# OBSERVATION OF CELL PINBALL THROUGH HIGH SPEED SWITCHING BETWEEN REFLECTION INTERFERENCE AND PHASE CONTRAST

*Ryo Murakami[1], Akihisa Yamamoto[2], Hiroaki Ito[1], Chia-Hung Dylan Tsai[1], Mitsuhiro Horade[1], Motomu Tanaka[3], and Makoto Kaneko[1]*

[1]Department of Mechanical Engineering, Osaka University, Osaka, JAPAN

[2]Institute for Integrated Cell-Material Science (WPI iCeMS), Kyoto University, Kyoto, JAPAN

[3] Institute of Physical Chemistry, University of Heidelberg, Heidelberg, GERMANY

## ABSTRACT

"Cell Pinball" is a phenomenon whereby rotating red blood cells (RBCs) move like pinballs inside a microfluidic channel where the cell inertia is negligible. The goal of this paper is to discuss the location of the actual rotational axis through the careful comparison between the contour and contact shapes of a moving RBC. By switching the reflection interference contrast (RIC) and the phase contrast (PhC) microscopes with the mean cycle time of 0.440 s, we found that the difference between the trajectories of each centroid of the visualized RBC by RIC and PhC is less than 0.8 μm.

## WHAT HAS BEEN REVEILED SO FAR?

In "Cell Pinball", a RBC moves across the channel accompanied by the rotating motion as shown in Figure 1. Based on the observation of RBCs under no-flow condition as shown in Figure 2(a), the contact model shown in Figure 2(b) has been proposed [1]. Figure 3 shows the proposed rotation mechanism, where the center of rotation shifts toward the downstream compared to the position of RBC centroid, resulting in the rotational instability. Here the contact force distribution was assumed to be uniform over the contact area, and the position of the contact area and the RBC centroid was implied different [1]. However, the verification of such a shift had not yet been confirmed experimentally.

## EXPERIMENTAL SETUP

Figure 4 shows the experimental system, where the RBCs exhibit "Cell Pinball" in a controlled laminar flow in a microfluidic channel. Figure 5 shows the dimensions of the channel, and the channel height and width of the channel cross-section are 4 μm and 50 μm in design, respectively.

## HIGH SPEED SWITCHING

We succeeded in the switching observations with the mean cycle time of 0.440 s between RIC and PhC microscopes, which are for visualizing the contact area and the contour of a RBC, respectively [2].

## RESULT

Figure 6 shows an example of the microscopes' outputs where white rings and black filled circles are obtained from PhC and RIC microscopes, respectively, and the blue line is the approximated trajectory obtained from the centroids by

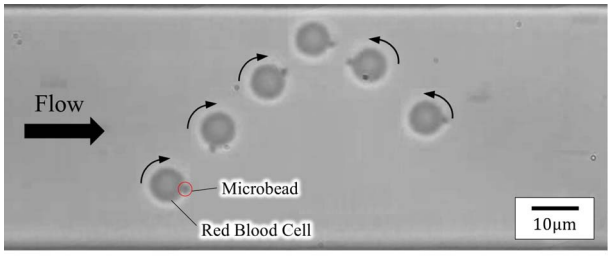


*Figure 1: Visualization of rotation motion of "Cell Pinball" by attaching a microbead.*

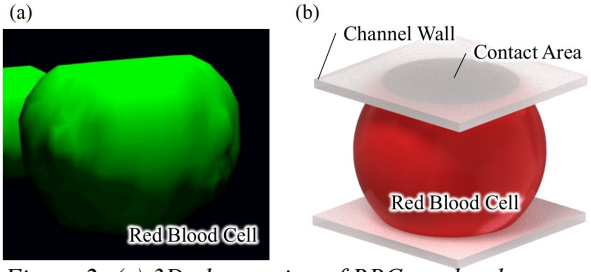


*Figure 2: (a) 3D observation of RBCs under the same osmotic condition with Cell Pinball by using confocal laser scanning microscopy. (b) Proposed contact model.*

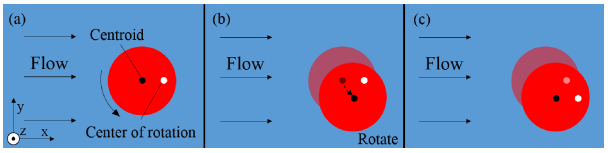


*Figure 3: Proposed rotation mechanism, where the centroid and the center of rotation are different.*

