Intelligent Molecular Switches that Learn and Emulate Synaptic Behavior

Christian A. Nijhuis
Department of Molecules and Materials, MESA+ Institute for Nanotechnology, Molecules Center and Center for Brain-Inspired Nano Systems (BRAINS), Faculty of Science and Technology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands.
C.A.Nijhuis@utwente.nl

Our brains constitute a molecular computer that is able to process enormous amounts of information with a tiny energy budget [1]. Inspired by the energy efficiency of brains and the ever-increasing demand for miniaturised electronics, there is a drive to develop devices that mimic the dynamic character of neurons and synapses. To achieve this goal, brain-like computing is emulated with energy inefficient and complex silicon-based circuits or with mesoscale memristors, but these approaches still require large amounts of energy. For these reasons, it is important to develop new types of hardware that can mimic brain-like computation processes [1,2]. We have been developing molecular switches that behave like synapses with the aim to realize spiking neural networks. I will introduce a new type of molecular switch that can remember its switching history [3]. By coupling fast electron transport to slow proton addition steps via dynamic covalent bonds, the switches display time-dependent switching probabilities which can be used for brains-inspired and reconfigurable electronics [4,5]. These artificial synapses are promising to develop alternative neural networks and open new ways to design electronic devices by exploiting their inherent dynamical properties.

References

1) Christensen et al. *Neuromorph. Comput. Eng.* **2022**, *2*, 022501.
2) Zhu, J., Zhang, T., Yang, Y.; Huang, R. A *Appl. Phys. Rev.* **2020**, *7*, 011312.
3) Thompson, D.; Barco, E. d.; Nijhuis, C. A. *Appl. Phys. Lett.* **117**, 030502 (2020).
4) Wang, Y.; Zhang, Q.; Nickle, C.; Venkatakrishnarao, D.; Zhang, Z.; Leoncini A.; Qi, D.-C.; Han, Y.; del Barco, E.; Thompson, D.; Nijhuis, C. A. *Nat. Mater.* **2022**, *21*, 1403-14011.
5) Zhang, Q.; Wang, Y.; Nickle, C.; Zhang, Z.; Leonchini, A.; Qi, D.-C.; Sotthewes, k.; Borrini, A.; Zandvliet, H.J.W.; del Barco, E.; Thompson, D.; Nijhuis, C. A. *Nat. Commun.* **2024**, *15*, 8300.