Flux-Charge Characterizing of Reset Transition in Bipolar Resistive-Switching Memristive Devices

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INTRODUCTION

Leon Chua stated in [2] the existence of the passive element called "Memristor" in 1971, mainly based on theoretical arguments. The original reasoning was based on a missing element relating the electric charge and the magnetic flux, that would complete the symmetry of passive electronic devices. This first definition was extended later to include other elements whose resistance depended on a state variable [4].

In this paper we characterize the reset transition of a bipolar ReRAM device. To do so, we have considered the ReRAM as a memristor, and we have worked in the Flux-Charge φ-Q space, instead of the usual Voltage-Current V-I once. We consider the case of a ramp input signal with different slopes, analysis the experimental results in the Flux-Charge φ-Q space beside the Voltage-Current V-I once, and study the effect of changing slope in the reset point. The flux (ϕ) and charge (Q) can be written as [4]:

$$\phi(t)=\int_{-\infty}^{t} V(\tau)\,d\tau \qquad (1) \qquad\qquad Q(t)=\int_{-\infty}^{t} I(\tau)\,d\tau \qquad (2)$$

FLUX-CHARGE CHARACTERIZATION

Fig. 1. (a) Sketch of the device pattern and (b) of the CF configurations for devices in the HRS and in the LRS.

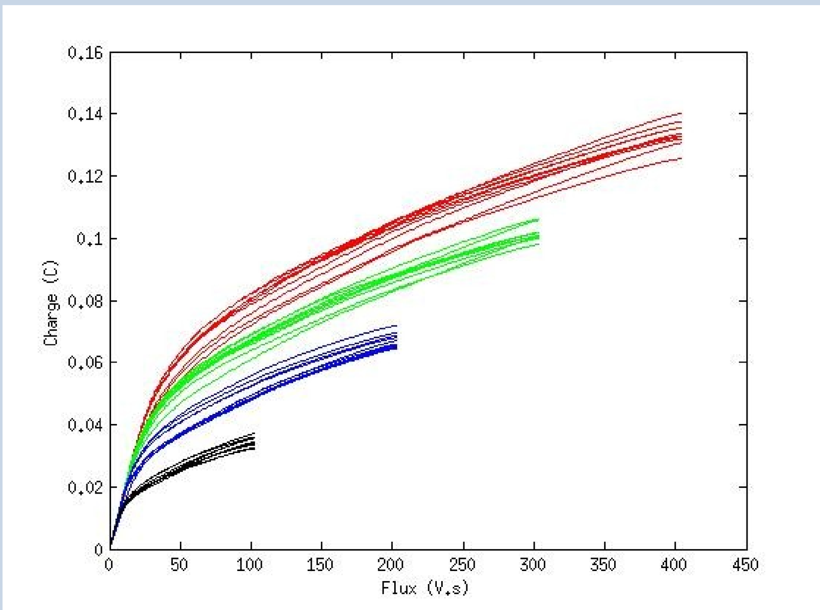

Fig.2. Reset cycles for different operating slopes in ϕ– Q domain.

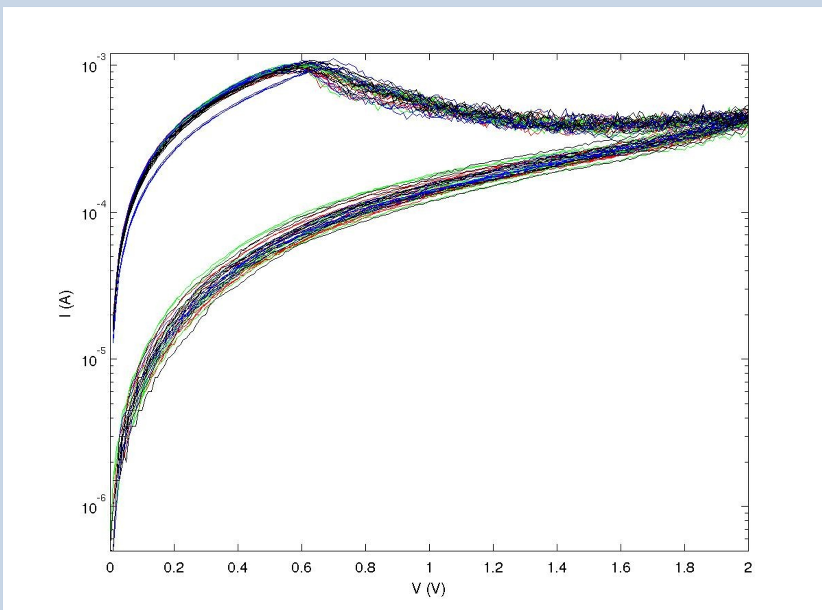

Fig.3. Reset cycles for different operating slopes in V-I.

