma treatment enables selective activation or apoptosis of individual cells.

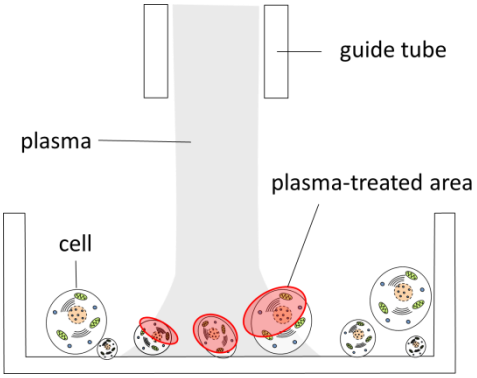

Fig.1: Schematic drawing of plasma treatment for cells.

Atmospheric pressure microplasma is ideal for the above objectives. Discharge condition is basically governed by Paschen's low. The condition is characterized by the multiple of pressure *p* and electrode gap distance *d*. Plasma ignition occurs at the *pd* which gives local minimum in the discharge curve. Under the low pressure conditions, which are used in semiconductor microfabrication, the plasma size is evaluated to several tens of centimeters. Under atmospheric pressure, the plasma size is reduced to 10–100μm. Moreover, the atmospheric pressure microplasma has 1000 times higher plasma density than conventional low pressure plasma [4]. This is advantageous for supplying large amounts of reactive plasma species for the treatment. However, there still remains a technical challenge for reducing the plasma irradiation to the sub-cell size.

In this study, a micro nozzle device was fabricated for reducing the plasma irradiation area to sub-cell size. Localized plasma treatment was conducted against a plant cell.

2. Experimental

Atmospheric pressure microplasma source

An atmospheric pressure microplasma source used was consisted of a capillary tube (O.D.: ϕ1.5mm, I.D.: ϕ1mm) and a coil antenna (Fig. 2). A floating wire was set inside the capillary tube [5]. When VHF (100MHz) power was supplied to the coil antenna, the inductive heating made the floating wire high electric potential to support plasma ignition. At the end of the source, jet of the microplasma was formed. However, the atmospheric pressure plasma was much larger than the cell. A device that reduces the plasma irradiation was needed for the individual cell treatment.

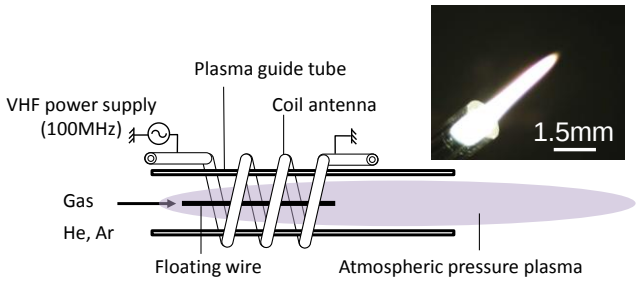

Fig.2: Schematic drawing of atmospheric pressure inductively coupled microplasma source. The inset is image of typical operation of the microplasma source.

Nozzle device for localized plasma irradiation

A plasma-nozzle device is consisted of trench and through-hole structures [Fig. 3(a)]. The through-hole is located in the center of the device. The nozzle device is attached to the end of a plasma guide tube. Output side of the nozzle device is directly contacted with a cell. The plasma treatment area is defined by the size of the through-hole [Fig. 3(b)]. The plasma gas not used is ex-

hausted through the trenches. A nozzle device was fabricated by etching of a Si substrate from front and back side Photoresist film is patterned on a Si substrate (t: 200μm) with SiO_2 layer (t: 0.2μm). The SiO_2 layer is etched with buffered HF. Trench structures are fabricated by reactive ion etching using Deep-RIE. Backside of the substrate is patterned and etched to make through-holes (ϕ5–20μm) [Fig. 3(c)]. Under He gas flow (0.5L/min), a microplasma is ignited at 20W of VHF power (100MHz). After the ignition, the gas is changed to Ar (1.0L/min), and VHF power is set to 23W. Plasma optical emissions increase significantly. During the plasma operation, membrane of the plasma-nozzle device (t: 30μm) is maintained without damage [Fig. 3(d)].

