Application of metamaterial nano-engineering for increasing the superconducting critical temperature

M. S. Osofsky, Vera N. Smolyaninova, Kathryn Zander, Thomas Gresock, Shanta Saha, Bradley Yost, Christopher Jensen, Joseph C. Prestigiacomo, Heungsoo Kim, Nabil Bassim, Richard L. Greene, and Igor I. Smolyaninov

1 Naval Research Laboratory, Washington, DC 20375, USA
2 Department of Physics Astronomy and Geosciences, Towson University, 8000 York Rd., Towson, MD 21252, USA
3 Materials Science and Engineering Department, McMaster University, Hamilton, Ontario L9H 4L7, Canada
4 Department of Electrical and Computer Engineering, University of Maryland, College Park, MD 20742, USA
Contact e-mail: michael.osofsky@nrl.navy.mil

We have demonstrated that the metamaterial approach to dielectric response engineering increases the critical temperature of a composite superconductor-dielectric system in the epsilon near zero (ENZ) and hyperbolic regimes. To create such metamaterial superconductors three approaches were implemented. In the first approach, mixtures of tin and barium titanate nanoparticles of varying composition were used [1]. An increase of the critical temperature of the order of 5% compared to bulk tin has been observed for a 40% volume fraction of barium titanate nanoparticles. Similar results were also obtained with compressed mixtures of tin and strontium titanate nanoparticles. In the second approach, we demonstrate the use of Al$_2$O$_3$-coated aluminium nanoparticles to form an ENZ core-shell metamaterial superconductor with a $T_c$ that is three times that of pure aluminium [2]. In the third approach, we demonstrate a similar $T_c$ enhancement in thin Al/Al$_2$O$_3$ heterostructures that form a hyperbolic metamaterial superconductor [3]. IR reflectivity measurements confirm the predicted metamaterial modification of the dielectric function thus demonstrating the efficacy of the metamaterial approach to $T_c$ engineering. The developed technology enables efficient nanofabrication of bulk aluminium-based metamaterial superconductors. These results open up numerous new possibilities of considerable $T_c$ increase in other superconductors. This work was supported in part by NSF grant DMR-1104676.

References