An Operando Testbed for Emerging Analog Memories (OpTEAM)

S. Oh[1], A. S. Christenson[2], J. J. Kistner-Morris[1], B. Gunn[1], A. L. Gross[1], P. S. Finnegan[2], S. Agarwal[1], E. J. Fuller[1], and A. A Talin[1]*

[1]Sandia National Laboratories, Livermore, CA, USA

[2]Sandia National Laboratories, Albuquerque, NM, USA

The rapidly growing amount of energy consumed in training and utilizing artificial intelligence such as the large language models (LLMs) has motivated an intense search for new computing hardware and algorithms to improve energy efficiency[1]. In-memory computing schemes based on emerging analog non-volatile analog memory (NVM) device concepts has the potential to dramatically lower the energy used for data movement in current digital architectures. However, despite numerous demonstrations of promising device characteristics for NVMs based on various mechanisms (e.g. filamentary, phase change, magnetic, etc.) the practical implementation of these approaches remains uncertain. This is due, in part, to non-ideal device characteristics such as non-linearity and excessive noise at high resistances, inadequate endurance and low retention. Some of these issues such as noise and non-linearity can be addressed using for example denoising procedures or various algorithms, but the increased latency and/or energy costs substantially lessen the appeal of the emerging NVM solution. Another challenge is the lack of well-defined fabrication processes, predictable and controllable characteristics and scalable, validated compact models for the design of arbitrary circuits and networks. The approach of fabrication and test of small batches of isolated devices often leads to poor reproducibility and is inadequate for the development of compact model needed for the design of functional networks. In this work, we demonstrate an operando testbed for emerging analog memory development (OpTEAM) (Fig. 1) designed for testing small networks (up to 16 devices) of NVMs without the need for integration with CMOS peripheral input/output circuitry or access devices. Additionally, the OpTEAM is designed to facilitate the correlation of electrical tests such as training or inference with other physical characteristics such as thermal or optical/spectroscopic measurements. As 'exemplar' devices we use TaO_x resistive memory and WO_x based electrochemical memory (WO_x-ECRAM). Taking advantage of the electrochromic quality of WO_x allows us to correlate programming of the memory elements with the spatial distribution of the oxygen vacancy dopants.

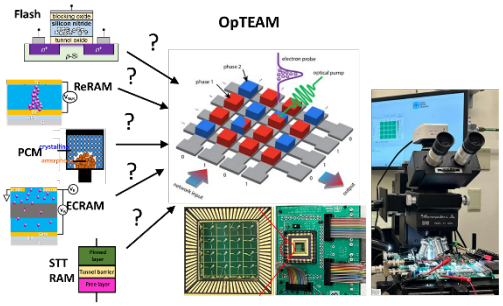

Figure 1. Operando Testbed for Emerging Analog Memory

[1] A. A. Talin and B. Yildiz, Introduction: Neuromorphic Materials, Chem. Rev 125, 4765, 2025.

+ Author for correspondence: aatalin@sandia.gov