RESULTS ANALYSIS

We can notice from Fig.5. and Table.2 that ϕ_{rst} for different slopes (α) can be written as:

$$\phi_{rst}=\frac{\lambda}{\alpha} \qquad (3)$$

where (λ) is a constant value for a given device. In this case (λ =0.2 V^2)

$$t_{rst}=\frac{\sqrt{2.\lambda}}{\alpha} \qquad (4)$$

$$Q_{rst}=\frac{w_{rst}.\lambda}{\alpha} \qquad (5)$$

where the (w_{rst}) is the memconductance at the reset point, defined as:

$$w_{rst}=\frac{Q_{rst}}{\phi_{rst}} \qquad (6)$$

The effects of changing the slope (α) on the reset point's parameters (flux, time and charge) is shown in Fig.5. with the estimation of these new parameters (time, flux and charge) versus the new slope using Eq.3, Eq.4 and Eq.5. The reset values of the parameters can be estimated as a function of the slope for arbitrary signal. It is also worth noticing that the reset memconductance is not dependent on the slope.

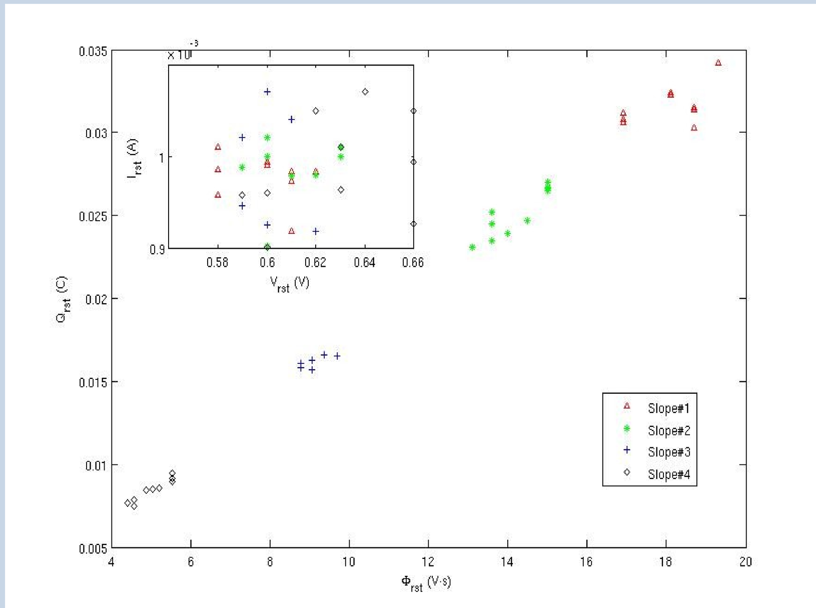

Fig.4. Q_{rst} vs. ϕ_{rst} for different operating slopes in Flux-Charge domain. The inset shows I_{rst} vs. V_{rst} for different operating slopes in Voltage-Current domain.

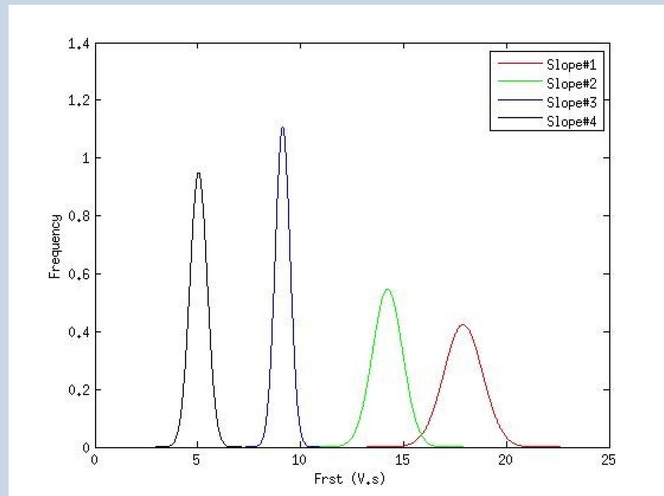

Fig. 6. ϕ_{rst} (V.s)

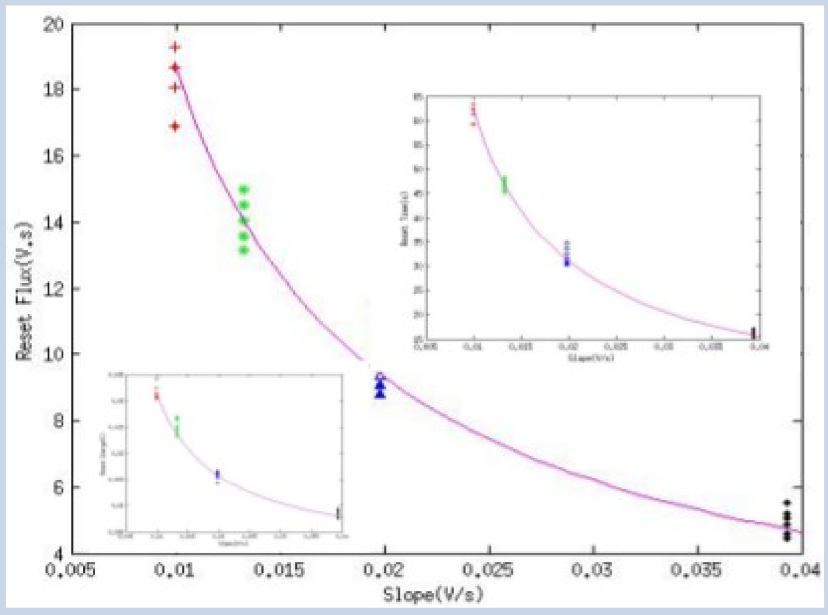

Fig.5. The effect of changing the slope on the reset flux (Line is Eq.3}). The insets show the effect of changing the slope on the reset time (right upper inset, Line is Eq.4) and the effect of changing the slope on the reset charge(Left bottom inset, Line is Eq.5).

