Memristors using Metal-Azo complexes – optimal devices for Low Energy Computing and Brain Inspired Electronics

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Artificial intelligence (AI) has been heralded as the flagbearer of the fourth industrial revolution. But it comes with a cost and that is computing power. It is projected that by 2040, we will need more computing energy than the total energy we can produce now. So, it is a dire necessity to invent devices (and eventually computing systems) that can offer higher computing/ storage density with low energy consumption.

We are addressing this challenge using a molecular-electronic route. Historically, organic electronic devices have stimulated scientific excitements in OLEDs but are yet to make any other significant technological impact. The reasons behind their limited success are their poor robustness, stability, endurance and most importantly, the lack of mechanistic understanding that restricts the emergence of approaches to solve these problems. We have overcome each of these difficulties in our memristors based on transition metal complexes of azo-aromatic ligands that exhibit high reproducibility (~350 devices), fast switching (≤30 ns), excellent endurance (~10^{12} cycles), stability (>10^{6} s) and scalability (down to ~60nm^2. Using *in-situ* Raman spectroscopy we are able to track the electronic changes in molecules *in-operando* at every point of our voltage sweep providing a clear picture of our molecular mechanism that enables us to do different molecular and device engineering to achieve targeted functionalities. Using devices of this genre we are addressing the existing computing challenges *via* three routes,

- ***(i)*** ***By designing devices with ultra-low power:*** We can design memristors with switching voltage as low as 70mV, with energy ~10aJ/ 60nm^2. The current and voltage levels of these devices meet the requirements specified in ITRS road map.
- ***(ii)*** ***By designing memristors and memcapacitors with multiple discrete plateaus:*** We have developed memristors with 3- 4 distinct conducting plateaus which also shows mem-capacitance. Their concomitant occurrence is enabled by symmetry breaking of our film-molecules driven by voltage, a new paradigm in condensed matter physics.
- ***(iii)*** ***Brain inspired computing:*** Using devices that exhibit concomitant memristive and memcapacitive functions we can simulate biological actions such as neuronal action potential and even cardiac myocyte pulsing.

Our current research spans from molecular engineering all the way to the realization of functional units such as in-memory logic circuits and brain inspired chaotic networks for probabilistic computing.

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