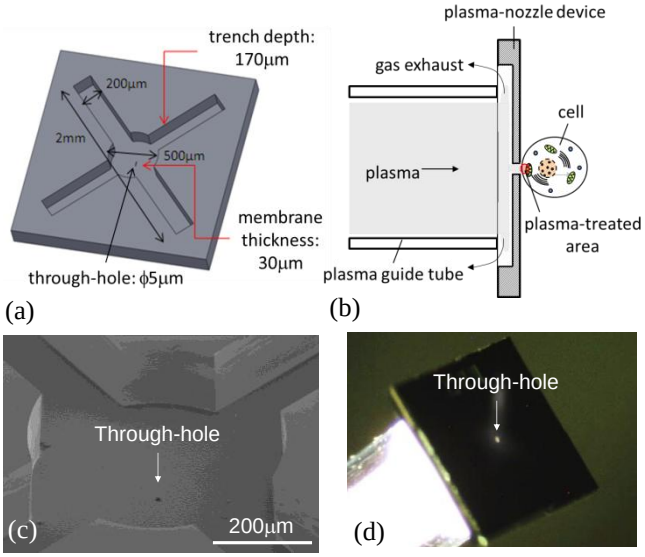

Fig.3: (a) Schematic drawing of plasma nozzle. (b) Cross-sectional drawing of localized plasma treatment. (c) Magnified SEM image of single hole nozzle device. (d) Operation of the single hole nozzle device.

3. Results and discussion

Preliminary experiment was conducted against PDMS film (t: 100μm). The PDMS film was directly attached to the output side of the plasma-nozzle device (multi-hole type, ϕ10μm) and plasma-treated. After 7 min. treatment, shapes of nozzle holes were transferred to the PDMS film [Fig. 4(a), (b)]. Sizes of the transferred patterns were ϕ5.5μm. White light interferometry revealed that the plasma-treated areas were protruded (h: 150–220nm). Localized heating or UV emission might have caused the structures. After 9 months, the plasma-irradiated sample was observed again [Fig.4 (c)]. The protruded structures were still remained in the PDMS film (h: 170–250nm). The plasma irradiation caused plastic deformation in the area.

The localized plasma treatment was conducted against a tissue of plant, *onion*. [Fig.5(a)]. The *onion* tissue was cut into block and attached with the nozzle device (multi-hole type, ϕ10μm). 5% O_2 gas was added to the main Ar gas flow (1.0L/min.) to enhance the chemical reactions. VHF power of 45W was supplied, and plasma was irradiated for 5 min. The plasma irradiation through the nozzle device opened holes in the cell membrane. The opened hole can be useful for drag administration. Size of the transferred nozzle pattern was ϕ10–15μm [Fig. 6(b)]. The onion tissue might have been deformed by the detaching process.

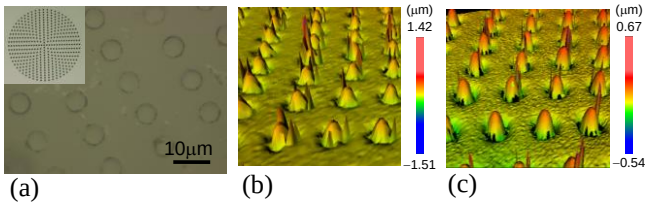

Fig.4: (a) Optical microscope image of plasma treated PDMS film surface. Size of plasma-treated area is ϕ5.5μm. (b) Surface profile of the PDMS film. (c) Surface profile measured after 9 months.

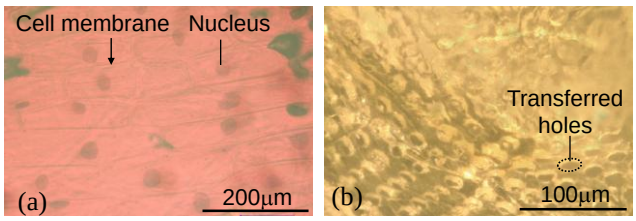

Fig.5: (a) Optical micrograph of onion tissue. The tissue is stained by acetic orcein. (b) Optical micrograph of plasma-treated onion tissue. Patterns of multi-hole nozzle are transferred.

4. Conclusions

A micro nozzle device was fabricated towards the localized plasma treatment for individual cells. Area of the plasma treatment was defined by the size of nozzle hole. Patterns of nozzle holes were transferred onto the tissue of onion. The localized plasma irradiation will be indispensable for the individual cell treatments.

Acknowledgements

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