Self-organizing nanowire networks: brain inspiration *versus* computing performance

C. Ricciardi[1], F. Michieletti[1], D. Pilati[1,2] and G. Milano[2]

[1] Politecnico di Torino - DISAT, Corso Duca degli Abruzzi 24, 10129 Torino, Italy

[2]Istituto Nazionale di Ricerca Metrologica - INRiM, Strada delle Cacce 91, 10135 Torino, Italy

*E-mail: carlo.ricciardi@polito.it

Since more than ten years, neuromorphic nanowire networks are attracting a growing research community because of their brain-inspired nature. The most distinguished features that associate such solid-state devices to biological neural networks are criticality, emergent behaviour, structure-function relationship, and structural plasticity. Such brain-inspired features are added to *standard* properties of neuromorphic devices like short- and long-term plasticity, non-linearity and low power consumption.

The simplistic assumption that could make self-organizing nanowire networks more promising than top-down crossbar memristive arrays is that the more similar to brain is the device behaviour, the more similar is expected to be its computing performance in terms of learning capability and energy saving. How much of this assumption was experimentally proved? While emergent criticality was the main inspiration factor from the very beginning[1], no experiment has clearly demonstrated yet that a nanowire network outperforms in a computational task when driven to a critical state from a non-critical one. On the opposite, many successful results have been reported about physical (*in materia*) reservoir computing with nanowire (or other nanoobjects) networks[2], even if the relationship with device emergent behaviour and structure-function relationship are not always deepened[3]. Finally, structural plasticity was just experimentally characterized at junction[4] and network[5] levels, without any highlighted action in a computing task.

The present work aims at better elucidating the link between brain inspiration and computing performance in self-organizing nanowire networks. New results will be also shown about how multielectrode characterization can give crucial insights on the impact of emergent dynamics and criticality to non-linear transformations.

[1] A. Stieg et al., Adv. Mater., 24, 286-293, 2012

[2] G. Milano et al., Nature Mater., 21, 195-202, 2022

[3] R. Zhu et al., Nature Commun., 14, 6697, 2023

[4] G. Milano et al., Adv. Intell. Syst., 2(8), 2000096, 2020

[5] G. Milano et al., Nature Commun., 14, 5723, 2023