Magnetic Resonant Imaging (MRI) is widely used for medical diagnosis to provide reliable health care. MRI is a noninvasive clinical procedure with non-ionizing radiation exposure unlike traditional x-rays or computed tomography scans. However, MRI can be detrimental and even life-threatening to patients if they have metallic implants in the body, because the radio frequency magnetic field of 63.86 MHz (at 1.5 T) used during MRI scanning induces eddy currents in metallic implants causing them to heat up. The purpose of this research is to modify the electromagnetic (EM) response of the implants to reduce heating so that MRI can be applied to patients even if they have metallic implants. Both theoretical and experimental studies have been carried out to achieve this research objective by considering the pacemaker lead as the implant material.

The nominal composition of pacemaker leads is typically an alloy of Ni (35 wt%), Co (35 wt%), Cr (20 wt%) and Mo (10 wt%) commonly called MP35N. A material selection model involving EM-metal interaction is developed to modify the EM response of MP35N. This model predicts that noble metals such as Ag, Au and Pt, which have high reflectivity of EM waves in the radio-frequency range of MRI, are suitable elements for this study. A novel laser technique is studied to diffuse these elements into MP35N for increasing the reflectivity of MP35N at the radio-frequency of MRI. A very thin layer of the noble metal was electro-deposited on MP35N wire which was subsequently heated with a laser beam to diffuse the coated atoms into the wire. Neither the coating nor the wire was melted during laser heating and thus the noble elements were incorporated into the wire by the solid-state diffusion process. The laser processing parameters are optimized by developing a three-dimensional laser heating model for wires. Although the wire diameter is very small yielding a value of the Biot number much less than 0.1, the temperature distribution is found to be non-uniform across the cross-section of the wire and, therefore, a three-dimensional heating model is necessary. Microstructural analyses using scanning electron microscope (SEM) and energy-dispersive X-ray spectroscopy (EDS) were performed on the wire surface and its cross section to determine the concentration of the diffusant atoms in the modified region. The solid-state diffusion process was found to be effective for coating thicknesses less than 1 µm.

The modified wires were tested in radio-frequency magnetic fields using a Helmholtz Coi (HC) apparatus for the heating reduction performance as a function of the diffusant concentration, and pacemaker leads were constructed using the modified wires. The performance of these leads and commercially available pacemaker leads were also tested using the HC apparatus. The Pt diffusant wires were found to cause the highest reduction in heating while the gold diffusant wires exhibited the next best performance. More heating was observed for the silver diffusant wires than the untreated wires in certain experiments. Platinum is, therefore, concluded to be the best element to reduce the eddy current-induced heating in pacemaker leads. It is found that higher concentration of platinum causes higher reduction in heating.
Approved for distribution by Aravinda Kar, Committee Chair, on October 25, 2016.

The public is welcome to attend.