Influence of device topology on in-materio reservoir computing

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In-materio reservoir computing (I-mRC) has been getting much attention due to the possibility of utilizing such devices to overcome current limitations arising from von Neumann's architecture. Nonetheless, such devices are in the initial stages of development and have not yet been fully realized. Various physical phenomena and techniques, such as spin-wave, optics, mechanical, electrical, etc., are utilized to construct an I-mRC device to function like the human brain ultimately. Recently, there have been significant developments in the field of nanomaterials and their use for I-mRC devices. Carbon nanotubes (CNTs)-Polyoxometalate (POM) being one of the many approaches [1]. The spatiotemporal non-linear dynamic and higher dimensional information mapping [2] resulting from semiconductive CNTs and redox-active POM make the CNTs-POM network ideal for I-mRC devices. In addition, due to the intrinsic properties of CNTs, such as the high aspect ratio, it is easy to fabricate a network that resembles the biological neuronal network.

There are still uncertain areas in I-mRC devices that need to be explored. We have recently shown that using the template technique, we could fabricate a three-dimensional (3D) I-mRC device using CNTs-POM [3]. By immersing a melamine sponge in CNTs-POM dispersion prepared through physical attachment via sonication of single-walled carbon nanotubes (SWCNTs) with phosphomolybdic acid hydrate (PMo_{12}) for 4 hours, we managed to fabricate a 3D I-mRC device. 3D I-mRC device was fabricated to mimic the same network structure as the human brain and determine the possibility of using CNTs-POM in such a manner. Our studies showed positive and promising results, for instance, robust higher dimensional mapping, memory capacity (Fig. 1A), and higher accuracy in waveform generation task (Fig. 1B), suggesting certain advantages in 3D I-mRC devices compared with the two-dimensional (2D) counterpart. The change in performance with respect to applied voltage signifies the voltage dependence non-linear activity of the CNTs-POM network. Although almost all the measurements and analysis indicate the superiority of 3D device to 2D, the population activity (Fig. 1C) was higher in the 2D device, implying a higher density of network activity while 3D network exhibit distribution dependent activity similar to the human brain making 3D I-mRC device suitable for task-dependent I-mRC.

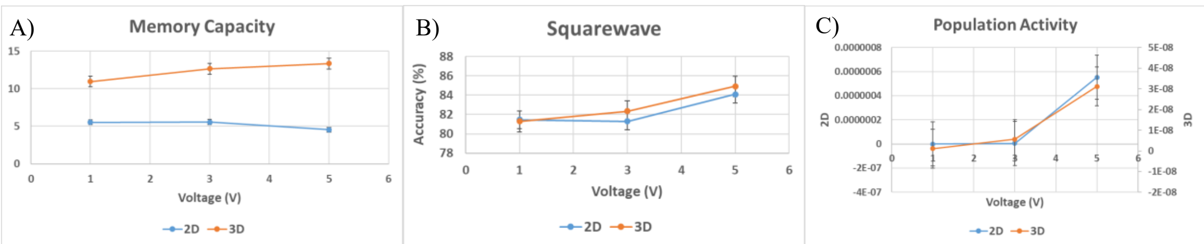

Fig. 1. A) memory capacity, B) waveform generation, and C) scale-free network exponent of 2D & 3D devices at various applied voltages

Refs.: [1] H. Tanaka *et al.*, ***Nat. Commun.*** 9, 1–7 (2018). [2] G. Tanaka *et al.*, ***Neural Networks*** 115, 100–123 (2019). [3] S. Azhari et al., "3D electric device and machine learning system" Japanese patent application #2020-174660.