

02383

Ultra fast operation of VO₂ oscillators

E. Neuromorphic computing and adaptive sensing: material challenges, advances and future prospects

**Zsigmond Pollner¹, Tímea Török^{1, 2}, László Pósa^{3, 4}, János Volk⁴,
András Halbritter^{1, 5}**

¹Budapest University of Technology and Economics - Budapest (Hungary), ²HUN-REN-BME Condensed Matter Research Group - Budapest (Hungary),

³Budapest University of Technology and Economics - Budapest (Hungary) - Budapest (Hungary), ⁴HUN-REN Centre for Energy Research - Budapest (Hungary), ⁵ HUN-REN-BME Condensed Matter Research Group - Budapest

Abstract

Neuromorphic circuits can be straightforwardly constructed using memristors, given that non-volatile resistive switches can serve as artificial synapses, while volatile memristors can function as artificial neurons capable of generating diverse neural spiking patterns [1]. Mott memristors are also effectively used in oscillating neural networks, where information is encoded in the oscillator phase and the computation result is found by minimizing the system energy [2]. Fast operation is essential for energy and time efficiency of these applications, but to date only oscillation frequencies of 10 MHz have been achieved, with the most common VO₂-based Mott memristors [3]. Focusing on nanoscale VO₂ Mott memristors with a ~30 nm active region between electrodes [4], we investigate their dynamic operation and explore the physical [5] and geometrical factors limiting the speed of VO₂ oscillators. This exploration involves analyzing time-resolved pulsed experiments and device state evolution during constant bias oscillatory operation. Through identifying and mitigating many of these limiting factors, we have designed oscillators capable of reaching more than 100 MHz operation frequency. Finally, we investigate the coupling of such high-frequency oscillators.

[1] Yi, W. et al. Biological plausibility and stochasticity in scalable VO₂ active memristor neurons. *Nature Communications* 9, 4661925 (2018)

[2] Maher, O., Jiménez, M., Delacour, C. et al. A CMOS-compatible oscillation-based VO₂ Ising machine solver. *Nat Commun* 15, 3334 (2024)

- [3] Mian, M.S. et al., Self-oscillation up to 9 MHz based on voltage triggered switching in VO₂/TiN point contact junctions, *Journal of Applied Physics*, 117, 215305 (2015)
- [4] Pósa, L. et al., Interplay of Thermal and Electronic Effects in the Mott Transition of Nanosized VO₂ Phase Change Memory Devices. *ACS Nano*, 6, 9137 (2023)
- [5] Schmid, S.W. et al., Picosecond Femtojoule Resistive Switching in Nanoscale VO₂ Memristors. *ACS Nano*, 18, 21966 (2024)