# 2P5-4

# Improvement of Vibration Characteristics of Vibrator for Microinjection

## VMI 用振動子の振動特性の改良

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## 1. Introduction

We proposed the vibratory microinjection method (VMI) to improve the operation of ordinary microinjection method which is widely used as the foreign-genes introducing method. In the VMI, a micropipette is vibrated with a vibrator to facilitate pipette insertion as shown in **Fig. 1**. In particular, VMI in the ultrasonic range is effective, and the efficiency of microinjection has been greatly improved in the experiments at a frequency of 35 kHz.[2)]

However, the characteristics of the current VMI vibrator are still not ideal. In VMI, it is assumed that resonance characteristics shift due to individual micropipette and the amount of DNA solution. Therefore, it is desirable that the vibration characteristic of the VMI vibrator has flat vibration characteristics over wide bandwidth at around 35 kHz. In this research, we tried to improve the vibration characteristics of the vibrator for VMI.

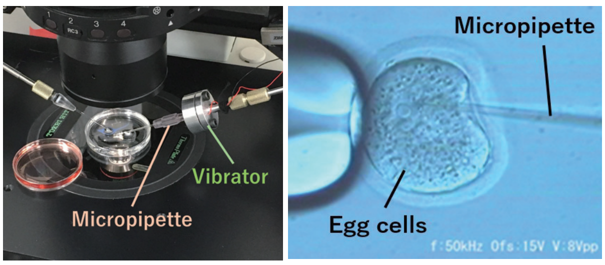


Fig. 1 Vibratory microinjection method (VMI).

## 2. Improvement of the VMI vibrator

**Fig. 2** shows the cube-shaped multilayer piezoelectric actuator (NGK SPARK PLUG CO., LTD., PAC133C) used for the VMI vibrators. Its dimensions are 3x3x3mm, and the maximum displacement at an applied voltage of 100V is 1.5 micrometers or more.

The structure of the conventional vibrator (CV) currently used in VMI is shown in **Fig. 3**. Three actuators are bonded concentrically at 120 degree intervals on the sub-plate. Actuators are pressurized by pushing the sub-plate with screws from the back of the vibrator.

**Fig. 4** shows the structure of the newly designed vibrator (NV). This is a structure that has arrived as a result of repeated trial manufacture of vibrators of various structures. Actuators are bonded directly to the rear housing without using the sub-plate. Actuators are pressurized by directly tightening the front and rear housings with hexagon socket head cap screws. The appearance of the prototype vibrator is shown in **Fig. 5**.

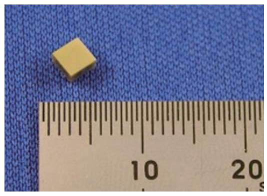


Fig. 2 Cube-shaped multilayer piezoelectric actuator (PAC133C).

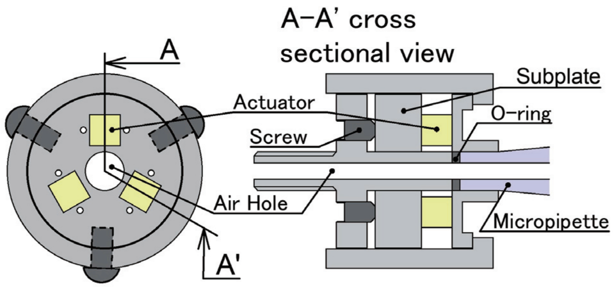


Fig. 3 Conventional VMI vibrator.

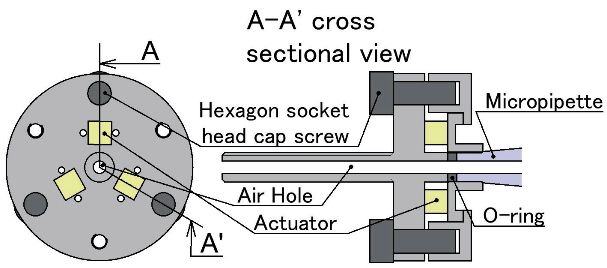


Fig. 4 Newly designed VMI vibrator.

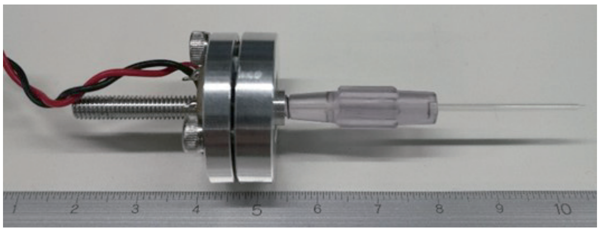

Fig. 5 Appearance of prototype vibrator.