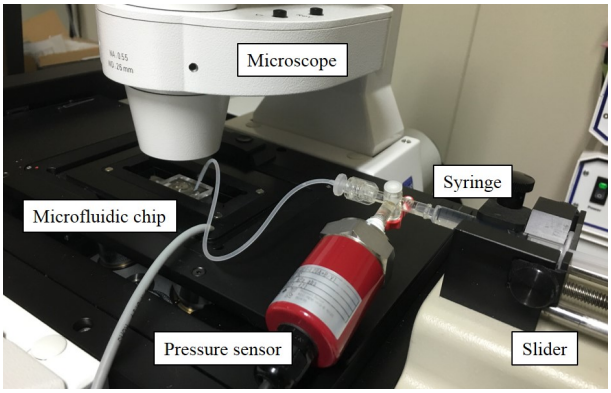


*Figure 4: Overview of the experimental setup.*

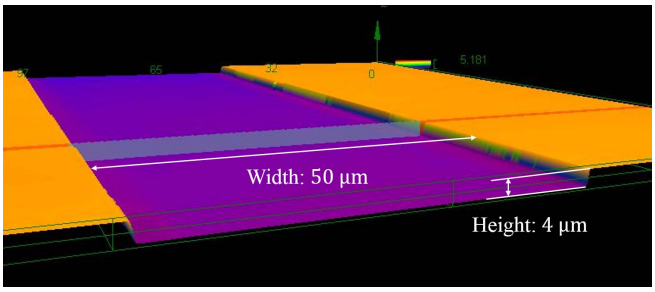


*Figure 5: Dimension of the microfluidic channel.*

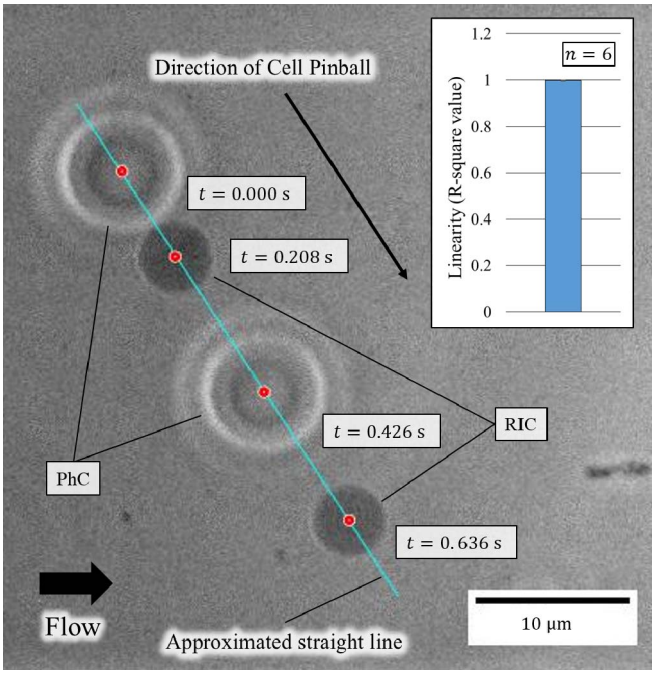


*Figure 6: Switching observation between RIC and PhC.*

the least square method. The approximation is fairly well that the obtained $R^2$ values are 0.9981 ± 0.0011 ($n$ = 6). Figure 7(a) shows the definition of the gap distance: $S_{total} = S_{PhC} + S_{RIC}$, where $S_{PhC}$ and $S_{RIC}$ are the distance along x-axis between the approximated straight line and each centroid. Figure 7(b) shows $S_{total}$ = 0.51 ± 0.19 µm (mean ± standard deviation) for the present six samples.

## DISCUSSIONS

The result shows that $S_{total}$ is less than the formerly estimated distance $S = L/2\pi n$ = 1.12 ± 0.16 µm, which is derived based on the small deviation model [1], where $L$ and $n$ are the RBC displacement along y-direction and the amount of rotation in revolution, respectively. According to the present results obtained by the real real-time high-speed switching of the two microscopies, we postulate a possible mechanism for Cell Pinball, that is, the contact force distribution on the contact surface is asymmetric as shown in Figure 8. Such force distribution would shift the center of rotation due to its asymmetry. As a future work, we are going to study more about the force distribution by using force sensing devices such as a traction force microscopy in order to make clear the mechanism of Cell Pinball phenomenon.

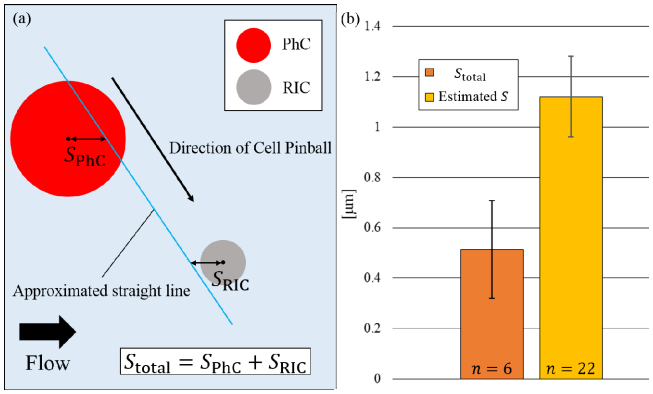


*Figure 7: (a) Definition of the gap distance $S_{total}$ between each centroid $S_{PhC}$ and $S_{RIC}$. (b) Comparison between the measured $S_{total}$ and $S$ estimated in the previous work.*

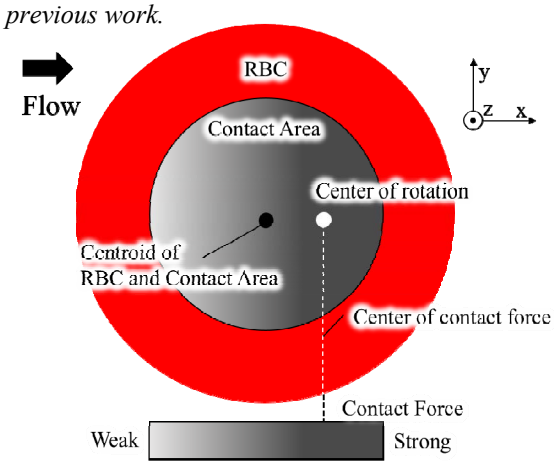


*Figure 8: Possible asymmetric contact force distribution.*

## CONCLUDING REMARK

We utilized the high-speed switching between RIC and PhC to visualize the centroids of the contact area and the contour of a RBC. The result of comparing the position of the two is less than 0.8 µm, which suggests that the contact force distribution on the contact surface of the Cell Pinball.

## ACKNOWLEDGEMENTS

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## REFERENCES

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## CONTACT

*Ryo Murakami, tel: +81-6-6879-7333;
murakami@hh.mech.eng.osaka-u.ac.jp