Supporting Information for

Interface Engineered V_2O_5-based Flexible Memristors towards High-Performance Brain-Inspired Neuromorphic Computing

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Artificial Neural Network simulation.

We have introduced following model and fit our data to the sigmoidal formulas $G_p = B_p\,(1\text{-}e^{-P/Ap}) + Gmin$ and $G_d = B_d\,(1\text{-}e^{-(P-Pmax)/Ad}) + Gmax$. Where $B_{p,d}$ = Gmax-Gmin/(1-$e^{-\frac{Pmax}{Ap,d}}$). G_p is the conductance of the potentiation; G_p is the conductance of the depression. *Pmax* is the maximum number of pulses. Ap and Ad quantify respectively the linearity factor of potentiation and depression. These extracted parameters are then incorporated into the constructed ANN. The network was used to perform supervised learning using the Modified National Institute of Standard and Technology (MNIST) database for handwritten digit recognition. Our model uses a multilayer perceptron (MLP) made of 400 input neurons, 100 hidden neurons, and 10 output neurons as detailed schematically in Figure (). The 400 input neurons correspond to 20 × 20 black and white pixels for the input picture, and the 10 output neurons correspond to digits from 0 to 9. The inner product between the input neuron signals and the respective synaptic weights from the first synapse array is transferred to the hidden neuron layer. The same computing scheme is then done from the hidden neuron layer to the output neuron layer through the second synaptic array, constituting one epoch. At each epoch, the ANN is trained on 60000 images randomly selected from the MNIST training data set, and the recognition accuracy is tested on distinct sub-dataset.

The confusion matrix:

The recognition accuracy achieved by the device-based simulation is 86.75%, whereas the ideal software-based simulation attains 90%, in agreement with the reviewer's observation. Furthermore, the confusion matrices for both the ideal and device-based simulations (Figure S1 (a,b)) have been included to provide a clearer illustration of the recognition performance across different digit classes. These results demonstrate the close agreement between the ideal and experimental synaptic models, confirming the reliability of the proposed device for neuromorphic computing applications.

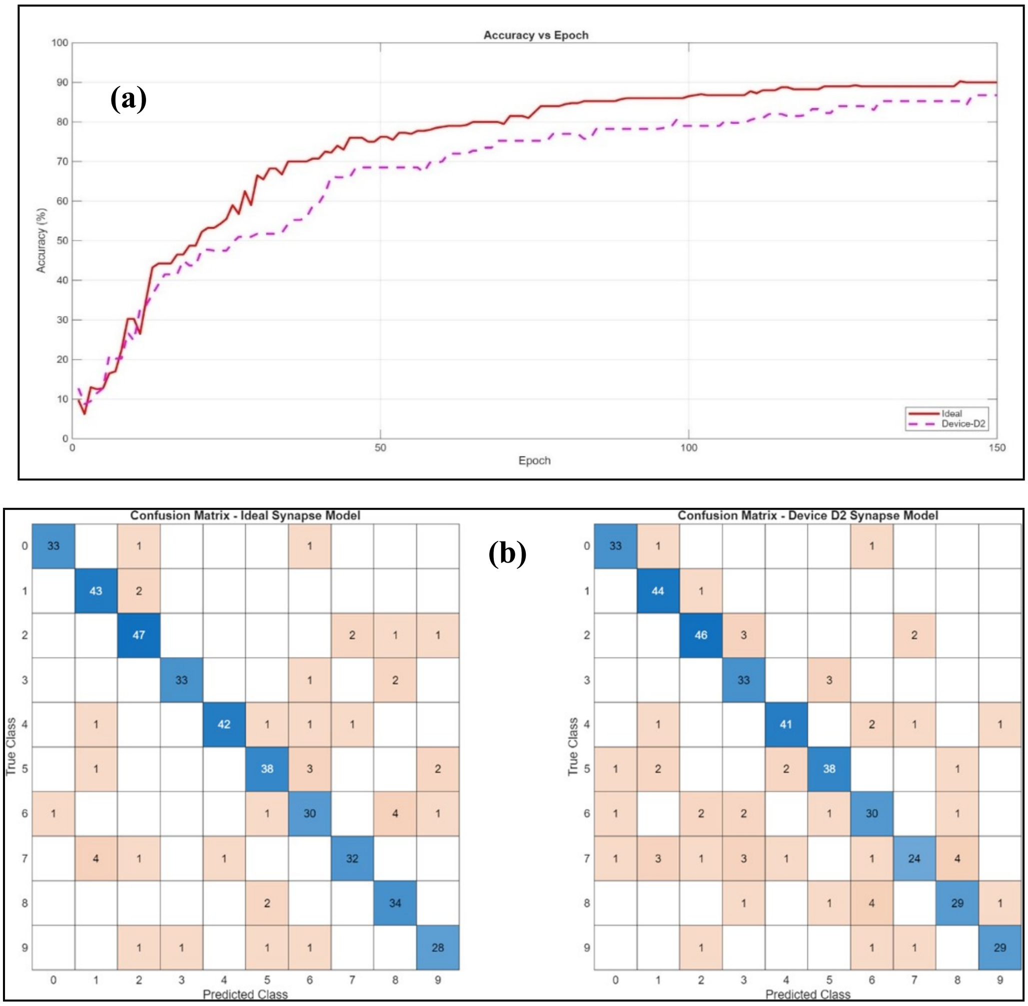

Figure S1. Illustrates (a) the accuracy as a function of epoch, and (b) the corresponding confusion matrix at epoch 150.

