On the global dynamic behavior of spiking memristor networks

MEMRISYS 2022

The 5th International Conference on Memristive Materials, Devices & Systems

TetraMem

rmv ROCKY MOUNTAIN VACUUM TECH

MIT AI Hardware

Nov 30 – Dec 2, 2022 (Hybrid Event)
Boston Marriott Cambridge
Cambridge, MA, United States

MEMRISYS 2022
(The 5th International Conference on Memristive Materials, Devices & Systems)

Nov 30   Dec 2, 2022, Cambridge, MA, USA

Boston Marriott Cambridge

Memristor technologies are expected to overcome the limits of conventional CMOS technology, opening up new paradigms of computing/memory systems that will become the forefront of ICT, AI, and IoT technologies. MEMRISYS 2022 will provide a forum to share and discuss the current state-of-the-art development process of memristive technologies.

The conference will cover a wide range of related fields such as physics, chemistry, material science, devices, circuits, systems, neuromorphic networks, and bio-inspired computing, to name a few. The purpose of this conference is to open a highly interdisciplinary forum in a single international conference that will bring a new holistic view on developments in the field.

We are confident that MEMRISYS 2022 will offer more to see, learn, and experience about future memristor technologies than ever before.

Session 1. Neuromorphic Sensors

Session 2. Memristive Materials

Session 3. Memristive Devices and Architectures

Session 4. Neuron Devices and Learning Algorithms

Session 5. Neuromorphic Edge Computing Applications

Session 6. Quantum Effect in Memristors

Program Overview

Day 1 (Nov 30)

Salon 3	Salon 4
Honorary Talk 08:00 – 09:00	
Session 5 09:00 – 10:10	**Session 2** 09:00 – 10:10
Coffee Break 10:10 – 10:30	**Coffee Break** 10:10 – 10:30
Session 5 10:30 – 12:00	**Session 3** 10:30 – 12:00
Lunch Break 12:00 – 13:30	
Session 3 13:30 – 14:50	**Session 2** 13:30 – 15:55
Coffee Break 14:50 – 15:10	**Coffee Break** 15:55 – 16:20
Session 3 15:10 – 16:35	**Session 4** 16:20 – 18:40
Banquet* 19:00 – 21:00	

Day 2 (Dec 1)

Salon 4	Salon 5
Session 5 09:00 – 10:10	**Poster Preparation** 09:00 – 10:00
Coffee Break 10:10 – 10:30	**Poster Session (Topic 3 & 4)** 10:00 – 12:00
Session 3 10:30 – 12:00	
Lunch Break 12:00 – 13:30	
Session 3 13:30 – 16:00	**Poster Preparation** 15:00 – 16:00
Coffee Break 16:00 – 16:20	**Poster Session (Topic 1, 2, 5 & 6)** 16:00 – 18:00
Session 3 16:20 – 18:00	
Editorial Session 18:10 – 18:40	

Day 3 (Dec 2)

Salon 3	Salon 4
Honorary Talk 08:00 – 09:00	
Session 4 09:00 – 10:00	**Session 3** 09:00 – 10:10
Coffee Break 10:00 – 10:30	**Coffee Break** 10:10 – 10:30
Session 2 10:30 – 12:05	**Session 1** 10:30 – 12:00
Lunch Break 12:05 – 13:30	
Session 6 13:30 – 15:55	**Session 5** 13:30 – 15:45
Coffee Break 15:55 – 16:20	**Coffee Break** 15:45 – 16:00
Session 2 16:20 – 18:35	**Session 2** 16:00 – 18:20
Closing	

*Banquet is only for oral speakers and editorial panelists (poster presenters not included).

[4] A. Ascoli, A.S. Demirkol, R. Tetzlaff, and L.O. Instability

and Selected Topics in Circuits and Systems (JETCAS), 2022, in press

2013

pp. 3435 3456, 2005

[7] A. Ascoli, A.S. Demirkol, R. Tetzlaff, and L.O. Origin for

Fundamental Bifurcation Phenomena in Memristive Trans. Circuits and Systems-I (TCAS-I): Regular Papers, under review

Session 3. 15:30 15:50 (Invited)

Ferroelectric Artificial Synapse and Neural Network for Wearable and Energy-efficient Neuromorphic Electronics

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For sustainable advancements in electronics technology, the field of neuromorphic electronics, i.e., electronics that imitate the principle behind biological synapses with a high degree of parallelism, has recently emerged as a promising candidate for novel computing technologies. Especially, this brain-inspired computing architecture is suitable for an e-textile/wearable computing platform because of the potential to efficiently process the large amount of unstructured sensing data, including diverse and complex signals from the human body or the surrounding environment. In this talk, I am going to present recent works on diverse types of ferroelectric organic artificial synapses for neuromorphic applications, which can apply to wearable and human-interactive electronic system. Additionally, I will present a novel type of three-dimensional barristor synaptic array that utilizes a heterostructure of ferroelectric organic layer (or HZO) and graphene to create a convolutional neural network, which can efficiently learn and recognize targeted images.

