Conformable permalloy composite cap for controlling transcranial magnetic stimulation fields near implanted devices

Wesley H. Lohr[1]*, Mohannad Tashli[2], Ravi L. Hadimani[1,2]
(1) Department of Biomedical engineering, Virginia Commonwealth university, Richmond, VA 23224 USA, e-mail: lohrw@vcu.edu.
(2) . Department of Mechanical and Nuclear Engineering, Virginia Commonwealth University, Richmond, VA 23224 USA, e-mail: tashlims@vcu.edu rhadimani@vcu.edu

Permalloy nanoparticle-based composite films serve as effective magnetic shields for transcranial magnetic stimulation (TMS) applications by redirecting magnetic field lines away from protected regions. These shields can help safeguard implantable devices, reduce overstimulation of cortical areas during deep brain targeting, and enhance patient comfort. Unlike rigid metallic shields, which generate loud noises due to Lorentz forces, these composite films are flexible and moldable, allowing for a seamless fit between the TMS coil and the patient's head. The shielding composite is tested using a conductively and anatomically accurate neuromodulation phantom. This work investigates the safety of using deep TMS with implanted devices and proposes a wearable shield that may allow for multimodal treatment of diseases like Parkinson's disease.

Transcranial magnetic stimulation (TMS) is expanding as an FDA-approved treatment for various brain disorders, but precise control over magnetic field distribution remains a challenge, especially when targeting deep brain regions. Passive magnetic shielding using high-permeability materials like permalloy offers a way to redirect magnetic fields, potentially improving treatment efficacy while reducing unwanted exposure [1]. Traditional metallic shields, however, produce noise due to Lorentz forces and lack flexibility to conform to individual head shapes. This paper introduces a novel polymer composite that provides effective, silent, and adaptable magnetic shielding, which could enhance TMS precision and protect brain implants in patients undergoing treatment and validates it in a conductively accurate TMS phantom.

Nickel-iron-molybdenum commercially known as permalloy nano-powder was purchased form the distributor Nanoamor of concentration $Ni80Fe17Mo3$, and average particle size of 70 nm. The permalloy powder was then mixed with sylgard 184 polydimethylsiloxane (PDMS) purchased from Dow chemicals to create a composite of 80 weight percent permalloy and 20 weight percent PDMS. A 3D printed housing was created for the composite to cure in and create the shape of the shield. The housing is later used to secure the shield to the TMS coil. A DBS probe is implanted into a conductively accurate neuromodulation head phantom along with several triaxial dipole probes to measure induced electric fields. The brain phantom is composed of a PDMS and carbon nanotube (CNT) composite mixed at 8 weight percent CNT to mimic brain conductivity. The permalloy composite shielding cap is placed around the head near the insertion point of the DBS lead. TMS is applied to the phantom and induced electric fields are measured using the triaxial dipole probes.

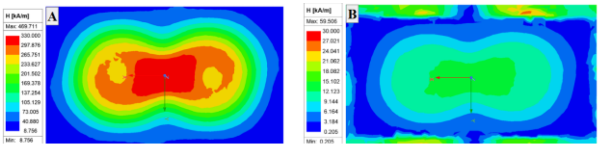

Figure 1: Simulations of TMS with and without Composite Shield

Simulated results (Fig.1) show that this conformal shielding composite can effectively shield TMS fields. A) No shield with 30% stimulator output (1500 amps) and a peak magnetic field of 0.59 T. B) composite shield with 30% stimulator output and a peak magnetic field of 0.075 T. This simulation shows 90% shielding effectiveness at 30%

[1] D. Ma et al., "A novel low-noise Mu-metal magnetic shield with winding shape," Sensors and Actuators A: Physical, vol. 346, p. 113884, Oct. 2022, doi: 10.1016/j.sna.2022.113884.