Quantitative Investigation of Energy Injection and Gas Flow Rate for the Plasma Used in Gene Transfection

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On a unique gene-transfection technique using plasma irradiation developed by some of us (Sato et al.), we have been studying transfection mechanisms with various plasma sources. In this work we have quantitatively compared the performances of two sources, i.e. arc plasma and plasma jet, on the effects of the injection energy and the gas flow rate.

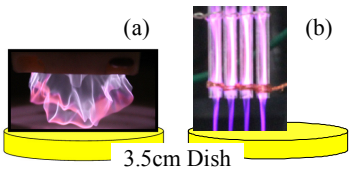

Figure 1: *Schematic of (a) arc and (b) plasma jet heads.*

Figure 1 shows schematic photos of the two plasma source heads in gene transfection: (a) arc plasma and (b) plasma jet. A sample solution containing COS 7 cells and pCX-EGFP DNAs in a Petri dish rotating at 75 rpm was exposed to each plasma for 0.2–4 s (arc head) or 10–100 s (plasma jets). The 20 kHz sinusoidal voltage of 5.8–8 kV peak to peak amplitude was applied with pulse-modulation at a frequency of 10–200 Hz and a duty ratio of 7–100% for arc head, while the 14 kHz sinusoidal voltage of 6–9 kV p-p was applied for the plasma jet head. The working gas was argon (16.8–28 slm) for the arc head and helium (0.8–9.8 slm) for the plasma jet head. After 24 h incubation, transfection rate and survival rate η were measured by fluorescence observation.

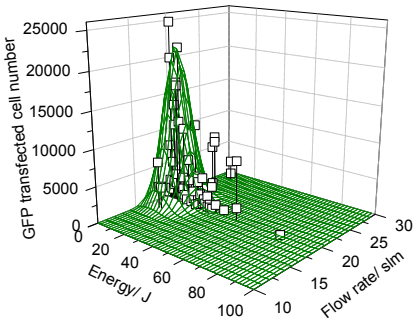

Figure 2: *Transfected cell number vs. injection energy and gas flow rate for the arc head.*

Figure 2 shows the transfected cell number n vs. the injection energy E and the gas flow rate F for the arc head. For both plasma heads, n and η have optimal values. These tendencies are fitted by Gaussian functions against E and F,

$$n = n_0 \exp\left[-\frac{(E-E_0)^2}{2w_E^{\,2}} - \frac{(F-F_0)^2}{2w_F^{\,2}}\right], \quad (1)$$

$$\eta = 0.15 + 0.85\exp\left(-\frac{E^2}{2w_E^{\,2}} - \frac{F^2}{2w_F^{\,2}}\right). \quad (2)$$

Table 1: *Fitting results.*

(a) Transfected cell number

Head	n_0	E_0/J	w_E/J	F_0/slm	w_F/slm
Arc	22 000	9	6.5	20	1.6
Jet	940	145	30	3.6	1.15

(b) Survival rate

Head	w_E/J	w_F/slm
Arc	19	10 000
Jet	450	10

Table 1 shows the specific numbers obtained by the above fitting for both plasma heads. From this result, it is found that larger injection energy (E_0) is required for the plasma jet source for the optimum n and η due to the inherent nature of localized (thin) plasma and too short duration. Moreover, the survival rate dependence on the gas flow rate (w_F) is very small for the arc head. Detailed analysis is shown at the conference.

This work was partly supported by the Grant-in-Aid (22654070) from JSPS.