

Charge Transport through Single-Molecule Junctions

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Molecular electronics is aimed at the use of individual or small ensembles of molecules as functional building blocks in electronic circuits [1–4]. This may provide possible advantages in future electronic applications such as small size, low power consumption and intrinsic functionality combined with high speed.

We have studied charge transport through individually contacted and addressed molecules using the mechanically controllable break-junction (MCBJ) technique [5–7]. Using a statistical measurement and analysis approach [8], we acquire simultaneously current–voltage (I – V) curves during the repeated formation and breaking of a molecular junction. The comprehensive data sets, containing many different microscopic configurations of the molecular junction, provide a reliable basis for statistical analysis to identify the most probable transport characteristics.

Exemplarily, a molecular model system consisting of one, two, three and four phenyl units terminated symmetrically by thiol linker groups has been investigated to elucidate the influence of π -conjugation and length on transport. Several hundreds of current-voltage curves have been measured during formation and breaking of a molecular junction at various temperatures in the range of 30 K to 300 K under ultra-high vacuum conditions. This enables us to determine the characteristic “fingerprint” of the molecule under investigation and to perform single-molecule spectroscopy [8].

Moreover, we have investigated the transport properties of single bipyridyl-dinitro oligo-phenylene-ethynylene dithiol (BPDN-DT) molecules and bipyridyl oligophenylene-ethynylene dithiol (BP-DT) molecules connected to gold electrodes at 100 K. In contrast to the BP-DT, the I – V characteristic of the Au–BPDN-DT–Au system exhibits a voltage-induced switching. Voltage pulses can be used to switch this system from a low to a high conductive “on” state, and, furthermore, to reset the system again to the “off” state. On this single-molecule level, collective phenomena or filament formation can be excluded. Hence, the observed switching in the BPDN-DT has truly a molecular origin. By direct comparison of the two molecular structures, it can be concluded that the additional nitro groups of the BPDN-DT are responsible for the switching mechanism.

Both states of the BPDN-DT molecule are stable and accessible via non-destructive reading. Combined with the ability to reset the switch, this opens the way to employ this single molecule as a memory element. We demonstrate repeated write–read–erase–read cycles with non-destructive read-outs. Thereby, a bit separation (I_{on}/I_{off}) ranging between 7 and 70 has been achieved. Furthermore, periodic reading of a stored bit (no voltage applied between readings) established that this single-molecule memory is non-volatile over a measurement time of several minutes at 100 K (see [9] for more details).

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