A SINGLE-MOLECULE SWITCH AND MEMORY ELEMENT

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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]. Our MCBJ system is operated under ultra-high-vacuum conditions in the temperature range between 5 and 300 K (see [8] for further experimental details). Using a statistical measurement and analysis approach [9], we acquire simultaneously current–voltage (*I–V*) curves during the repeated formation and breaking of a molecular junction. Thereby we have investigated the transport properties of single bipyridyl-dinitro oligophenylene-ethynylene dithiol (BPDN-DT) molecules and bipyridyl oligophenylene-ethynylene dithiol (BP-DT) molecules (see Fig. 1) 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 (see Fig. 2). 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 the 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 [8] for more details).

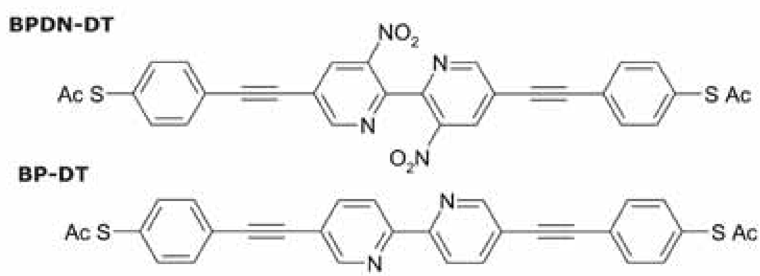

Fig. 1: Molecular structure of BPDN-DT (Bipyridyl-dinitro oligophenylene-ethynylene dithiol), and BP-DT (bipyridyl oligophenylene-ethynylene dithiol).

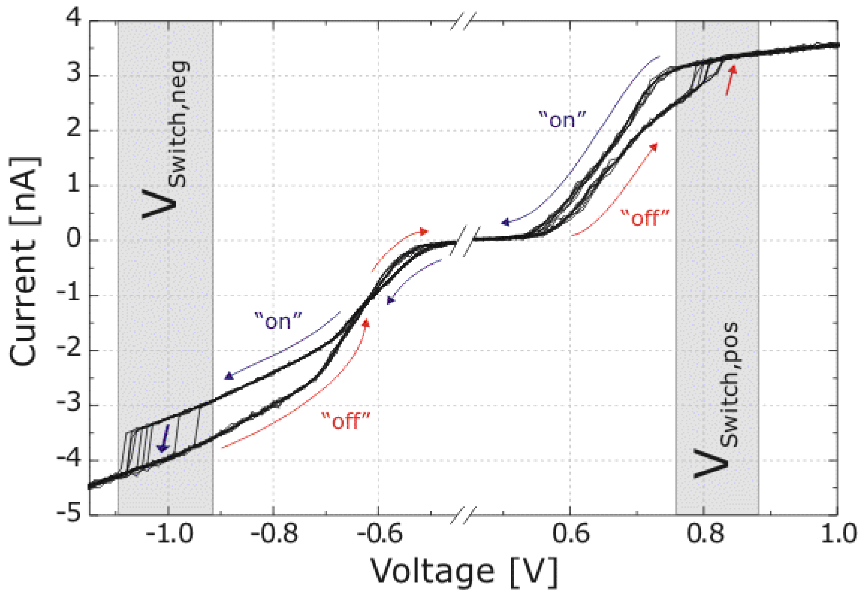

Fig. 2: Several repeated switching cycles of the BPDN-DT: If the voltage applied to the metal–BPDN-DT–metal junction exceeds a certain positive threshold value ($V_{Switch,pos}$), the system switches from the initial "off" state to the "on" state. This state is maintained when operating only at voltages above $V_{Switch,pos}$. A negative voltage sweep or a pulse below the negative threshold value ($V_{Switch,neg}$) resets the molecule again to the initial "off" state.

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