ULTRAHIGH SPEED CELL MANIPULATION BY ROBOT ON A CHIP:
A Levitated Structure with Three-Dimensionally Patterned Surface

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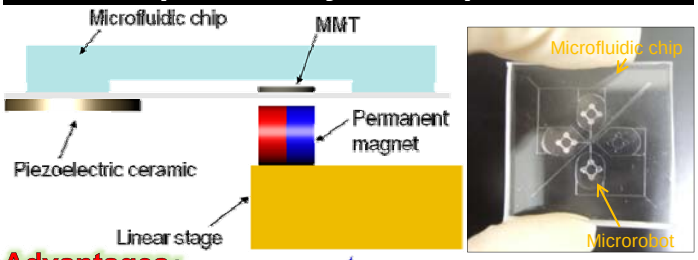
What's New ? : Fluid friction reduction of microrobot by riblet surface

1. Background

Cell Manipulation by On-chip Robot

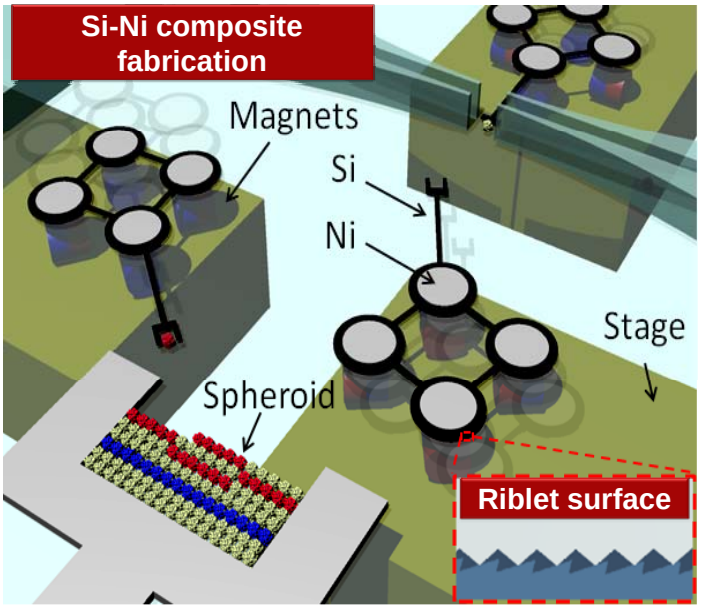


Advantages:
- Strong output force (mN)
- Precise accuracy (μm)

- Velocity dependent
- Ni is NOT biocompatible

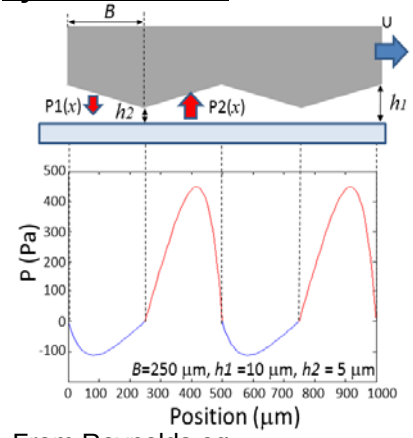
2. Concept

Si-Ni composite fabrication



3. Design

Friction Reduction by riblet surface



From Reynolds eq.

$$P_1 = \frac{6\eta UB}{h_1^2}\frac{1}{a-1}\{\frac{a}{1+a}(\frac{1}{\bar{h}^2}-\frac{1}{a^2})-\frac{1}{\bar{h}}+\frac{1}{a}\}$$

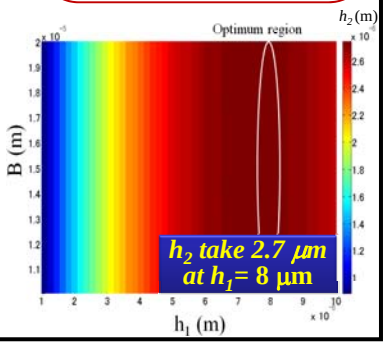
$$P_2 = \frac{6\eta UB}{h_2^2}\frac{1}{a-1}\{\frac{1}{\bar{h}}-\frac{1}{a}-\frac{a}{1+a}(\frac{1}{\bar{h}^2}-\frac{1}{a^2})\}$$