The confusion matrix at Epoch 1050

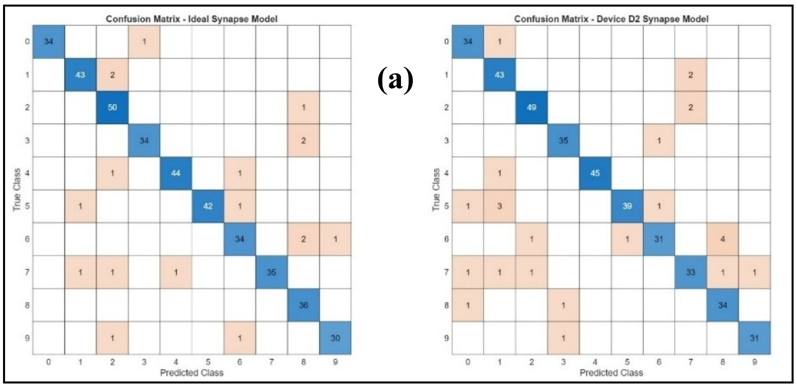

Figure S2.(a) the confusion matrix obtained at epoch 1050.

Neuromorphic computing, the stability between devices also warrants discussion:

Additional experimental results illustrating the LTP/LTD characteristics confirm consistent synaptic behavior and reproducibility among the memory cells, as presented in the newly added Figure S2(a,b). Furthermore, the uniformity of D2 is observed to be higher than that of D1.

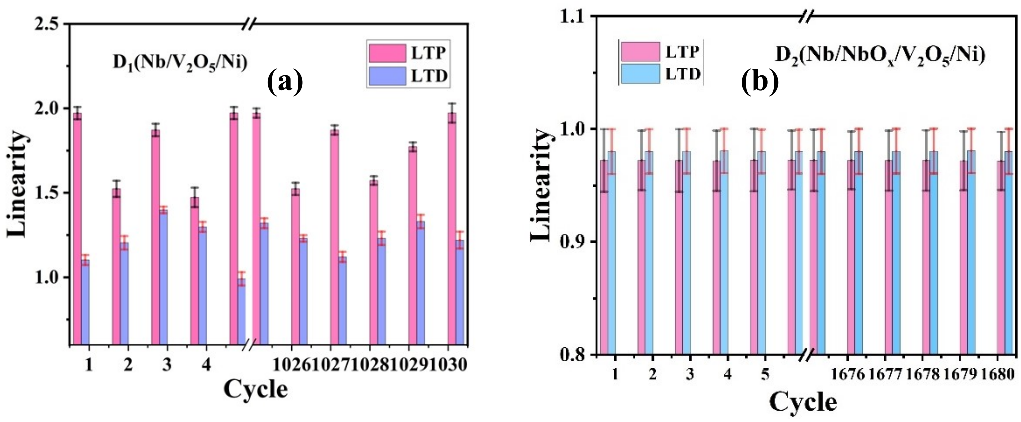

Figure S3.(a,b) Illustrates the cycle-to-cycle LTP/LTD linearity characteristics.

The Richardson-Schottky equation of the I–V characteristics:

At the Nb/NbOx interface, the Schottky barrier height can be calculated using the Richardson–Schottky equation. The Richardson–Schottky equation of the I–V characteristics is given by

$$I = AA^{*} T^2 \exp\{-q(\frac{(\Phi_B - \sqrt{qE4\pi\epsilon})}{kT}\} \qquad 1$$

Where, where, A = π(50 μm)2 = cell contact area, A*= $\frac{4\pi q M_n^* k^2}{h^3}$ = Richardson constant, T = temperature, q = electric charge, ϕ_B = Schottky barrier height, E = electric field, ϵ = dielectric constant of material and k = Boltzmann constant. Taking the natural logarithm of eqn (1) and replacing E by V/d, where d is the distance between the Nb top and Ni bottom electrode, we get

$$\ln(I) = \{\ln(AA^*T^2) - \frac{q}{kT}\phi_B\} + \frac{q}{kT}\sqrt{\frac{q}{4\pi\epsilon}}\sqrt{V} \qquad 2$$

By taking the value of A* = 119.56 A/K^2 cm^2 (M_n^* =M$_0$), Schottky barrier height (ϕ_B) is calculated from the intercept of ln(I) vs $\sqrt{V}$.