2015년도 대한전기학회 하계학술대회 논문집 2015. 7. 15 - 17

슈퍼박테리아 감염 치료를 위한 저전압 구동 플라즈마-온-칩

임토우, **황 솔**, 김영민
홍익대학교

Low Voltage Plasma-on-a-Chip for Inactivation of Superbacteria

Towoo Lim, Sol Hwang, Youngmin Kim
Hongik University

Abstract – We report a plasma-on-a-chip (POC) which provides a non-thermal atmospheric plasma for superbacteria infection treatment A three-electrode configuration allows an initiation carrier injection prior to a primary discharge, leading to a significant reduction in a breakdown voltage. A stable non-thermal argon plasma is generated using a pulsed glow discharge and inactivation of anti-biotic resistant bacteria, for example MRSA, is successfully demonstrated by exposing the bacteria to the argon plasma in a couple of minutes.

1. 서 론

Atmospheric plasma has been of much interest for its versatile applications, such as air pollution control and spectroscopy, without an expensive vacuum system[1,2]. Recently reported are studies on plasma treatment for inactivation of bacteria[3]. Non-thermal atmospheric plasma is desirable for biological application, where heat needs to be critically controlled. Atmospheric plasma often generates excessive heat due to the high breakdown voltage of gas. A conventional two-electrode discharge must undergo the Townsend regime before reaching a glow discharge, which requires a high electric field to generate both initiation carriers and impact ionization. This results in a breakdown voltage that is greater than a discharge sustaining voltage, causing peak power consumption during the discharge to be larger than necessary. In this work, a three-electrode configuration is proposed to implement an initiation carrier injection assisted discharge. Use of the proposed device enables a non-thermal atmospheric plasma at only half of breakdown voltage needed for a conventional two electrode discharge. Also, inactivation of anti-biotic resistant bacteria (MRSA) is demonstrated by exposing the non-thermal plasma to the bacteria.

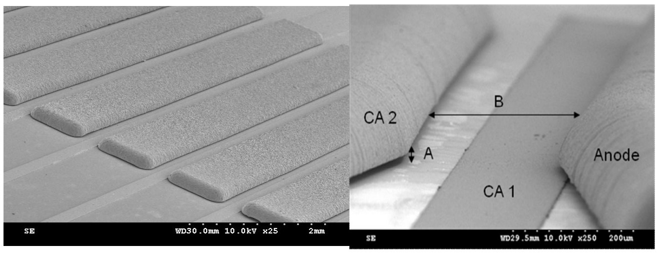
2. 본 론

2.1 Experimentals

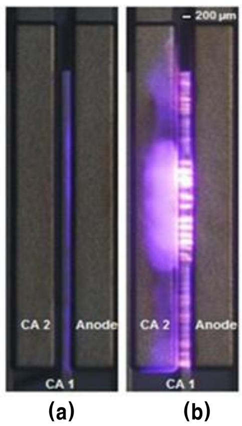
The POC was fabricated on a glass substrate using micromachining techniques. Nickel electrodes were electroplated on a patterned seed layer of Ti/Cu and a photoresist was used as a sacrificial layer to build an uniform gap between anode and cathode. More details of the fabrication process was reported in our previous work [4]. Two gaps, 10 um and 280 um, are formed in a device and shown in Fig. 1. First discharge is induced across 10 um gap and the afterglow from the first discharge is utilized as an initiation carrier for the following primary discharge across 280 um gap. In the presence of the initiation carrier, the primary discharge was obtained at a very low voltage(< 400 V). The initiation carrier injection is found to significantly lower a gas breakdown voltage, which can be as low as a discharge sustaining voltage. A photographic image of the atmospheric plasma formation along the electrode is shown in Fig. 2. The plasma is generated by a pulsed glow discharge and temperatures of the plasma is estimated by measuring optical emission intensities from a nitrogen discharge. Estimated electron and gas temperatures are 3000 K and 1000 K, respectively, suggesting non-thermal plasmas. The uniformly formed surface plasma allows efficient delivery of reactive ions to a cell without a high speed gas flow, offering an alternative to a plasma jet Also, the electron density of 5×10^{13} cm^{-3} in the plasma is estimated using a drift current model. .

