Electropolymerization of PEDOT:PSS for neuromorphic and biohybrid applications

Master thesis project | Neuromorphic Engineering

Introduction | Organic neuromorphic materials

Brain-inspired (**neuromorphic**) computing has recently demonstrated major advancements in pattern and image recognition as well as classification of unstructured (big) data [1]. These artificial **neural networks (ANN)** are ideal for classifying difficult ambiguous data such as biomarkers or cells.

Organic materials are excellent candidates for hardware-based neural networks as they are cheap, easy to use, flexible and biocompatible [1]. However, fabricating large crossbar array of these devices remains a challenge.

PEDOT:PSS is one of the most widely used conductive polymers and has been demonstrated to be useful as artificial synapses to be used in arrays [2]. However, electropolymerization of these conductive polymers was also demonstrated to yield interesting synaptic phenomena such as short and long term plasticity [3].

Project | Controlled Electropolymerization of PEDOT:PSS

In this project we want to investigate the electropolymerization capabilities of PEDOT:PSS useful in neuromorphic applications. This includes reservoir computing as well as **direct** forming of (simple) ANN networks as shown in Fig 1. Finally, this biocompatible nature of PEDOT:PSS allows for direct interfacing with biological cells and tissue [5]. We want to use this property to develop artificial axons (Fig 3) that can directly interface with real neurons in a biohybrid fashion.

Goal | milestones and achievements

The goals of this project are:

1. To develop a reliable electro-polymerization technology for PEDOT:PSS.
2. To use these (branched) PEDOT wires in simple 1-1 bridges connecting electrodes
3. To investigate reservoir computing capabilities for larger (4 x 4) networks.
4. To grow these PEDOT wires as artificial axons, possible to be directly coupled with biological cells (neurons and axons).

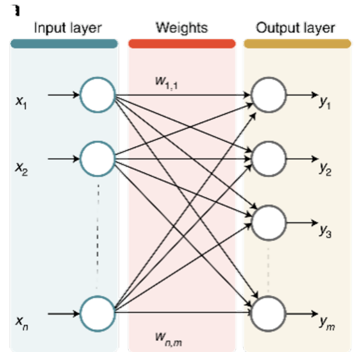

Fig. 1. Schematic of an Artificial Neural Network [1.2]

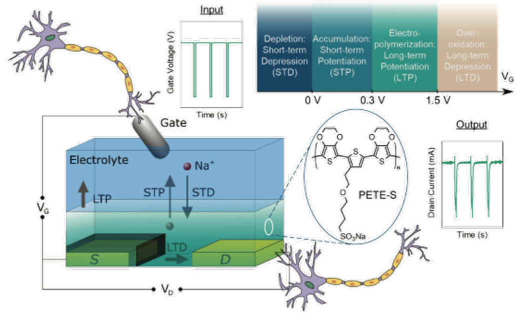

Fig. 2. Example for using electropolymerization as long term memory in organic transistors [3].

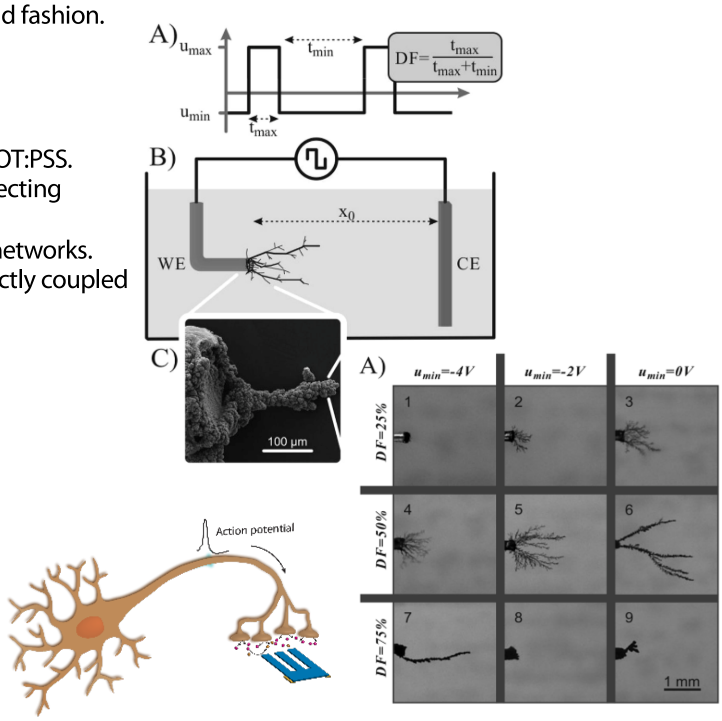

Fig. 3. Process of electropolymerization. Branching can be used to directly grow ANN [4,5]

References

1) Organic Electronics for Neuromorphic Computing, Y van de Burgt, et al. **Nature Electronics**, 2018
2) Organic Electronics for Neuromorphic Computing, Y van de Burgt, et al. **Nature Materials**, 2017
3) An Evolvable Organic Electrochemical Transistor for Neuromorphic Applications, Gerasimov et al. **Advanced Science,** 2019
4) Pulsed electropolymerization of PEDOT enabling controlled branching, Eickenscheidt et al. **Polymer Journal** 2019
5) A biohybrid synapse with neurotransmitter-mediated plasticity, Keene, Lubrano, Kazemzadeh et al. **Nature Materials**, 2020

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