Design Optimization

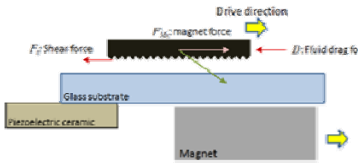
Maximize
h_2 (lubrican thickness)

Design Variables
h_1 (depth), B (width)

Constraints
$F_{gravity} + F_{magnet} + F_{fluid} = 0$



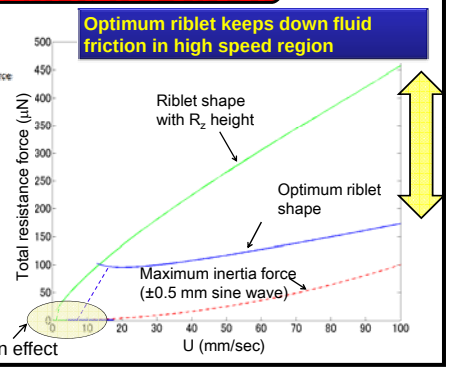
4. Analysis of optimum riblet effect



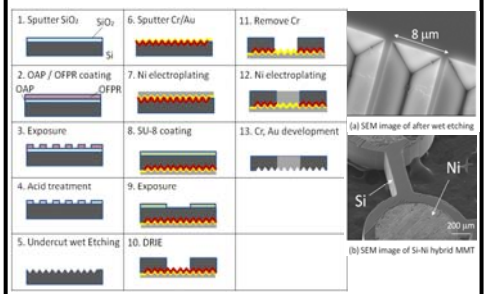
$$m\frac{dU}{dt} = F_{Mx} - D(U) - F_t(U)$$

Drag force: $D(U) = \frac{C_D}{2}\rho U^2 A$

Shear force: $F_t(U) = \mu\frac{dU}{dh_2}\cdot A$



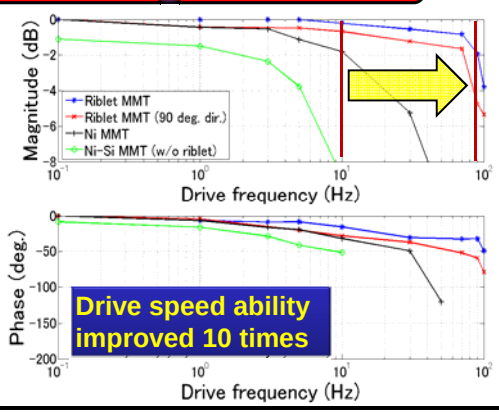
5. Fabrication



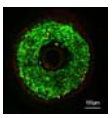
Riblet surface ➡ Wet etching

Composite fabrication ➡ DRIE, electroplating

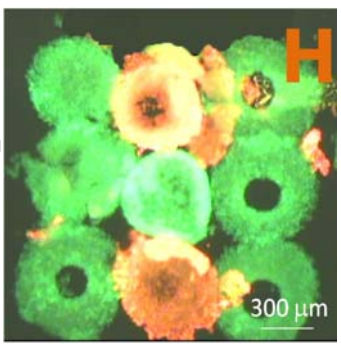
6. Experiments



Assembly for Toroidal shape spheroid



Red: Dil
Green: Calcein-AM



7. Conclusions

1. Comprehensive analysis of riblet surface effect and optimum design to minimize fluid friction were achieved
2. Composite fabrication of Si and Ni by wet and dry etching was achieved
3. Drive speed ability improved 10 times by optimum riblet surface
4. High speed spheroid assembly was achieved

【References】:

M. Hagiwara, T. Kawahara, T. Masuda, T. Iijima, Y. Yamanishi, and F. Arai, "Ultrahigh Speed Cell Manipulation by Robot on a Chip: A Levitated Structure with Three-Dimensionally Patterned Surface", Proc. of the 15th Int. Conf. on Miniaturized Systems for Chemistry and Life Sciences (mTAS), pp.1548-1550, 2011.

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