1P4-4

# A Novel Approach to Swimmer Actuation via Surface Acoustic Wave

弾性表面波による新型スイマーアクチュエータ

Deqing Kong[1‡], Minoru Kuribayashi Kurosawa[1]
([1]Tokyo Institute of Technology)
孔　徳卿[1‡]，黒澤　実[1]（[1]東京工業大学）

## 1. Introduction

Robotic swimmer represents a rapidly emerging and fascinating research area. Particularly, small size swimmer is attempt to be a drug carrier or fixer inside the human body. Simultaneously, acoustic microfluidics represents one of very few inertial phenomena that may actually play a significant role in microfluidic devices. In this study, a novel approach to the swimmer actuator via surface acoustic wave (SAW) is first proposed in the world. Surface acoustic wave is excited with a unidirectional interdigital transducer in the 128˚ y-rotated x-propagation lithium niobate substrate. The velocity and thrust of the swimmer are measured.

## 2. U-IDT Actuator

Leaky surface acoustic wave (LSAW), converted from Rayleigh wave, propagates along the boundary surface between the solid and liquid, as shown in Fig 1. Simultaneously, a pour longitudinal wave is excited into the water with the Rayleigh angle of $\theta_R$,[1)]

$$\theta_R = \sin^{-1}\frac{v_l}{v_R}\ , \qquad (1)$$

where $v_l$ is the velocity of the longitudinal wave in liquid, $v_R$ is the propagation velocity of Rayleigh wave in solid. $\theta_R$ can be calculated to 22˚ form $v_l$ = 1492 m/s and $v_R$ = 3980 m/s, where 128˚ y-rotated x-propagation lithium niobate substrate is set into water.

A acoustic radiation force is caused by the the longitudinal wave in water. Acoustic radiation force represents one of very few inertial phenomena that may be a feasibility as the acoustic propulsion of swimmer. To investigate acoustic radiation force for swimmer, a schematic view of the swimmer with SAW is displayed in Fig. 2. The unidirectional interdigital transducer (U-IDT) actuator is utilized to generate the acoustic radiation force in water, as the acoustic propulsion of the swimmer. A kickboard is set to make the swimmer float in water. An angle $\theta$ is kept between the U-IDT actuator and the kickboard to make the horizontal acoustic streaming propulsion in the rear of swimmer. $\theta$ is

$$\theta = \frac{\pi}{2} - \theta_R\ . \qquad (2)$$

Because of 22˚ $\theta_R$ from equation (1), where 128˚ y-rotated x-propagation lithium niobate substrate is set into water. $\theta$ can be estimated to 68˚.

To generate the unidirectional acoustic radiation force in water, a U-IDT actuator was designed. After the simulation, the parameters of the U-IDT were determined and are shown in Fig. 3 and Table I,[2)] where the driving frequency was 9.61 MHz.

## 3. Fabrication and Measurements

The U-IDT actuator was fabricated by the surface micro-machining process. The substrate was 128˚ y-rotated x-propagation lithium niobate. Aluminum were deposited by sputtering process to

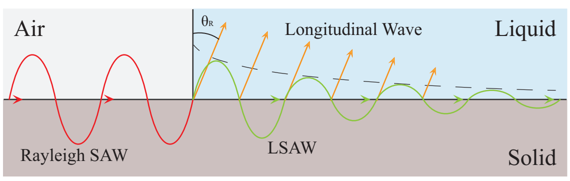


Fig. 1 Acoustic radiation into liquid by SAW.

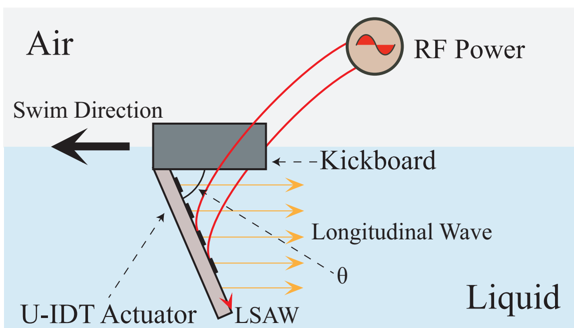


Fig. 2 Schematic view of a swimmer by SAW.

E-mail address: kong.d.aa@m.titech.ac.jp

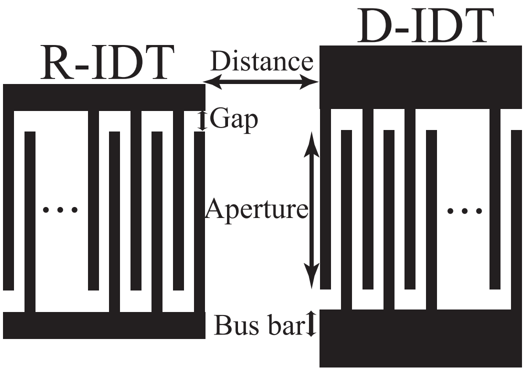


Fig. 3 Geometry of U-IDT.

