

# Conmutación Resistiva

Memristores, ReRAM y computación neuromórfica.

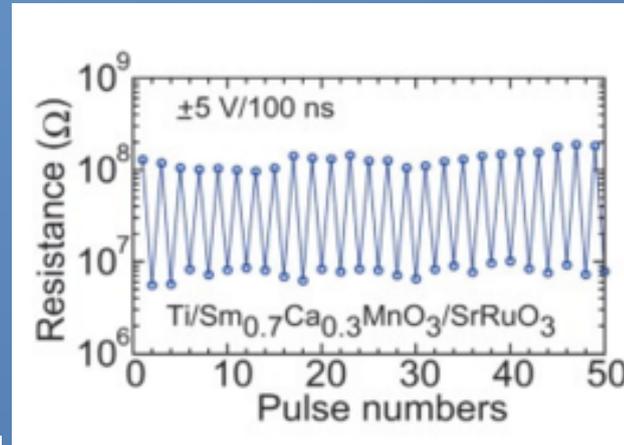
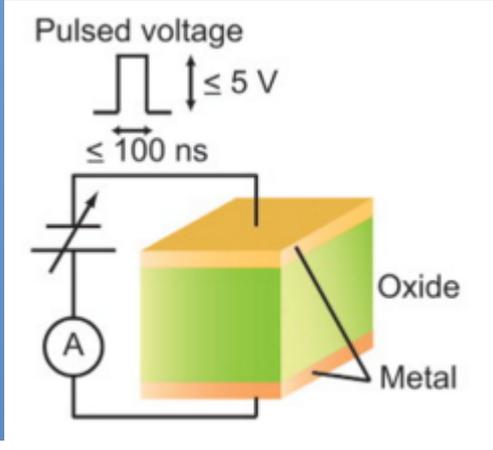
Federico Tesler

Director: Marcelo Rozenberg

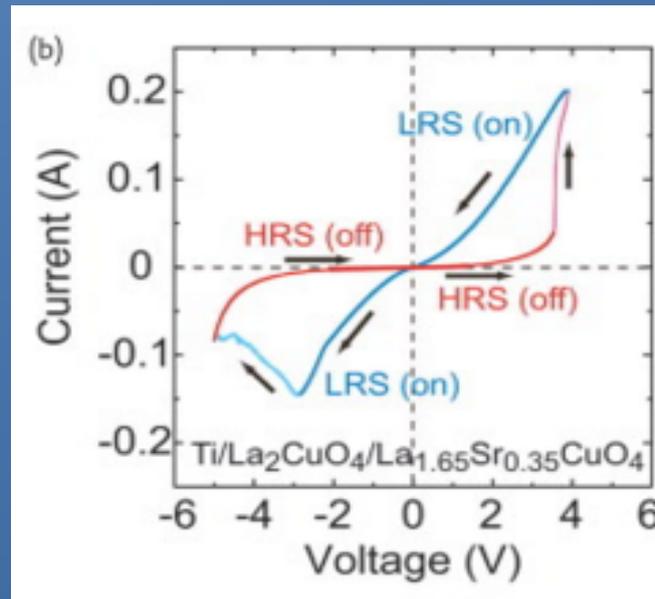
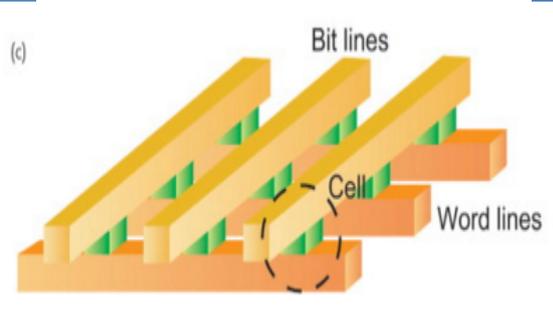
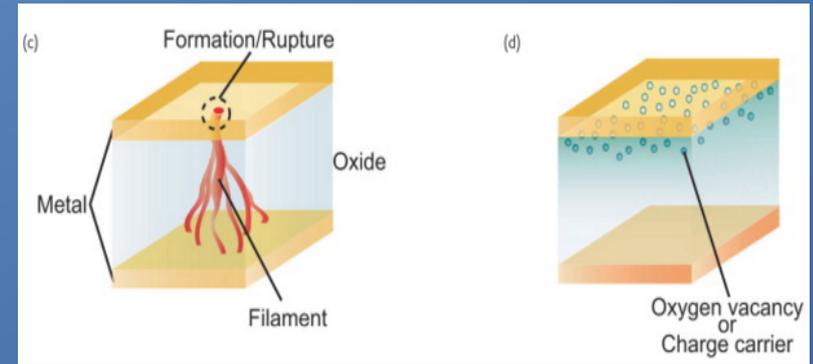
Co-director: Alberto Camjayi

