Targeting of Cancer Cells using Controlled Nanoparticles and Robotics Sperms

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Abstract

We achieve selective penetration of MCF-7 breast cancer cells using iron-oxide nanoparticles without causing a permanent damage to the membrane and without any effect on the cell morphology. The nanoparticles are controllably pulled towards the cells under the influence of the magnetic field gradients. First, the nanoparticles are fabricated and their magnetic dipole moment is characterized to be 7.8×10^{-8} A.m^2, at magnetic field of 60 mT and mass of 1.80×10^{-9} kg. This characterization is done by measuring the magnetic force exerted on their dipole moment under the influence of controlled magnetic field gradient. Second, a magnetic-based control system is designed and used to achieve selective targeting of the cells under microscopic guidance. We find that the magnetic control achieves immediate uptake of nanoparticles in the MCF-7 cells without incubation for relatively long time, using magnetic force less than 51 nN. In addition, a microforce sensing probe is used to characterize the impendence of the cells to limit the exerted magnetic force during penetration and to avoid causing damage to the membrane. We find that a single cell can overcome penetration force in excess of 13.3 μN.

We also control robotic sperms under the influence of weak oscillating magnetic fields (milliTesla range) to selectively target cell mockups (i.e., gas bubbles with average diameter of 200 μm). The robotic sperms are fabricated by electrospinning using a solution of polystyrene, dimethylformamide, and iron oxide nanoparticles. These nanoparticles are concentrated within the head of the robotic sperms, and hence enable directional control along external magnetic fields. The magnetic dipole moment of the robotic sperms is characterized (using the *flip-time* technique) to be 1.4×10^{-11} A.m^2, at magnetic field of 28 mT. In addition, the morphology of the robotic sperms is characterized using Scanning Electron Microscopy images. The characterized parameters and morphology are used in the simulation of the locomotion mechanism of the robotic sperms to prove that their motion depends on breaking the time-reversal symmetry, rather than pulling with the magnetic field gradient. We experimentally demonstrate that the robotic sperms can controllably follow S-shaped, U-shaped, and square paths, and selectively target the cell mockups using image guidance and under the influence of the oscillating magnetic fields.

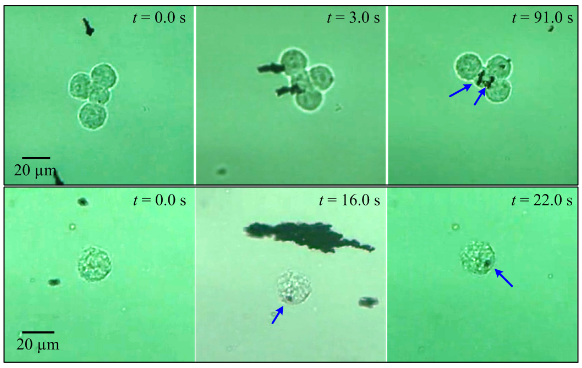

Figure 1: Pre- and post-conditions of MCF-7 cell aggregate and single MCF-7 cell subjected to penetration using clusters of iron-oxide nanoparticles. Top: two clusters target cell aggregate and the uptake is observed after 91 seconds. Bottom: A cluster targets a cell and the uptake is achieved in 22 seconds. The applied magnetic field and gradient are 60 mT and 5 T.m^{-1}, respectively. The cell membrane is not damaged after the accumulation of the nanoparticles.

References

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