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Development of Actuators for the Vibratory Microinjection
マイクロインジェクション用振動子の開発

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1. Introduction

The microinjection method is widely used as the foreign-genes introducing method. However, technical skills are required to operate micropipette insertion adequately. One of the major technical difficulties is the large deformation of the egg cells. The vibratory microinjection (**VM**) was proposed to improve the conventional method (ordinary microinjection: **OM**), and actuators to vibrate the micropipette were developed.

2. Actuators for the vibratory microinjection

We developed three types of actuators for VM. **Figures 1-3** show the structures of them. They have one or more multilayer piezoelectric ceramic actuator sandwiched between the parts of housing made of duralumin. Vibrations of the ceramic are transmitted via the housing to a micropipette fixed at the front surface of the housing. A thin hole is made in the center of the housing to let compressed air go through.

The actuator shown in Fig.1 is the first prototype and has a cylinder type ceramic actuator (NEC TOKIN CORP.: AER type, fr=75kHz). This was named VM Actuator for audible range (VMA-A1) since its frequency bandwidth for practical use was up to around 15kHz due to the relatively low resonant frequency of AER actuator.

The actuators shown in Figs. 2 and 3 are VM Actuators for ultrasonic range (VMA-US1 and VMA-US2) and have three cubic type ceramic actuators (Nihon Ceratec Co., Ltd.: PAC-133-C, fr>500kHz) of 3mm. In VMA-US1, housing parts are tightened with three screws, while they are tightened by the whole circumference edge of the front housing part in VMA-US2.

A piezodriver with built-in oscillator (NF CORP.: As-310-1) is used to drive those actuators.

VMA-A1 and VMA-US1 were evaluated under the injection experiment after the evaluation of their vibration characteristic. VMA-US2 is not yet used for injection.

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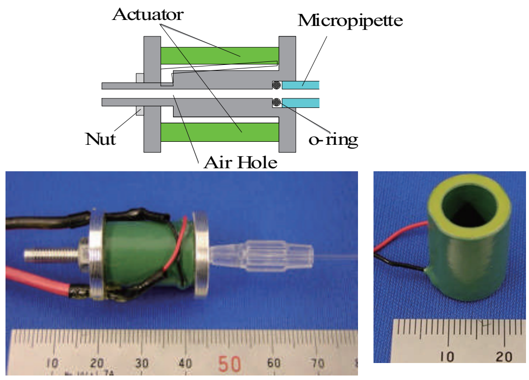

Fig. 1 VM Actuator for audible range (VMA-A1).

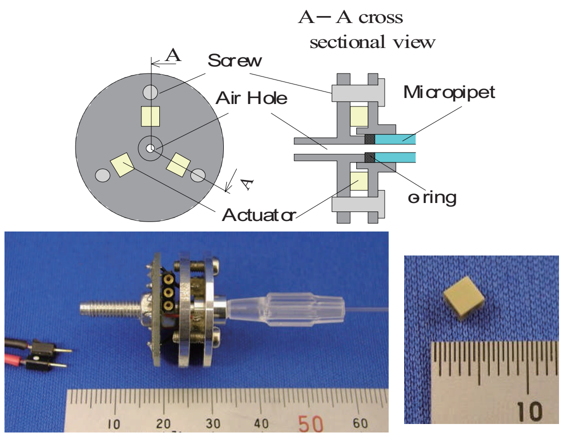

Fig. 2 VM Actuator for ultrasonic range (VMA-US1)

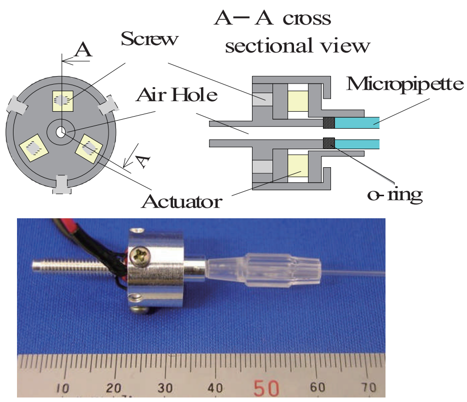

Fig. 3 VM Actuator for ultrasonic range (VMA-US2)

3. Vibration characteristics of the actuators

A reflection type optical displacement sensor system was used for the evaluation of the vibration characteristics. (**Fig.4**) This sensor system has the characteristics of frequency bandwidth of 80kHz, displacement resolution of 10nm, and displacement dynamic range of more than 90dB. For evaluation of three-dimensional movement of the pipette tip, a small acrylic cube with reflecting surfaces was fixed on the pipette tip. For the measurement of actuator itself, a small light reflector was fixed instead of a pipette.

