Performance Analysis and Optimization of Fructose-Memristor Based Neuromorphic Systems

Harshvardhan Uppaluru[1], Md Shakil Mahmud Jiban[2], Shah Zayed Riam[1], Feng Zhao[2], Jinhui Wang[1*]

[1]*Electrical and Computer Engineering, University of Alabama, Tuscaloosa, AL, USA*

[2]*Electrical Engineering, Washington State University, Vancouver, WA, USA*

Natural organic materials based memristors have demonstrated promising synaptic behavior, positioning them as strong candidates for synaptic devices in neuromorphic computing. Such natural organic memristor based neuromorphic systems also offer significant benefits - environmental sustainability, low production and disposal costs, non-volatility, and compatibility with bio/CMOS-based systems. This paper systematically demonstrates and evaluates a neuromorphic system based on fructose-memristors. First, the manufacturing process of 16-level and 32-level fructose-memristors is described in detail. Second, the nonlinear property [1] associated with fructose-memristors is investigated, and a piecewise linear approximation (PLA) method [2, 3] is introduced and applied to mitigate the effects of nonlinearity. The effectiveness of the approximation method is evaluated using 2-segment, and 3-segment models. Simulation results demonstrate that fructose-memristors based neuromorphic systems achieve maximum training accuracies of 78% for 16-level devices and 82% for 32-level devices using 2-layer fully connected neural network and MNIST dataset. Using piecewise linear approximation method has further increased the inference accuracy by up to 4% in 16-level and 32-level devices. On CIFAR-10 dataset using VGG-8 network, the neuromorphic system achieves a peak training accuracy of 60% for 16-level and 71% for 32-level devices. These findings not only demonstrate the viability of fructose-memristors but also highlight their potential in sustainable neuromorphic systems. The fructose-memristor represents a promising addition to sustainable alternatives for neuromorphic systems, encouraging further exploration into natural organic materials.

* Corresponding author: Jinhui Wang, email: jwang231@ua.edu

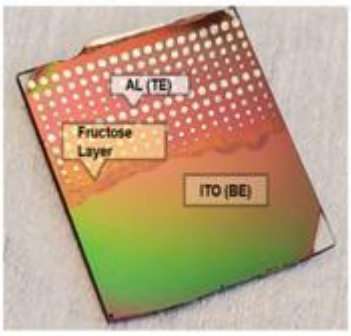

Figure 1: Finished sample with circular Al/Fructose/ITO memristors

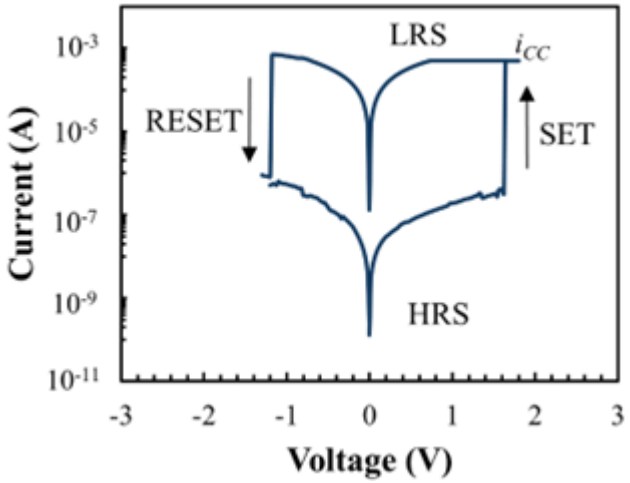

Figure 2: Bipolar resistive switching behavior of an Al/Fructose/ITO memristors

References

[1] P.-Y. Chen, B. Lin, I.-T. Wang, T.-H. Hou, J. Ye, S. Vrudhula, J.-s. Seo, Y. Cao, and S. Yu, "Mitigating effects of non-ideal synaptic device characteristics for on-chip learning," in 2015 IEEE/ACM International Conference on Computer-Aided Design (ICCAD). IEEE, 2015, pp. 194–199

[2] H. Uppaluru, Z. Templin, M. R. Khan, M. O. Faruque, F. Zhao, and J. Wang, "256-level honey memristor-based in-memory neuromorphic system," Electronics Letters, vol. 60, no. 17, p. e70029, 2024.

[3] H. Uppaluru, M. M. H. Tanim, M. O. Faruque, M. R. Khan, Z. Templin, F. Zhao, and J. Wang, "Variation-aware non-linear mapping for honey-memristor based neuromorphic system," in 2024 International Conference on Neuromorphic Systems (ICONS). IEEE, 2024, pp. 32–38.