# Conmutación resistiva y memristores

## Dispositivo estándar



## Mecanismos básicos



## Características

- Non-volatile
- Reversible
- Fast

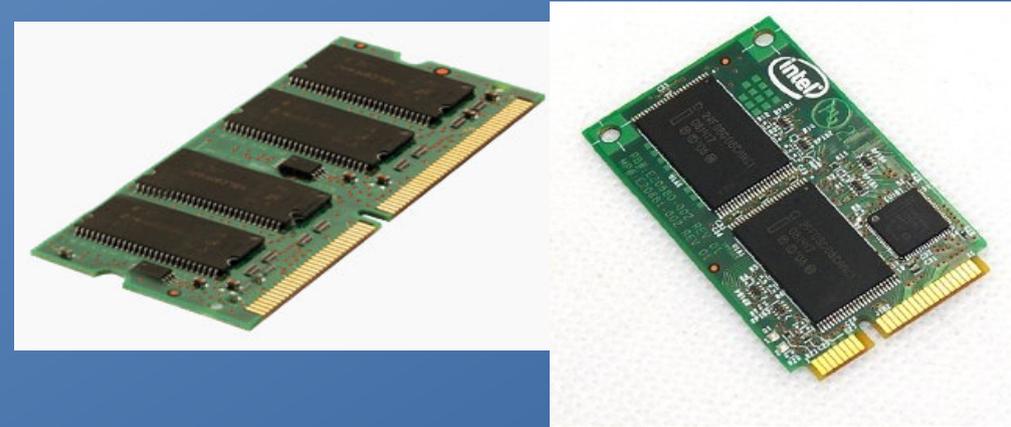
Summary of common inorganic storage media and corresponding switching characteristics				
Storage medium	Switching mode	ON/OFF ratio	Operation speed	Endurance (cycles)
<i>Binary oxides</i>				
MgO <sub>2</sub>	Unipolar, bipolar	>10 <sup>5</sup>	-	>4 × 10 <sup>7</sup>
AlO <sub>2</sub>	Unipolar, bipolar	>10 <sup>6</sup>	<10 ns; <10 ns	>10 <sup>7</sup>
SiO <sub>2</sub>	Unipolar, bipolar	>10 <sup>7</sup>	<100 ps; <100 ps	>10 <sup>8</sup>
TiO <sub>2</sub>	Unipolar, bipolar	>10 <sup>3</sup>	<5 ns; <5 ns	>2 × 10 <sup>7</sup>
CrO <sub>2</sub>	Bipolar	>10 <sup>2</sup>	<4 μs; <5 μs	>6 × 10 <sup>5</sup>
MnO <sub>2</sub>	Unipolar, bipolar	>10 <sup>4</sup>	<100 ns; <200 ns	>10 <sup>7</sup>
FeO <sub>2</sub>	Bipolar	>10 <sup>3</sup>	<10 ns; <10 ns	>6 × 10 <sup>5</sup>
CoO <sub>2</sub>	Unipolar, bipolar	>5 × 10 <sup>3</sup>	<20 ns; <20 ns	>10 <sup>7</sup>
NiO <sub>2</sub>	Unipolar, bipolar	>10 <sup>6</sup>	<10 ns; <20 ns	>10 <sup>7</sup>
CuO <sub>2</sub>	Unipolar, bipolar	>10 <sup>3</sup>	<50 ns; <50 ns	>1.2 × 10 <sup>7</sup>
ZnO <sub>2</sub>	Unipolar, bipolar	>10 <sup>3</sup>	<5 ns; <5 ns	>10 <sup>7</sup>
GaO <sub>2</sub>	Bipolar	>10 <sup>3</sup>	<400 ns; <600 ns	>10 <sup>7</sup>
GeO <sub>2</sub>	Unipolar, bipolar	>10 <sup>3</sup>	<20 ns; <20 ns	>10 <sup>7</sup>
ZrO <sub>2</sub>	Unipolar, bipolar	>10 <sup>6</sup>	<10 ns; <10 ns	>10 <sup>7</sup>
NbO <sub>2</sub>	Unipolar, bipolar	>10 <sup>6</sup>	<100 ns; <100 ns	>10 <sup>7</sup>
MoO <sub>2</sub>	Unipolar, bipolar	>10	<1 μs; <1 μs	>10 <sup>6</sup>
