**Supporting Information**

**Ultrathin SrTiO3-based oxide memristor with both drift and diffusive dynamics as versatile synaptic emulators for neuromorphic computing**

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**Note 1. Thermionic emission (TE) model**

Charge carriers have the possibility to overcome the barrier by thermal excitation when temperature is above zero, which is called thermionic emission (TE)[1]. For the HRS, the transport is dominated by the Schottky barriers, where the current (*I*TE) increases exponentially with voltage in forward bias. The thermionic emission mechanism is thus adopted to describe the HRS current. For the thermionic emission (TE) currents, under forward bias (*V* > 3*k*B*T*/*q*), the current across the Schottky barrier is given by[2]

$I\_{TE}=SA^{\*}T^{2}θ\_{n}exp(-\frac{Φ\_{B}}{k\_{B}T})exp(\frac{qV}{ηk\_{B}T}) $ (S1)

Where *S* is the electrode area, *A*\* is the standard Richardson constant, *T* is the absolute temperature, *θ*n is the transmission coefficient for tunneling across the interfacial layer, *Φ*B is the Schottky barrier height, *k*B is the Boltzmann’s constant and *η* is the ideality factor. In the calculations, *A*\*=156 A cm-2 K-2. Through fitting the *I*-*V* curve at HRS, the calculated Schottky barrier height is about 0.505 eV.

**Note 2.** **Direct tunneling (DT) model and Fowler-Nordheim tunneling (FNT) model**

At LRS, direct tunneling (DT) is conspicuous at a low voltage and Fowler-Nordheim tunneling (FNT) dominates at a high voltage[3]. Essentially, direct tunneling currents and FN tunneling currents have the same origin, both being tunneled through the potential barrier by carriers with energy below the barrier height to the other side of the barrier. The main difference between them is the difference in the pressure drop across the oxide layer when tunneling occurs[4]. Direct tunneling is a quantum mechanical tunneling process with lower energy carriers, and it is also an elastic transport process close to equilibrium. The low-voltage part of the nonlinear LRS *I*-*V* curves can be well fitted to the direct tunneling (DT) model based on a trapezoidal barrier. The DT current *I*DC through a trapezoidal barrier can be described as[5]

$I\_{DC}=-S\frac{4em^{\*}}{9π^{2}ℏ^{3}}\frac{exp\left\{α(V)[(Φ\_{2}-\frac{eV}{2})^{\frac{3}{2}}-(Φ\_{1}+\frac{eV}{2})^{\frac{3}{2}}]\right\}}{α^{2}[(Φ\_{2}-\frac{eV}{2})^{\frac{1}{2}}-(Φ\_{1}+\frac{eV}{2})^{\frac{1}{2}}]^{2}}×sinh\left\{\frac{3}{2}α(V)[(Φ\_{2}-\frac{eV}{2})^{\frac{1}{2}}-(Φ\_{1}+\frac{eV}{2})^{\frac{1}{2}}]\frac{eV}{2}\right\}$ (S2)

Where $α(V)=\frac{4d(2m^{\*})^{\frac{1}{2}}}{3ℏ(Φ\_{1}+eV-Φ\_{2})}$, *Φ*1 and *Φ*2 are the barrier height at Cr/STO and STO/NSTO interface, respectively. *S* is the electrode area, *m*\* is the effective electron mass, *ħ* is the reduced Planck constant and *d* is the STO barrier width of about 4 nm. Here, *Φ*1 and *Φ*2 are used as fit parameters to describe the direct tunnelling through a trapezoidal potential barrier. The calculated *Φ*1 and *Φ*2 are 0.36 eV and 0.47 eV for STO.

FN tunneling is a field-induced electron tunneling process. When the applied voltage exceeds the interfacial barrier height, part of the energy barrier profile will lie beneath the Fermi energy level of the electrode, consequently, the effective tunneling barrier become triangular-shaped potential barrier[6]. Fowler-Nordheim tunneling (FNT) is tunneling across a triangular-shaped potential barrier, which is formed by applying an electrical field *E* to a rectangular or trapezoidal barrier. FNT is basically the same physical phenomena as direct tunneling, but in a different voltage regime, i.e., the high-voltage regime. The tunneling current is given by[7]:

$I\_{FNT}=S\frac{e^{3}}{8πhΦ\_{i}}(\frac{V}{d})^{2}exp[-\frac{8π\sqrt{2m^{\*}}dΦ\_{i}^{\frac{3}{2}}}{3heV}]$ (S3)

where *Φ*i is the height of trapezoidal barrier. In our experiment, we estimate that the threshold voltages for transition from DT to FNT are -0.1 V and +0.1 V, respectively. According to the fitting results of the FNT model, *Φ*i was found to be 0.071 eV.



**Figure S1** Schematic diagram of the voltage pulse sequence for the endurance test in Figure 1g.

**References**

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