Highly Efficient and Selective Isolation of Rare Tumor Cells Using a Microfluidic Chip with Wavy-herringbone Micro-patterned Surfaces

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Numerical simulation for geometry optimization

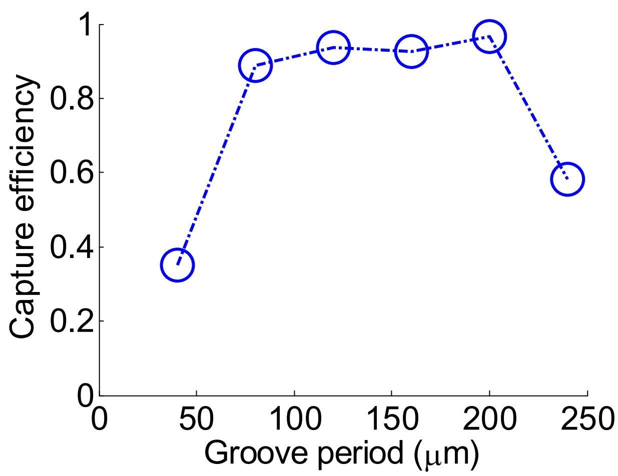

Figure S1 Numerical simulation reveals the effect of the groove period on capture efficiency.

Cell-surface contact mode and pattern surface area

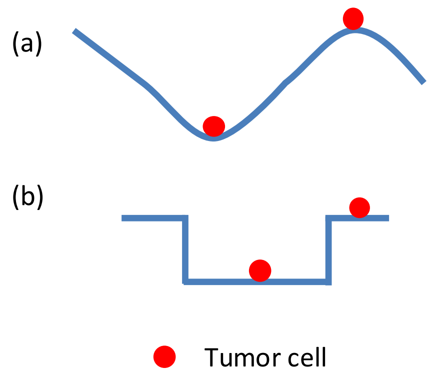

Figure S2 A sketch of cell-surface contact modes for both (a) wavy pattern and (b) grooved pattern. Plot is not in scale.

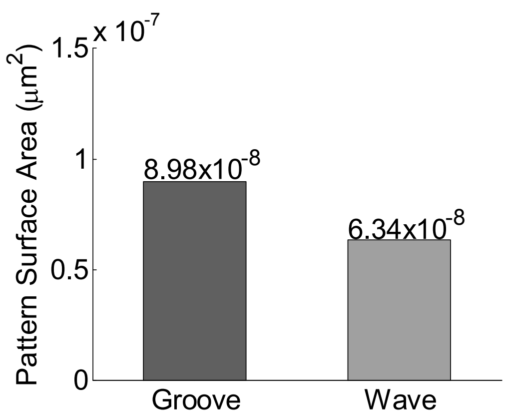

Figure S3 Total pattern surface area for one period of groove and wave patterns.

Investigation of the fabrication reproducibility

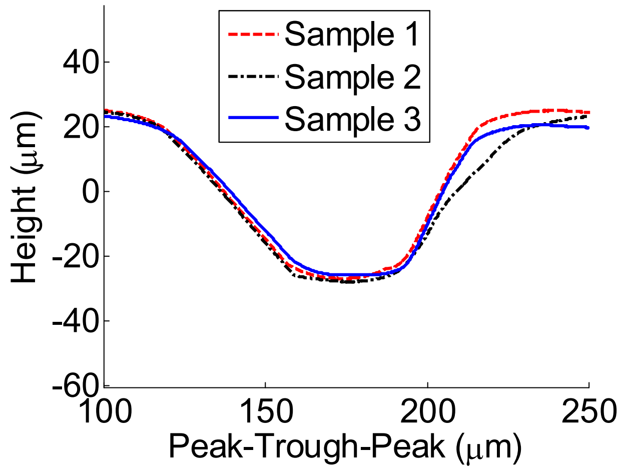

Figure S4 Profilometer results of the wavy pattern for three samples made by the reflow approach.

Distributions of CTCs and WBCs along the flow direction

To evaluate the device performance, the distributions of both CTCs and WBCs along the flow direction were investigated first. Shear rate ranging from 60/s to 400/s, which were commonly used in literature,[1,2] was studied here. Captured CTCs and non-specifically bound WBCs in the first 20 sections of each window with a width of 1.14 mm were counted and normalized in percentage, as shown in Figure S5(a)-(d). It is found that focusing regions of CTCs tend to move towards the tail sections with increasing shear rate in both grooved-HB and wavy-HB chips (Figure S5(a)-(b)). This shift is speculated due to the increased shear force proportional to the increasing shear rate, which agrees well with the results in literature[3]. Interestingly, the wavy-HB chip presents a relatively more uniform distribution with the focusing sections shifted more towards the tail section when compared with the grooved-HB chip. It can be explained by the fact that the smooth wavy patterns lack extremely low shear-rate sections (namely, the sharp trough sections in the grooved-HB chip), allowing for more cells to flow towards the tail section, which is especially reflected at lower shear rates (60/s and 100/s). WBCs also exhibit a similar trend with the focusing sections shifting towards the tail sections with the increasing shear rate (Figure S5(c)-(d)), although the trend is not so significant compared with that for CTCs. This is attributed to the inherent weak non-specific capture force for WBCs, which allows WBCs to have a relatively longer flow pathway. It is also noticed that there are small percentages of peaks in the entry section under lower shear rates (60/s and 100/s), which are probably due to the geometry transition from the flat plane to the patterned regions, namely, wavy or grooved structures.