HfO <sub>2</sub>	Unipolar, bipolar	>10 <sup>6</sup>	<300 ps; <300 ps	>10 <sup>8</sup>
TaO <sub>2</sub>	Unipolar, bipolar	>10 <sup>6</sup>	<105 ps; <120 ps	>10 <sup>8</sup>
WO <sub>2</sub>	Unipolar, bipolar	>10 <sup>4</sup>	<300 ns; <50 ns	>10 <sup>7</sup>
CxO <sub>2</sub>	Unipolar, bipolar	>10	<1 μs; <200 ns	>10 <sup>7</sup>
GdO <sub>2</sub>	Unipolar, bipolar	>5 × 10 <sup>3</sup>	<1 ns; <1 ns	>10 <sup>7</sup>
YbO <sub>2</sub>	Unipolar, bipolar	>10 <sup>3</sup>	-	>10 <sup>7</sup>
LuO <sub>2</sub>	Unipolar, bipolar	>10 <sup>4</sup>	<10 ns; <30 ns	>8 × 10 <sup>7</sup>
<i>Ternary and more complex oxides</i>				
LaAlO <sub>3</sub>	Bipolar	>10 <sup>4</sup>	-	>10 <sup>7</sup>
SrTiO <sub>3</sub>	Bipolar	>10 <sup>3</sup>	<5 ns; <5 ns	>10 <sup>6</sup>
BaTiO <sub>3</sub>	Unipolar, bipolar	>10 <sup>4</sup>	<10 ns; <70 ns	>10 <sup>7</sup>
LC(or SMO)	Bipolar	>10 <sup>3</sup>	<25 ns; <25 ns	>10 <sup>7</sup>
PCMO	Bipolar	>10 <sup>3</sup>	<8 ns; <8 ns	>10 <sup>6</sup>
BiFeO <sub>3</sub>	Unipolar, bipolar	>10 <sup>3</sup>	<50 ns; <100 μs	>10 <sup>7</sup>
<i>Chalcogenides</i>				
Cu <sub>2</sub> S	Bipolar	>10 <sup>6</sup>	<100 μs; <100 μs	>10 <sup>6</sup>
Ge <sub>2</sub> S	Bipolar	>10 <sup>3</sup>	<50 ns; <50 ns	>7.5 × 10 <sup>6</sup>
Ag <sub>2</sub> S	Bipolar	>10 <sup>6</sup>	<200 ns; <200 ns	-
Ge <sub>2</sub> Se <sub>3</sub>	Bipolar	>10 <sup>6</sup>	<100 ns; <100 ns	>3.2 × 10 <sup>6</sup>
<i>Nitrides</i>				
AlN	Unipolar, bipolar	>10 <sup>3</sup>	<10 ns; <10 ns	>10 <sup>8</sup>
SiN	Unipolar, bipolar	>10 <sup>7</sup>	<100 ns; <100 ns	>10 <sup>9</sup>
<i>Others</i>				
a-C	Unipolar, bipolar	>3 × 10 <sup>3</sup>	<50 ns; <10 ns	>10 <sup>7</sup>
a-Si	Bipolar	>10 <sup>3</sup>	<5 ns; <10 ns	>10 <sup>8</sup>
AgI	Bipolar	>10 <sup>6</sup>	<50 ns; <150 ns	>4 × 10 <sup>7</sup>

