Graphene Nanoelectromechanical Systems as Stochastic-Frequency Oscillators

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Abstract

We measure the quality factor Q of electrically-driven few-layer graphene drumhead resonators, providing an experimental demonstration that $Q \sim 1/T$, where T is the temperature. We develop a model that includes intermodal coupling and tensioned graphene resonators, yielding good quantitative agreement to experiment. Because the resonators are atomically thin, out-of-plane fluctuations are large. As a result Q is mainly determined by stochastic frequency broadening rather than frictional damping, in analogy to nuclear magnetic resonance. Additionally, at larger drives the resonance linewidth is enhanced by nonlinear damping, in qualitative agreement with recent theory of damping by radiation of in-plane phonons. Parametric amplification produced by periodic thermal expansion from the ac drive voltage yields an anomalously large linewidth at the largest drives. Our results contribute towards a general framework for understanding the mechanisms of dissipation and spectral line broadening in atomically thin membrane resonators.