Mesoscopic Models of Stochastic Transport Active Particles, Molecular Motors and Resistive Switching:

Transport phenomena occur in biological and artificial systems at all length scales. In this thesis, we investigate them from a mesoscopic perspective, in which fluctuations around their average properties play an important role. The transport processes are active, i.e. they consume energy in dissipative systems outside of thermal equilibrium. They will be dealt with using concepts of stochastic processes, such as ratchets, Langevin equations and master equations.

In the first part, we investigate the unbiased diffusive motion of active Brownian particles with an additional torque. It can appear in many real life systems, for example in sperm cells, bacteria, nanorods and Janus particles. They are driven by a correlated noise modeled by the Ornstein-Uhlenbeck process, which leads to a persistence in their motion. By confining the Brownian particles into an infinite channel geometry of varying width, biased transport appears in a nonequilibrium situation, where the noisy drive and the dissipation of momentum are decoupled. This way, we have realized a novel kind of ratchet.

In the second part, we study intracellular cargo transport in the axons of nerve cells. It is performed by molecular motors walking on the cytoskeleton, which is modeled by an asymmetric exclusion process model, i.e with a hopping process on a lattice. For high motor densities, jams of motors emerge. In a new approach, we add a cargo exchange interaction between the motors. This way, the characteristics of slow axonal transport, such as a motor density dependent cargo transport speed and transport direction reversals, can be accounted for with a single motor species. It is explained by the transient attachment of cargos to reverse walking motors jams, which can be considered as quasi particles.

In the third part, we discuss resistive switching, the non-volatile change of resistance in a dielectric due to electric pulses. It is exploited for applications in computer memory. We propose a stochastic lattice hopping model based on the on oxygen vacancies. The transport of the vacancies alters the electric properties of the switch. We define binary logical states by means of the underlying vacancy distributions, and establish a framework of writing and reading such a memory element with voltage pulses. Considerations about the discriminability of these operations under fluctuations together with the markedness of the resistive switching effect itself enable us to predict on optimal vacancy number.