# Aplicaciones

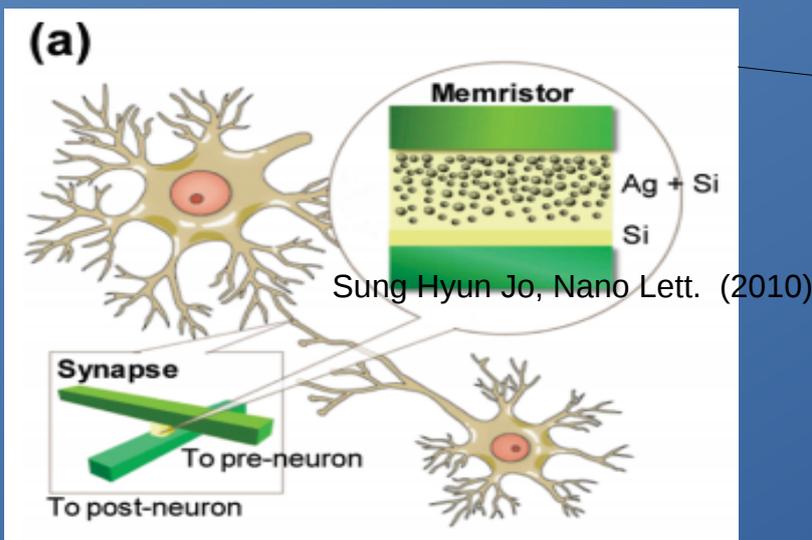
Disco duros y SSD



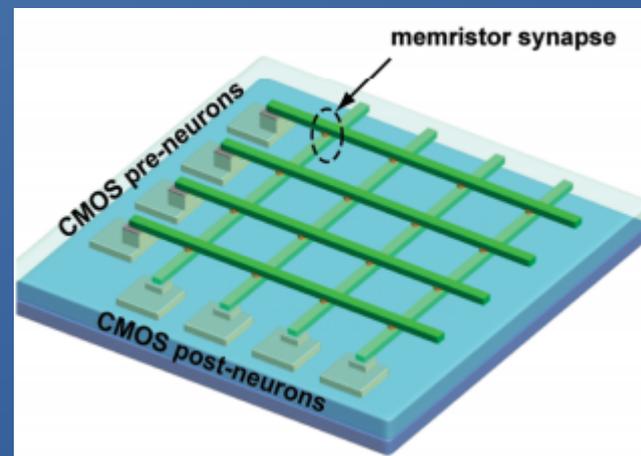
RAM y Cache memory



Artificial neuron synapse