Table I Parameters of U-IDT.

| | D-IDT | R-IDT |
|---|---|---|
| Periodic length (μm) | 400 | 414 |
| Strip-electrode pairs | 21 | 32 |
| Aperture (mm) | 9 | 9 |
| Bus bar (μm) | 3000 | 1750 |
| Gap (μm) | 300 | |
| Distance (μm) | 858.5 | |
| Metallization ratio | 0.5 | |

form the IDT. The admittance characteristics of the U-IDT were measured using a precision impedance analyzer as shown in Fig. 4.

A prototype swimmer is displayed in Fig. 5. The dimension of U-IDT actuator are 27 mm by 16 mm and 1 mm in thickness. At 9.61 MHz driving frequency, the velocities of the swimmer versus the driving voltage was shown in Fig. 6. The velocity was measured out, when the driving voltage was up to 85 $V_{pp}$. At 225 $V_{pp}$ driving voltage, 0.1 m/s velocity was confirmed. Furthermore, The thrust of the swimmer was measured with a force gauge; the sensor head was connected to the back of the swimmer. The thrusts of the swimmer versus the driving voltage was shown in Fig. 6. Even the swimmer did not move less than 30 $V_{rms}$ driving voltage. 0.25 N thrust was measured at 225 $V_{pp}$.

## 4. Conclusions

The SAW swimmer actuator is first presented and demonstrated in the world. The evidences of movement and force were confirmed in water by the measurements. Because the miniaturized SAW device is simple, the SAW swimmer actuator can be expected for the small robot inside the human body.

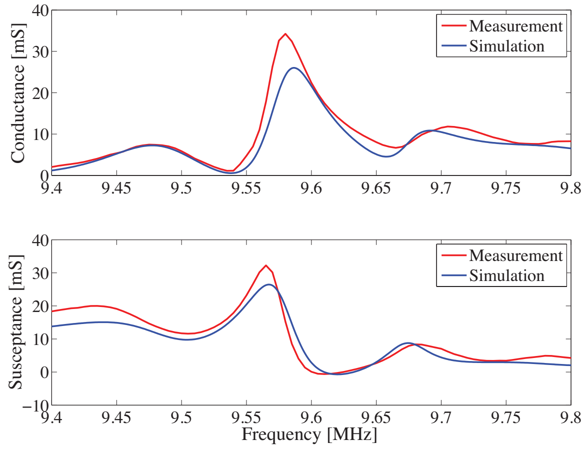


Fig. 4 Admittance characteristic of U-IDT actuator.

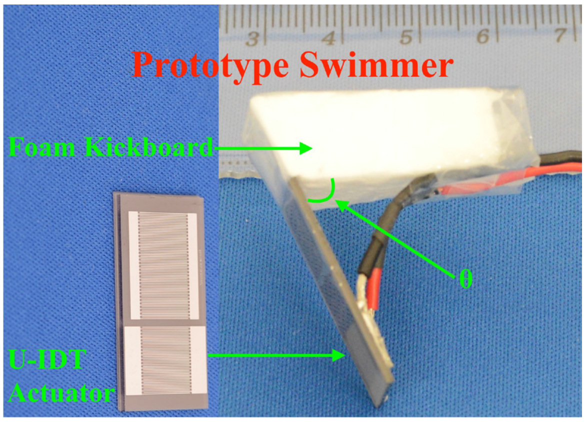


Fig. 5 Prototype swimmer for experiment.

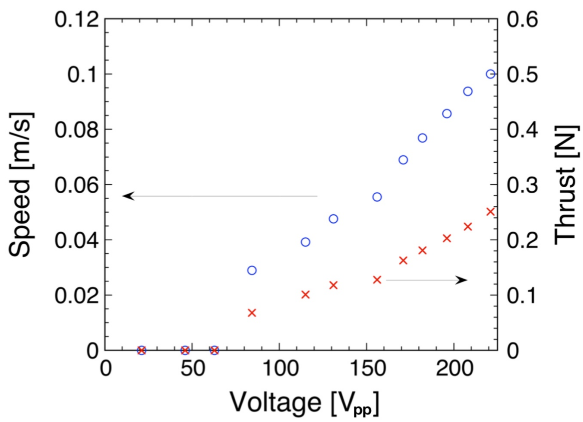


Fig. 6 Speed and thrust of swimmer by diverse voltages.

## 5. Acknowledgement

The authors wish to thank the The Japan Keirin Association Foundation (JKA Foundation) for providing research funds.

## References

1. S. Shiokawa, Y. Matsui and T. Moriizumi, Jpn. J. Apple. Pays. **28** (1989), pp. 126.
2. D. Kong and M. K. Kurosawa, Jpn. J. Appl. Phys. **54** (2015), 07HB01.