Advanced magnetic nanomaterials at the frontier of the wireless neurotech

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Abstract

Materials science plays a pivotal role in unlocking the transformative potential of converting magnetic fields into diverse neural manipulation mechanisms using nanomaterials. Magnetic materials are especially intriguing in the field of neuromodulation as they offer wireless interaction with external magnetic fields, without spatial limitations, as magnetic fields are transparent to biological tissues [1]. Firstly, the utilization of magnetic nanoparticles enables hysteresis-driven heating in high-frequency alternating magnetic fields (MFs), allowing for precise modulation of neural activity in the deep brain through activation of chemosensory ion channels [2]. Secondly, the development of novel anisotropic magnetite nanomaterials, such as magnetite nanodiscs (MNDs), has demonstrated the capability to generate piconewton torques under slow MFs through vortex magnetization-driven moments, facilitating selective activation of mechanoreceptors in neural tissues [3]. Lastly, the integration of anisotropic magnetite as ferromagnetic cores in 1D and 3D embedding enables efficient conversion of magnetic fields into electric potentials, opening avenues for wireless electrical neuromodulation [4]. Additionally, meticulous surface engineering allows for targeted interactions with neurobiological systems, combined with innovative material design, drives advancements with immense promise for revolutionizing neural interfaces and neurostimulation tools, offering less invasive and more precise interventions.

References

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Figures

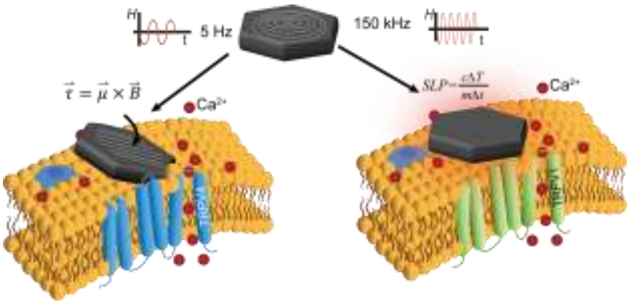

Figure 1. Scheme of magnetite nanodiscs performing as bimodal neuromodulators. Under low frequencies (5Hz) they transition from vortex to in plane magnetization and transduce torques to mechanosensory ion channel in the neuronal membrane. At kHz frequencies (right) they undergo hysteretic heating that is leveraged for the activation of the thermosensory ion channels.