# Inelastic electron tunneling accompanied by plasmon emission in graphene-based heterostructures

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The heterostructures based on graphene and related two-dimensional materials are considered as building blocks of novel electronic and nanophotonic devices. The transport in vertical graphene-based heterostructures involving elastic electron tunneling is well-studied both experimentally and theoretically [1,2]. Apart from elastic tunneling, the tunneling accompanied by emission/absorption of photons and surface plasmons in graphene heterostructures is possible. The latter process might be responsible for the recently observed gate-controlled electroluminescence of graphene-based tunnel junctions [3] and potentially used for creation of nanoscale plasmon sources and detectros. In this report we develop for the first time a theory of plasmon-assisted tunneling in graphene-insulator-graphene junctions and reveal the effect of such tunneling on current-voltage [I(V)] characteristics and luminescence [4,5].

Our theoretical approach is based on evaluation of tunneling current due to dynamically screened Coulomb interactions between charge carriers. The dynamic screening leads to the resonant enhancement of tunneling if the energy and momentum transferred upon scattering coincide with those of surface plasmons. This resonant contrubution, which is plasmon-assisted tunneling, can be explicitly singled out of the full inelastic current. We also present a simplified approach to evaluation of plasmon-assisted current based on the field quantization of plasmon modes. Our calculation shows that the I(V)-curves of tunnel-coupled graphene layers possess the full-scale resonances due to the enhanced interaction between collinear electrons and surface plasmons. This resonance is closely related to the linear electron-hole dispersion in graphene and is absent in coupled layers with massive carriers. The resonance in plasmon-assisted current for aligned layers will be accompanied by a resonance in the integrated electroluminescence. We estimate the radiative decay rate of surface plasmons in graphene-insulator-graphene tunnel junctions and show that the efficiency of plasmon-to-photon conversion can be 10%.

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