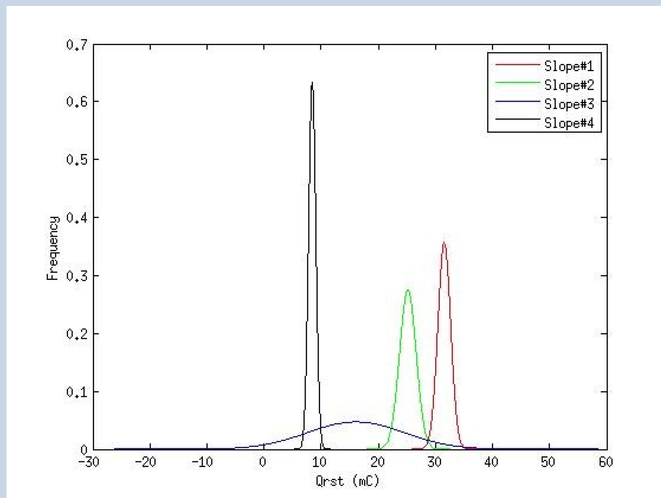

Fig. 7. Q_{rst} (mC)

Slope (V/s)	V_{rst} (V)		I_{rst} (mA)	
	Average	Stand. div	Average	Stand. div
0.01	0.60	0.02	0.98	0.02
0.0133	0.61	0.02	0.99	0.03
0.0198	0.60	0.01	0.99	0.06
0.0393	0.63	0.03	0.99	0.06

Table 1. Mean values and standard deviations of the obtained reset values for the voltage and current.

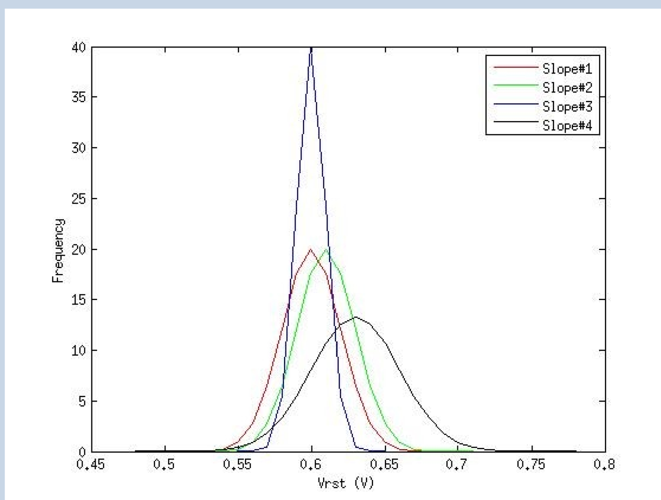

Fig. 8. V_{rst} (V)

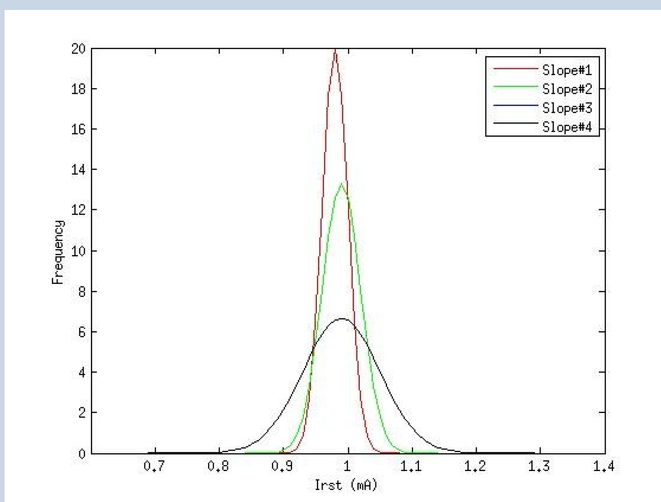

Fig. 9. I_{rst} (mA)

Slope (V/s)	ϕ_{rst} (V.s)		Q_{rst} (mC)	
	Average	Stand. div	Average	Stand. div
0.01	17.90	0.94	31.55	1.12
0.0133	14.22	0.73	25.17	1.45
0.0198	9.13	0.36	16.17	0.37
0.0393	5.04	0.42	8.45	0.63

Table 2. Mean values and standard deviations of the obtained reset values for the flux and charge.

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