3D vibration characteristics of the pipette tip of VMA-A1 and VMA-US1 with the driving voltage of 5Vp-p are shown in **Fig.5** and **Fig.6** respectively. VMA-US1 had more peaks and dips in the frequency characteristics than VMA-A1. Since this problem was considered to be based on the asymmetric structure of the actuator, VMA-US2 was newly developed to solve the problem. Not only the frequency characteristic but also the vibration amplitude was improved in VMA-US2 evidently. **Fig.7** shows the example of the comparison of vibration amplitude of VMA-US2 with that of VMA-US1.

4. Injection experiment

VM was compared with OM by experiments to inject Venus gene to the fertilized eggs of the mouse. It was found that VM improved the deformation rate of the fertilized eggs remarkably. This tendency was more evident in the ultrasonic frequency range. Fig.8 shows an example of those deformations. In addition, development rate of fertilized eggs was improved, too. Furthermore, the events of pulling out the nuclear DNA decreased. As a result, VM improved efficiency of the microinjection.

5. Conclusion

We developed several types of actuator for VM, and it was confirmed that the VM improves the operation of microinjection remarkably and that vibrations in the ultrasonic range are more effective than those in the audible range.

References

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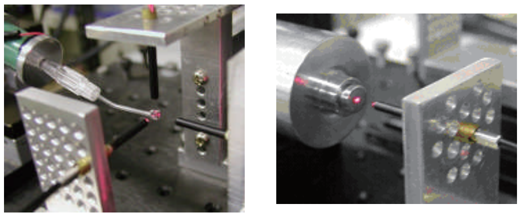

Fig. 4 Settings for vibration measurements.
(Left: 3D vibrations of pipette. Right: actuator.)

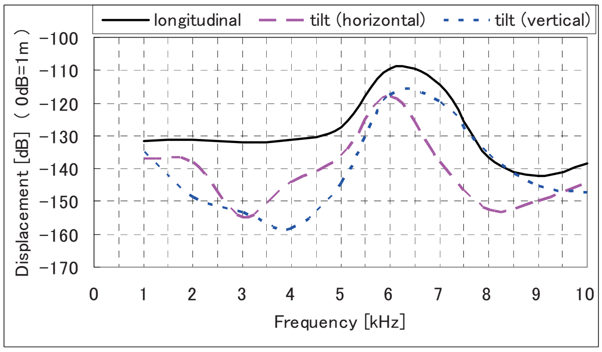

Fig. 5 3D vibrations of pipette driven by VMA-A1.

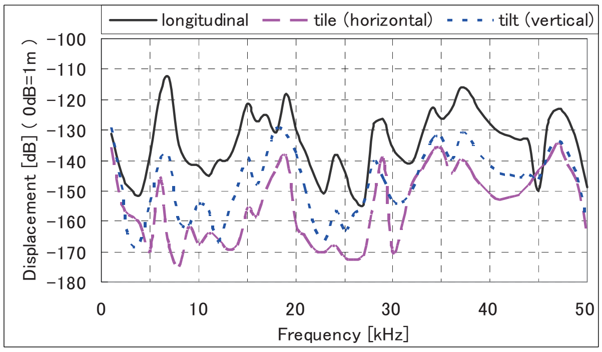

Fig. 6 3D vibrations of pipette driven by VMA-US1.

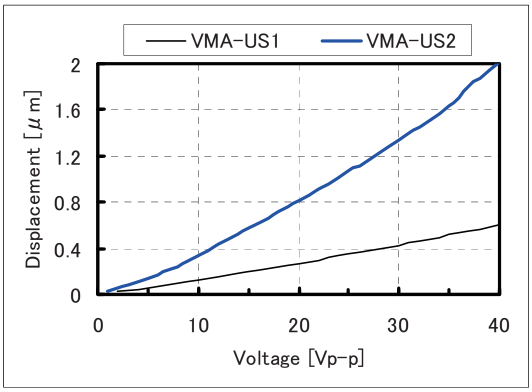

Fig. 7 Displacements of the center of the actuators.
(Comparison of VMA-US2 with VMA-US1)

Fig. 8 Samples of deformation of the egg cell.