Optoelectronic nanojunctions

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Abstract

The interplay between electrical transport and optical stimulation in tunable nanoscale molecular junctions is the focus of this project. Starting with metal contacts, the investigations will be extended to graphene contacts where better mechanical stability and enhanced control and can be implemented.

Brief project description

The field of single molecule electronics has revealed a variety of novel effects in the past decade thanks to significant experimental developments and deeper theoretical understanding [1]. At the interface between molecular electronics and plasmonics, the interplay of light and electrical transport in molecular junctions raises an increasing interest [2].

A molecule within two contacting electrodes, a molecular junction, can be seen as an optoelectronic interface for energy conversion. On the one hand, an optical stimulus can generate a photoelectrical current through the junction [3]. Alternatively, driving an electrical current through the junction can result in a photon emission process within the molecule in the form of electroluminescence [4].

Because of their small optical absorption cross-sections, typically ~1-10pm^2, efficiently addressing individual molecules is not trivial. Metallic nanoscale gaps come to help by enhancing the effective absorption cross-section of the molecular junction by orders of magnitude through plasmons generation and near-field enhancement. This gives the charge extracting electrodes a dual function since they also act as an optical nanoantenna [5]. This principle has been shown to result in large field enhancements within the gap [6] and applied to local Raman spectral mapping at the nanometer scale using scanning probe techniques [7],[8]. Photo-induced conductance effects have however been barely investigated to date. While the metallic electrodes can enhance the absorption through field enhancement, they can also quench emission via energy transfer. The exact nature of the molecule-metal coupling determines which effect dominates, a point that is particularly critical in electroluminescence studies.

In this project, the optoelectronic properties of junctions embedding simple conjugated compounds will be investigated. First a mechanically-controllable break junction (MCBJ) system [9] will be integrated in an optical setup to investigate the junctions' photoluminescence and photoconductance. These investtigations will be extended to graphene contacts that offer additional possibilities, in particular stable mechanical contacts and tunable electronic coupling.

References

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