Driven nanosystems: From charge transport in energy conversion materials to peristaltic pumping of charges

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Abstract:

Nonequilibrium particle and charge transport in low-dimensional biological, chemical and physical systems is of vital importance for many applications and has hence attracted much attention in recent years. Prominent examples are Brownian motors and ratchets, photovoltaic cells, thermoelectric devices, nanowires or quantum dots architectures. From the fundamental point of view, driven systems are also of vital interest to gain a better understanding of the physics of non-equilibrium steady states and restricted equilibrium states under the presence of driving forces. I will give a brief overview of different tools in nonequilibrium physics that enables us to describe hopping transport in driven systems, which is a decisive mechanism in many nanostructured energy conversion materials. In particular, we investigate the performance of a photovoltaic heat engine set-up, which provides a thermodynamic view on a photovoltaic energy conversion process. Thus, efficiency limits of renewable energy converters can be obtained by thermodynamic arguments when looking at the zero-power operation of a solar cell or when looking at the maximum power point.

For example, the zero-power limit is given under open-circuit operation of an energy converter when considering two competing driving forces. The open-circuit voltage defines a stopping point at which the applied voltage stops the current that is generated by light or temperature differences. Moreover, another interesting driving mechanism is given by a peristaltic modulation of site energies in nanostructures. Particles are pumped against a bias by a traveling wave potential. A peristaltic driven mechanism against a bias can led to a current reversal, which can be a possibility for an electronic switch in a nonequilibrium multi-particle regime. When looking at a realization of a peristaltic pump, a promising nanosystem is given by serial coupled quantum dots operating in the Coulomb blockade regime.