Remotely responsive magnetic nanomaterials for neuromodulation

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The emergence of a new era in neuromodulation is led by the intriguing potential of functional materials to replace or control neural activity. Wireless neuromodulation schemes can replace invasive brain surgeries and enable cell-precise neuronal control. Intrinsic properties of magnetic nanomaterials coupled to external magnetic fields (MFs) have recently permitted deep brain stimulation and relief of Parkinsonian symptoms in rodents trough hysteretic heating of magnetic isotropic nanoparticles acting on chemosensory ion channels in high-frequency alternating MFs[1]. More energy efficient approach for neuronal modulation with high spatiotemporal precision is based on development of novel class of anisotropic magnetic nanomaterials, magnetite nanodiscs (MNDs).These MNDs exhibit a characteristic vortex alignment of magnetic spins with zero net magnetization in the absence of external MFs. When the MF is applied, magnetization transitions from *vortex* to *in plane* allowing for the exertion of the torques on the pN scale, sufficient to activate mechanosensitive ion channels in cell membranes. We have shown remote control of activity in sensory neurons with weak (7–26 mT), slow-varying (1–5 Hz) magnetic fields coupled to MNDs. When coupled to mechanosensory ion channels, such as Transient receptor potential vanilloid family member 4 (TRPV4), a cell/protein- specific modulation is achieved[2].
Consistent with geometry and chemical composition, MNDs exhibit direction-dependent hysteresis loops and with high specific loss power (SLP) at kHz frequencies and low concentrations. Targeted activation of heat gated channels is thus permitted at high frequency alternating MFs. Therefore, MNDs allow for simultaneous stimulation of neurons by selectively activating mechanoreceptors at 1-5 Hz MFs, while heat dissipation and consequent activation of heat-gated ion channels is allowed at frequencies 75-150 kHz.

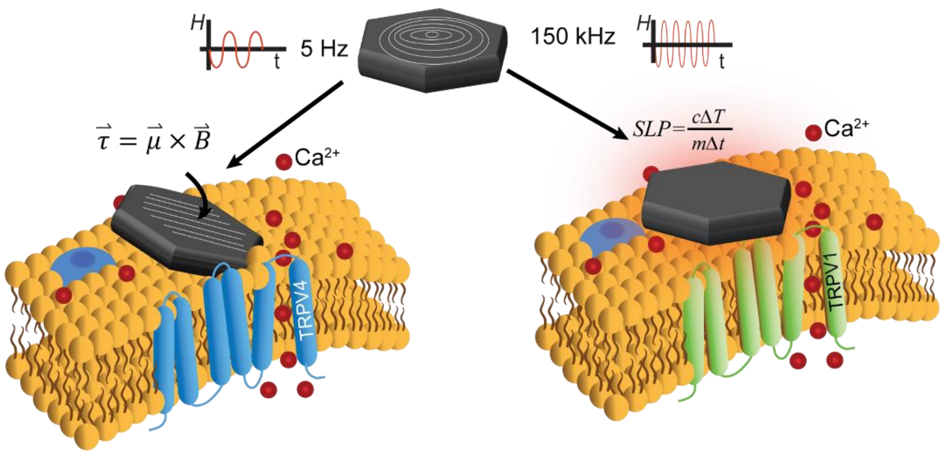

Figure 1. Remote selective activation of heat- and/or mechanosensitive neurons by switching between MF parameters

References

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