# Development of Plasma-on-Chip: Plasma Treatment of Individual Cells using Gas-Liquid Interface

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The plasma medicine is one of the promising application fields using low-temperature plasmas at atmosphere [1]. It is based on the interaction between plasma and cells but it's mechanism has not been understood well. If the area of plasma irradiation is smaller than the size of an individual cell [2], it will be possible to trigger cell functions individually and make detailed analysis of the reactions. However, it has not been easy to irradiate plasma directly to the cells because they always need to be submerged in liquid such as culture medium. Cells will be dried and dead in short time if they were taken out from the medium during plasma treatment. To achieve the plasma irradiation for individuall cells in regular culture conditions, we are developing a MEMS device, "plasma-on-chip".

The plasma-on-chip has microwells and sources of atmospheric pressure plasma (Fig.1a). The microwells have through-holes at the bottom. When the microwells are filled with culture media, gas-liquid interface is formed at the through-holes. The opposing side has array of gap-electrodes for plasma generation. Reactive species from the plasma reach the cells through the gas-liquid interfaces fromed at aforementioned through-holes. The plasma-on-chip was fabricated using MEMS techniques (Fig.1b).

First, the microwells were filled with pure water and plasma ingnition was tested. He gas was blown to the gap-electrodes and an atmospheric pressure plasma was generated between the electrodes by applying 800V at 1kHz (Fig.2). Optical emission spectra revealed the presence of NO and OH chemical species, radicals of which are known to affect cell activities [2]. Next, a liquid containing plant cell, *Chlorella*, was poured in the microwells and plasma treatment was conducted. The activity of *Chlorella* was analyzed by fluorescence imaging. After 3 min of plasma treatment, the fluorescence intensity was decreased. The result indicates that the plasma treatment inactivated the *Chrollera*.

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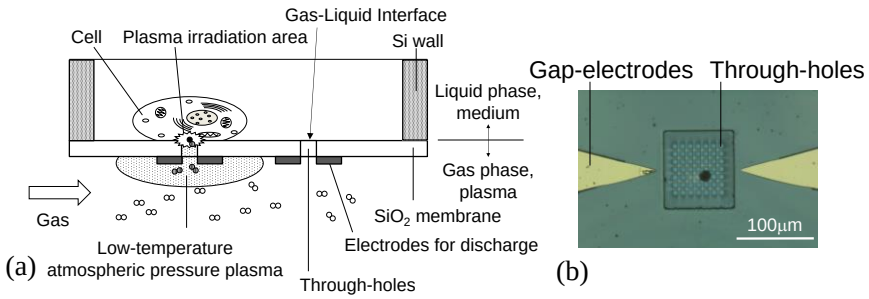


Fig. 1: Schematic drawing (a) and top view image (b) of plasma-on-tip.

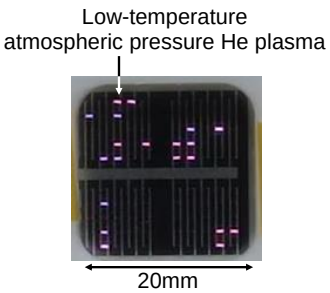


Fig. 2: Plasma discharge.

[1] Friedman et al., Plasma Process. Polym. **5**, 503 (2008). [2] Xiong et al., Stem Cell Res. **12**, 387 (2014).