Magneto-Mechanical Actuation: A Novel Approach to Targeted Cancer Cell Destruction

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We report the fabrication process, magnetic behavior as well as the surface modification of ferromagnetic microdisks suspended in aqueous solution. They posses unique properties such as high Ms, zero remanence due to spin vortex formation, intrinsic spin resonance at low frequencies, and capability of delivering more than one type of bio-substance at once. Furthermore, because of their anisotropic shape, our magnetic particles rotate under alternative magnetic field of small amplitude. One finds that just ~10-50 millisecond long field pulse of only few Gauss in amplitude is enough to achieve complete rotation (alignment) of suspended 1micron, 50nm thin Fe20Ni80 disks. This can be used for promoting new approach of targeted magneto-mechanical cancer cell destruction by the application of an unprecedentedly slow and weak magnetic fields using unique class of materials that possess a spin vortex ground state.

We demonstrate that successful interfacing of lithographically defined ferromagnetic materials with a spin vortex ground state with (cancer) cells can be achieved in vitro. When an alternative magnetic field is applied the magnetic vortices shift, leading to oscillatory motion of the disks causing the magneto-mechanic stimulus is to be transmitted directly to the cell membrane into sub-cellular compartments. Such magnetic spin vortex-induced magneto-mechanical stimulus results into (a) cancer cell membrane damage, as well as into (b) cellular signal transduction and amplification, causing initiation of apoptosis, also known as programmed cell death. Manifestation of apoptosis is of clinical significance because the malignant cells are known to be almost "immortal" (due to suppressed apoptosis), and, consequently, highly resistant to conventional chemotherapy.

An alternating magnetic field as slow as 10 Hz and as small as ~90 Oe applied only for 10 minutes was sufficient to cause ~90% cancer cell destruction in vitro [1]. This approach, for the first time, offers a realistic scalable solution to the cancer therapy improvement using spin vortex microdisks as a novel multifunctional platform. Because of the individual cell-targeted energy transduction phenomenon, an external **power supplied to the cultures in our experiments is at least ~100,000s times smaller than the best hyperthermia use of magnetic nanoparticles to fight cancer known to date**. Those weak fields mean that the method has great potential for a low cost, large working volume and minimally invasive therapies. Besides the field frequencies and amplitude, the most striking difference is that in our approach allows the energy is delivered directly to the cell, e.g. potentially without damaging the surrounding normal cells or tissues.

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References

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