Optical tuning of integrated organic neuromorphic devices for on-chip machine-learning

Master thesis project | Neuromorphic Engineering

Introduction | neuromorphic engineering

Neuromorphic Engineering tries to learn from the brain to develop an efficient computing technology capable of embedding **artificial neural networks (for AI applications)** directly in hardware. This way these complex networks do not need to be simulated on an energy-inefficient (super) computer, but can be fabricated physically on a chip, resulting in highly efficient operation and reduced energy consumption.

At the heart of these networks we use an **organic material** (PEDOT:PSS), not only because this material is relatively cheap and easy to process, but more importantly, since it possesses excellent **electrical, chemical and mechanical tuneability** characteristics, opening up a wide range of properties and applications.

Project | tuning of organic artificial synapses

Our organic electronic devices (**ENODe**) have a great potential to be used in crossbar arrays (see Fig 1b) for efficient neuromorphic computing algorithms. The *single* ENODe devices can be tuned on conductance (see Fig 2b), directly resembling the **synaptic weight** of connections in neural networks (Fig 1).

However, access to and training of individual devices in these crossbar arrays can be challenging due to "**sneak currents**", unwanted programming occurs (inset of Fig 1).

One solution could be to have local training using **light pulses**. This way, the voltage/current from the gate electrode is only allowed when light hits a small photodetector connected to the device (see Fig 3).

Goal | milestones and achievements

The goals of this project are:

1. To develop a single **hybrid device**, connecting an organic photodetector with a programmable ENODe device.
2. Tuning the **synaptic weight** (conductivity) of this device using light pulses.
3. Finally **small arrays (2 x 2)** of these hybrid devices will be fabricated, for examples as shown in Fig 4.

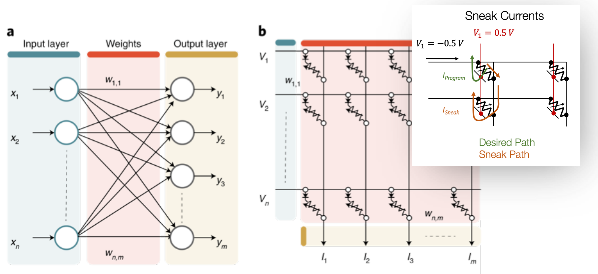

Fig. 1. (a) Schematic of a neural network and **(b)** relevant hardware implementation

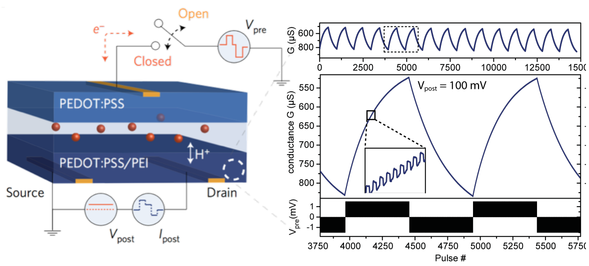

Fig. 2. (a) Device structure and **(b)** conductance tuning of an ENODe device

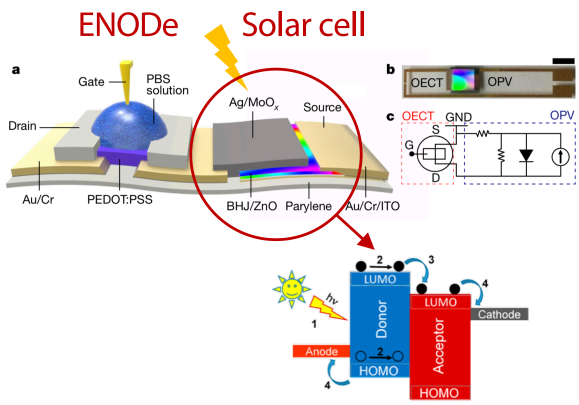

Fig. 3. (a) example of hybrid device **(b)** photo of actual device **(c)** circuit of OPV with OECT/ENODe **(d)** working principle of an OPV

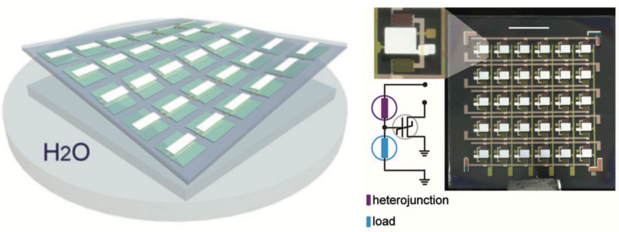

Fig. 4. examples of device array to be developed

References

1) A non-volatile organic electrochemical device as a low-voltage artificial synapse for neuromorphic computing, Y van de Burgt, et al. **Nature Materials**, 2017
2) Self-powered ultra-flexible electronics via nano-grating-patterned organic photovoltaics, **Nature**, 2018
3) A Ferroelectric/Electrochemical Modulated Organic Synapse for Ultraflexible, Artificial Visual-Perception System. **Advanced Materials,** 2018

Interested?

dr. Y. van de Burgt (y.b.v.d.burgt@tue.nl) | GEMZ 3.126