Low Loss and tunable superconducting terahertz metamaterial

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Superconducting planar terahertz (THz) metamaterials (MMs) are fabricated on 200 nm thick niobium nitride (NbN) films deposited on MgO substrates. They are characterized by time-domain THz spectroscopy over a temperature region from 8 K to 20 K, crossing the critical temperature of NbN films. The unloaded quality factor reaches as high as about 178 at 0.6 THz and 8 K, which is about 24 times as many as gold MMs with the same pattern, demonstrating low loss property. Meanwhile, four MMs with different resonant frequencies are also investigated. As the gap frequency f_g is 1.18 THz, the experimentally observed THz spectra span a frequency region from below f_g to above it. We found that the MMs exhibit a wide relative tuning range of 30% as the resonance frequency approaches to f_g due to remarkably large variance of inductance. This stimulates us to realize a larger tuning range about 41% as the film thickness is reduced to 100nm. All these experimental observations are well understood in the framework of Bardeen-Cooper-Schrieffer theory and equivalent circuit model. Our work offers an efficient way to design and make high-performance THz electronic devices.