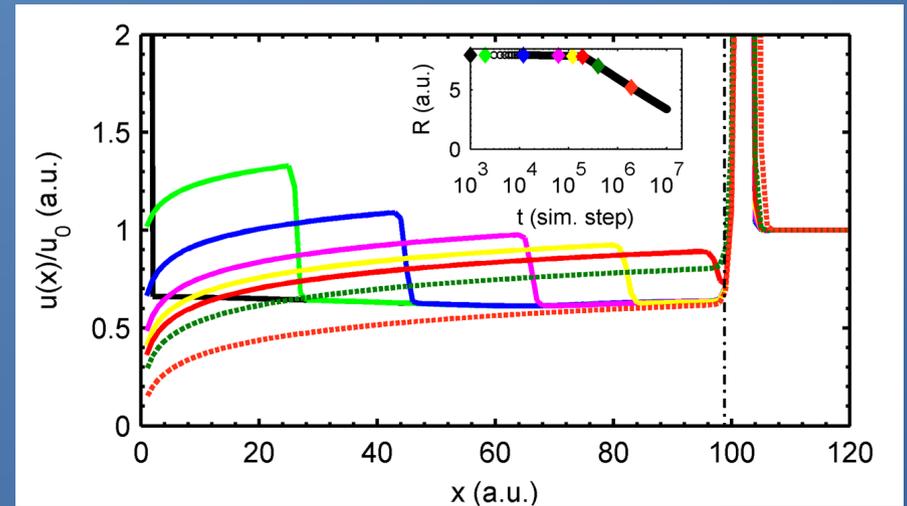
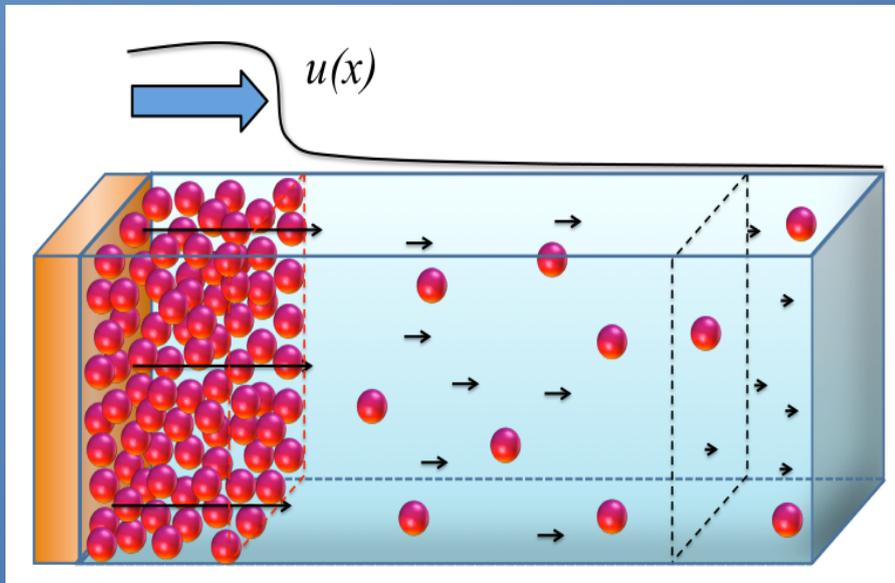
Redes neuronales y Computación neuromórfica



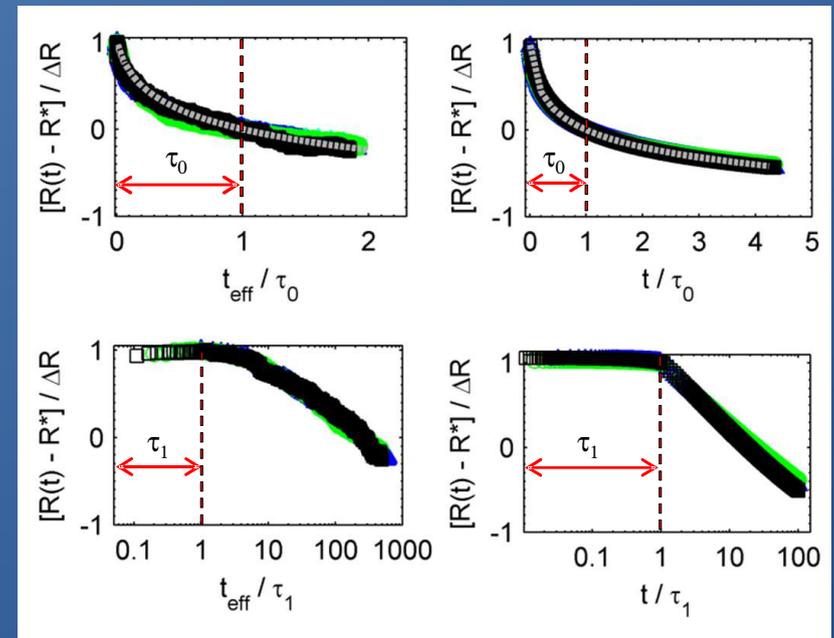
Current Trends:

- Machine Learning
- Deep learning
- Data mining

# Ondas de choque en manganitas



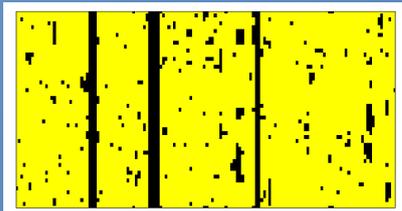
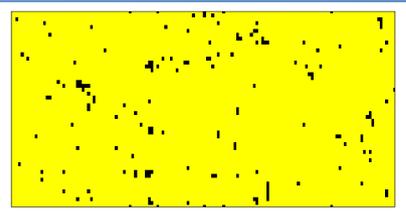
$$\partial_t u + f(u) \partial_x u = D \partial_{xx} u$$



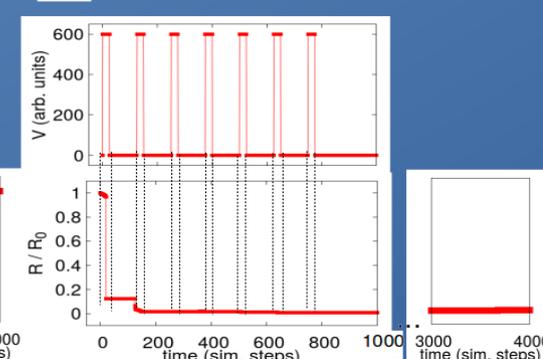
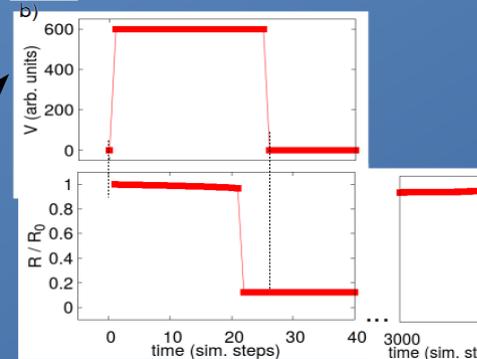
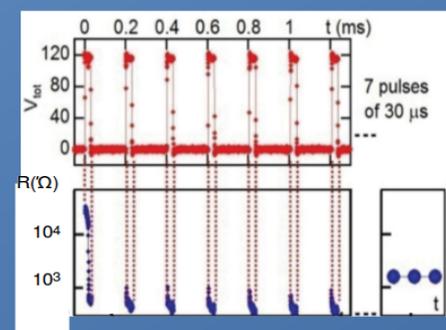
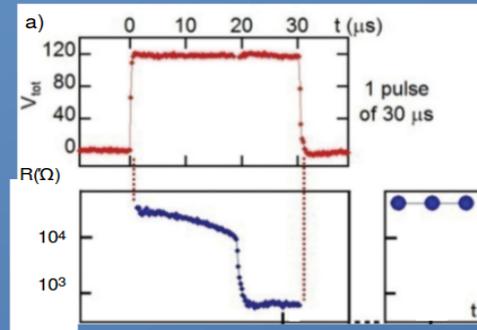
# Aisladores de Mott (AM4Q8)