2.2 Results and Discussion

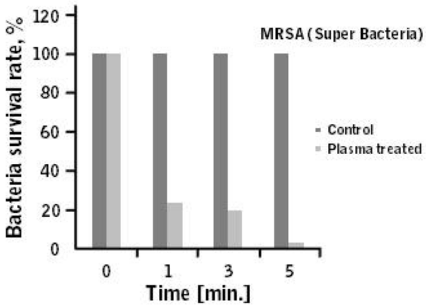
For inactivation of an anti-biotic resistant bacteria (Methicillin-Resistant Staphylococcus Aureus), an argon atmospheric plasma is generated using a 1 W pulsed glow discharge and it is formed at 1 cm above the bacterial. Diffusion of argon ions and some oxidative radicals is carried out on the cells and exposure of the chemical reactive species is found to inactivate the MRSA effectively. Fig. 3 shows measured survival rate of the MRSA after plasma treatment for a few minutes and it exhibits a strong dependence on plasma exposure durations. To investigate a possible cause for the inactivation of the bacteria, SEMs are taken for a plasma treated cell. Fig. 4 shows severely damaged cell after plasma exposure and untreated control one. Unlike chemical based antibiotic treatment, the direct treatment of plasma on the MRSA is found to result in physical damages of the cell membrane as shown in Fig. 4. Several mechanisms for the inactivation of the bacteria, such as electric field induced one or UV induced one, have been suggested, but yet to be fully understood due to the presence of mixed several species in the plasma. Further investigation to correlate a possible cause with a type of cell damages is underway.



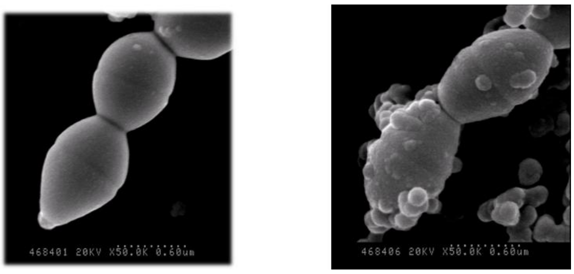
<Fig. 1> Fabricated Plasma-on-a-chip showing an array of device and a three-electrode configuration. CA1 and CA2 represents for cathode1 and cathode2, respectively.



<Fig. 2> Argon atmospheric plasma. (a) two electrode glow discharge (b) initiation carrier injected three electrode glow discharge. Lateral atmospheric plasma is uniformly generated along the electrode.



<Fig. 3> Inactivation of an anti-biotic resistant super bacteria



(a) control **(b) plasma treated**

<Fig. 4> SEM images for plasma treated cells.

3. 결 론

A non-thermal atmospheric plasma at a significantly reduced voltage is achieved by injecting initiation carriers prior to a primary discharge. A plasma-on-a-chip, integrated with an array of three-electrode discharge devices, offers a scalable non-thermal compact plasma source for medical treatments. By utilizing non-thermal Ar plasma, inactivation of antibiotic resistant bacteria, e.g., MRSA, is successfully demonstrated, suggesting an advantage of a direct plasma treatment for infection treatment.

[감사의 글]

This work was supported in part by the Korean government [Ministry of Education, Science and Technology (MEST)] under Korea Science and Engineering Foundation Grant 2009-0078875 and in part by the National Research Foundation of Korea (NRF) funded by MEST under Basic Science Research Program (Grant 2012R1A1A2006537).

[참 고 문 헌]

[1] A. Fateev, et al., Plasma Process. Polym., (2005), P.193~200.
[2] Z. Machala, et al., J. Mol. Spectroscopy, (2007), P.194~201.
[3] M. Laroussi, “Low-Temperature Plasmas for Medicine?” IEEE Trans. Plasma Sci., vol. 37, no. 6, June 2009.
[4] L. Lee and Y. Kim, "Low voltage Atmospheric Plasma Generation by utilizing afterglow initiation carrier," IEEE Trans. Plasma. Sci., vol.41, no. 1 2013.