## 3. Vibration characteristics of the actuators

The optical displacement sensor system of our laboratory[3)] was used for the measurement of vibration characteristics of the vibrators. The longitudinal vibrations at the front housing of the vibrators were measured. The AC and DC components of the driving voltage of the vibrator were set to 10 Vpp and 10 V, respectively.

**Fig. 6** shows a comparison of frequency characteristics of the vibration between the CV and the NV. The NV was measured up to 50 kHz, but the CV was measured up to 40 kHz because of the large resonance at around 40 kHz, which could cause the overheat generation. The CV has a relatively narrow flat characteristic around 35kHz, while the NV has a relatively wide flat characteristic above 35 kHz, especially from 41 kHz to 48 kHz. As explained in the introduction, this kind of flat frequency response is ideal for VMI vibrators.

The dependencies of the characteristics of the NV vibration on the tightening torque of the hexagon socket head screws were also evaluated by using a torque driver. **Fig.7** shows the results. At a relatively weak tightening torque of 3.6 cNm, small peaks and dips are observed over the frequency range from 34 kHz to 40 kHz. On the other hand, at a relatively strong tightening torque of 5.2 cNm, large dip exists at around 37 kHz, and the vibration level is gradually decreasing above 41 kHz. As a result, the appropriate tightening torque was 4.4 cNm, and at that value relatively flat frequency characteristic was obtained over a wide frequency range above 35 kHz.

## 4. Conclusion

In order to realize the ideal vibration characteristics of the VMI vibrator, a vibrator with a new structure was designed and prototyped. As a result of adjusting the screw tightening torque, ideal frequency characteristics with relatively flat response over a wide frequency range in the ultrasonic region, where good results were obtained with VMI, were realized.

However, the reason why such ideal characteristics can be realized is not clear at this stage. Based on the knowledge from the various prototypes we made, it is clear that the tightening screw part has an effect, but detail is not clear so far. In the next stage, we will try to clarify its reason by the simulations using the finite element method, and try to improve its characteristics further.

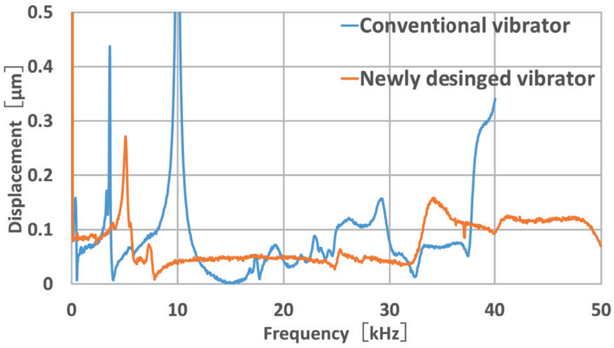


Fig. 6 Comparison of frequency characteristics of the vibrations of VMI vibrators.

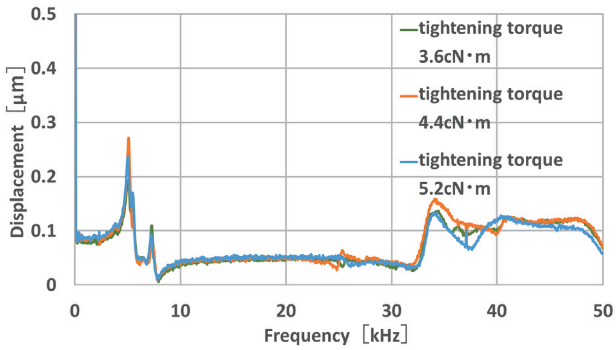


Fig. 7 Tightening torque dependencies of the vibration characteristics of the newly designed VMI vibrator.

## References

1. J. Hasegawa, K. Kobayashi and F. Miyawaki: Proc. of USE2010. **31** (2010) 511-512
2. D. Kudereti, F. Miyawaki, K. Kobayashi and J. Hasegawa: J. Mamm. Ova Res. **29** (2012) 48-54
3. A. Seki and J. Hasegawa: Proc. of the JSEM Joint Workshop on Experimental Techniques 2015. **15-2** (2015) 14-18