Session 3. 15:50 16:05

On the Global Dynamic Behavior of Spiking Memristor Networks

Marco Gilli (Politecnico di Torino)

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Second-order memristors exhibit some specific features of neuron synapses, specifically Spike-Timing-Dependent-Plasticity (STDP), and consequently can be considered good candidates for neuromorphic computing [1]. They present a conductance depending on two orders of variables, namely the geometric parameters and the internal temperature, which resemble some state-of-the-art biophysical models of synaptic plasticity [2]. Spiking memristor networks, particularly crossbar structures, are suitable for implementing locally competitive algorithms and tackling classification problems by exploiting temporal learning techniques. The analysis and prospectively the synthesis of memristor networks requires accurately evaluating the mem-conductance variations due to arbitrary pre/post synaptic spikes sequences.

In [3], we have derived a simplified differential model of a second-order memristor, which only involves two state variables, the mem-conductance and the internal temperature.

We have shown that, through this model, the mem-conductance variation, due to various spike combinations, can be almost analytically computed. In addition, second-order memristor's most significant synaptic properties are easily studied and predicted, including the response to spike pairs, triplets, and quadruplets. Memristor spiking networks are described as discrete nonlinear dynamic systems, with mem-conductances as state variables and pre and postsynaptic spikes as inputs and outputs. By exploiting the model mentioned above, we have explicitly derived the state equations governing the mem-conductance evolution, and we have shown that it provides many insights concerning memristor network global dynamic behavior.

In this paper, we address dynamic behavior more systematically. Firstly, we show that the explicit expression of the state equation allows us to reproduce and predict the response of rather complex memristor networks through standard nonlinear simulation tools. Secondly, we show that the qualitative network dynamics can be investigated by employing theoretical and numerical advanced nonlinear techniques. Thirdly, we explore how an in-depth understanding of dynamic behavior can be exploited to develop efficacious unsupervised and supervised temporal learning algorithms.

[1] S. Kim, C. Du, P. Sheridan, W. Ma, S. Jin Choi,

second-order memristor and its ability to

Letters, vol. 15, pp. 2203-2211, 2015.

alcium-based plasticity model explains sensitivity of synaptic

Proceedings of the National Academy of Sciences - USA, vol. 109, pp. 3991-3996, 2012.

[3] F. Marrone, G. Zoppo, F. Corinto, and M. Gilli dynamic system approach to spiking second order

and Systems 1654, April 2022.

Session 3. 16:05 16:20

Kinetics Acceleration of Memristive Devices Driven by Thermal Confinement

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Filamentary ReRAM devices have been reported to exhibit significant temperature accelerated switching kinetics. Here we demonstrate a significant improvement in the kinetics of the SET process by engineering this thermal acceleration for the memristive model system SrTiO3.

In particular, we have implemented a novel approach of thermal engineering in the ReRAM device stacks, without altering the properties of the switching oxide or its interfaces. In this work we present two different variations: i) we have used reduced tantalum oxide as the main body of the active electrode, which is electrically conductive, but still has relatively low

have introduced an electrically insulating, low thermal

of the device. In both approaches, the introduced materials act as a thermal barrier in the z-direction, which reduces the thermal conductance through the active top electrode.

Our results demonstrate that using these two approaches, the memristive devices can be switched to their low resistive state (LRS) in significantly faster times, for the same voltage pulses applied, compared to the reference sample of Nb:STO/STO/Pt. The sample with the TaOx as main body of the top electrode switches to the LRS at least 10 times faster than the reference sample, while the sample with the embedded HfO2 interlayer shows even better performance, achieving the LRS in 3 orders of magnitude faster times, compared to the reference.

From these results we conclude that the introduction of a heat blocking layer, embedded in the active electrode of a ReRAM device, is an efficient way to improve the kinetics of the switching oxide. Decreasing the thermal losses in the switching layer, maintains a higher local temperature in the filament vicinity, created by the Joule heating during the switching process. The higher local temperature accelerates the ionic movement necessary for the SET process to take place, resulting in much faster switching times. The fact that there are no modifications of the main stack of the ReRAM device (ohmic contact/switching oxide/Schottky contact) makes this approach a more general mechanism to accelerate the switching kinetics in ReRAM devices and not limited to the specific memristive SrTiO3 stack used in this work.

Session 3. 16:20 16:35

Controlling Switching Stochasticity in Hybrid Memristors by Vapor-Phase Infiltration

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Resistive random-access memory (RRAM) is promising for next-generation data storage and non-von Neumann computing hardware. However, tuning device switching characteristics and particularly, controlling their stochastic variation remain as critical challenges. Here, new organic-inorganic hybrid RRAM media are reported whose bipolar switching characteristics and stochasticity can be controlled by vapor-phase infiltration (VPI), an ex situ hybridization technique derived from atomic layer deposition. Hybrid RRAMs based on AlOx-infiltrated SU-8 feature facile tunability of device switching voltages, off-state current, and on-off ratio by adjusting the amount of infiltrated AlOx in the hybrid. Furthermore, a