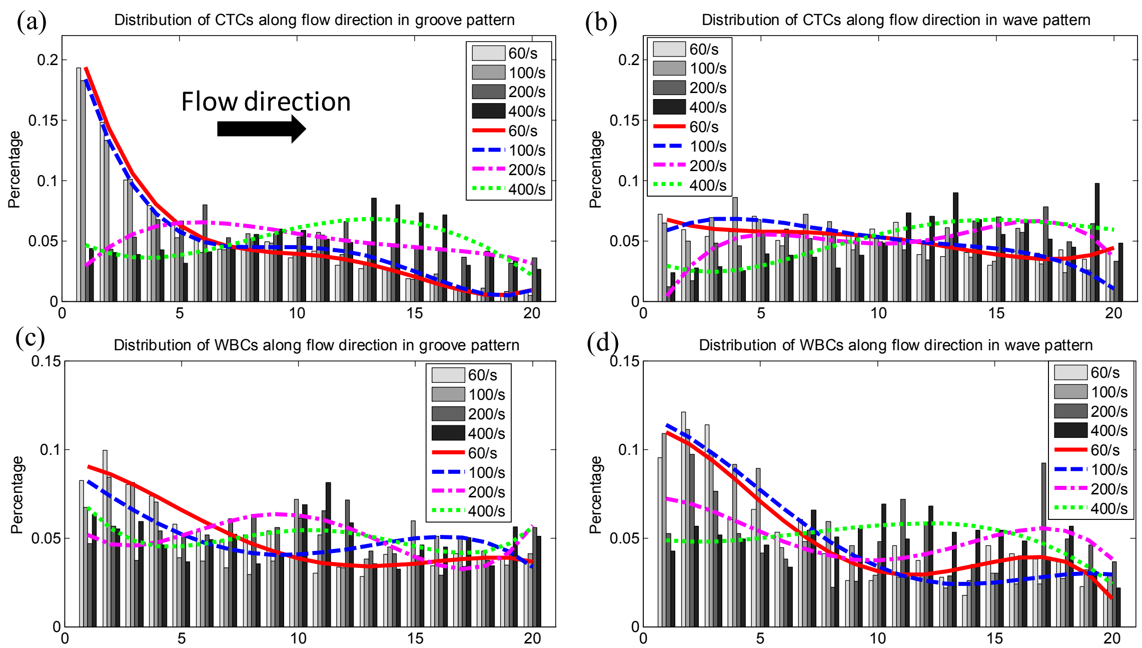

Figure S5 Distributions of CTCs along flow direction in (a) grooved patterns and (b) wavy patterns; Distribution of WBCs along flow direction in (c) grooved patterns and (d) wavy patterns. The microfluidic device is equally divided into parallel sections along the flow direction, with the first 20 sections with a width of 1.14mm shown here. Curve fitting are adopted in each group to indicate the trend of the cell distribution profile.

Validation of the clinical utility for the wavy-herringbone chip

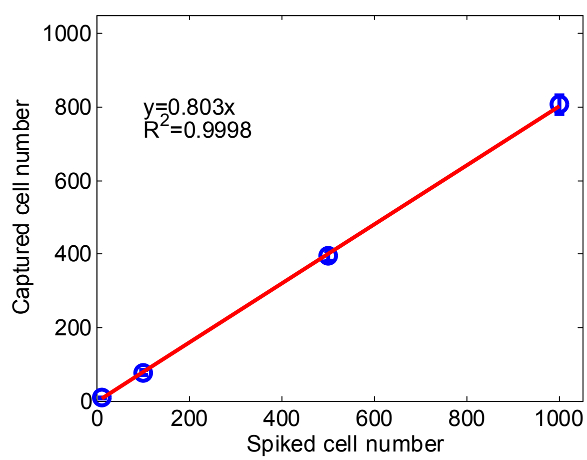

Figure S6 Linear regression analysis of the captured cell amount versus spiked cell amount. HCT-116 cells at various concentrations were spiked in PBS buffer solution and captured cell amount were then counted. Error bars stand for standard deviations in three independent experimental trials.

References

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