We present a quantitative analysis of the electron transfer between single gold nanorods and a monolayer of graphene under no electrical bias. Using single particle dark-field scattering and photoluminescence spectroscopy to access the homogenous linewidth, we observe broadening of the surface plasmon resonance for gold nanorods on graphene compared to nanorods on a quartz substrate. Because of the absence of spectral plasmon shifts, dielectric interactions between the gold nanorods and graphene are not important and we assign the plasmon damping to charge transfer between plasmon-generated hot electrons and the graphene that acts as an efficient acceptor. Analysis of the plasmon linewidth yields an average electron transfer time of 160 ± 30 fs, which is otherwise difficult to measure directly in the time domain with single particle sensitivity. In comparison to intrinsic hot electron decay and radiative relaxation, we furthermore calculate from the plasmon linewidth that charge transfer between the gold nanorods and the graphene support occurs with an efficiency of ~ 10%. Our results are important for future applications of light harvesting with metal nanoparticle plasmons and efficient hot electron acceptors as well as for understanding hot electron transfer in plasmon-assisted chemical reactions.

Figure 1. A, B) Dark-field scattering images of gold nanorods on quartz (A) and graphene (B). C) Normalized scattering spectra of a representative single nanorod on quartz and graphene as indicated by the circles in the images. The homogeneous linewidth (Γ) and resonance energy (E_{res}) were determined from a Lorentzian fit. D) The complementary cumulative distribution function of the plasmon linewidth from 100 single nanorods on quartz and 95 single nanorods on graphene. The same data is shown as a histogram in the inset.