Antes

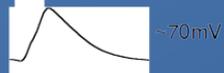
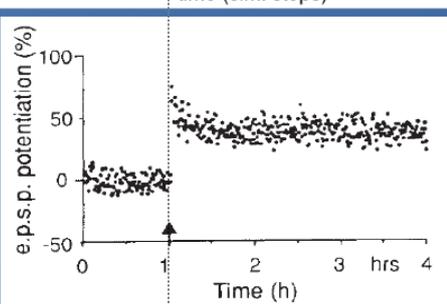
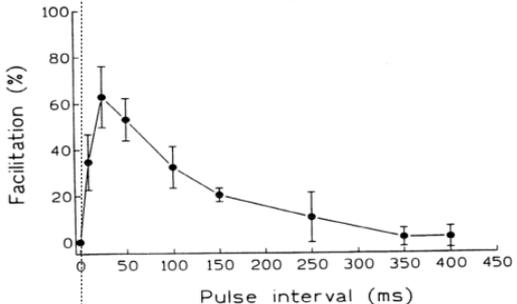
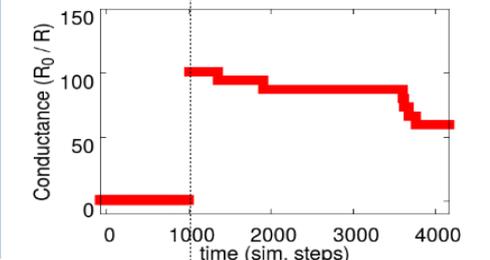
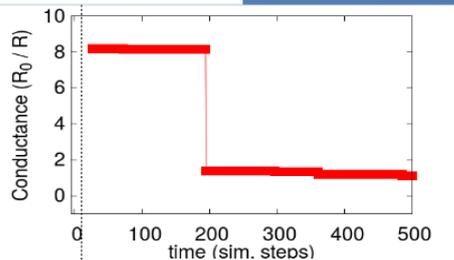
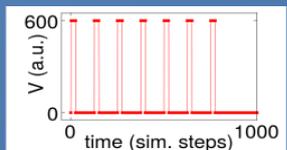
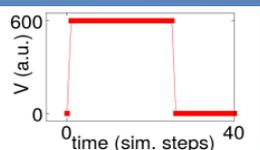
Después



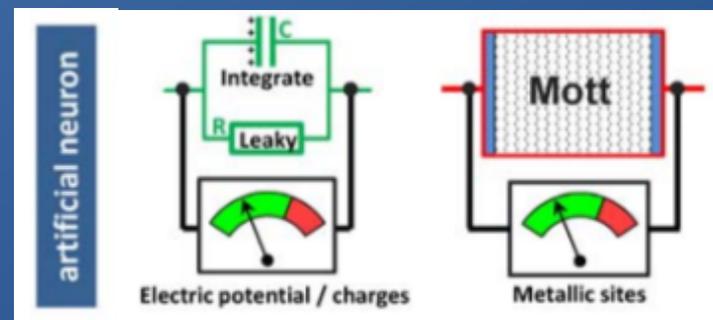
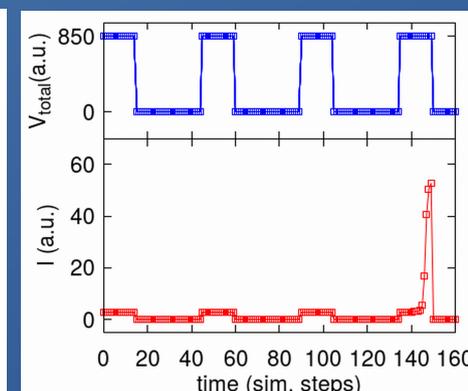
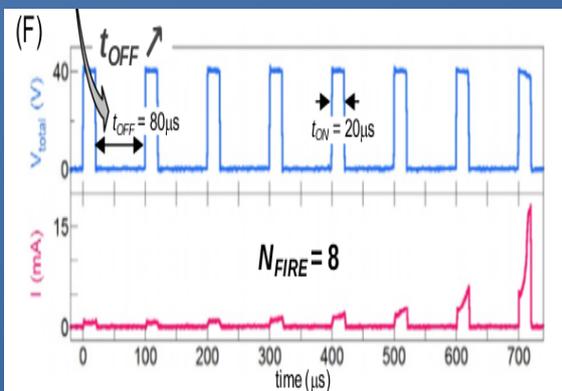
Retentividad variable  
(volátil a no-volátil)



## Potenciación sináptica de corto y largo plazo



## Neurona LIF



Electric potential / charges

Metallic sites

Gracias!!!