NANO-TEC Workshop 2

Memristors

Speaker : Julie Grollier
Discussant : Dag Winkler
Rapporteur : Clivia M Sotomayor Torres

Benchmarking memristors

Benchmark separately :

- memristors as digital memories

- memristors as analog memories (application ex : artificial synapses)

Memristor applications as 2 state resistances

- **non-volatile digital memories**
($R_{OFF}/R_{ON}>1000$)

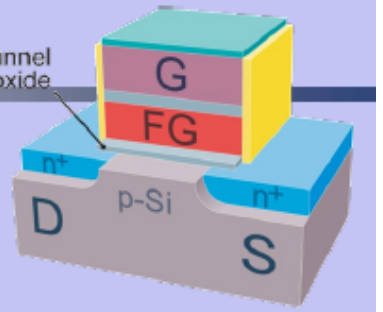
- **logic functions** (no transistors)
Kuekes et al., JAP 2005
Borghetti et al., Nature 2010

- **Reconfigurable Architectures**
(Field Programmable Gate Arrays)

1 – memristors as digital memories

Requirements

... to compete with Flash

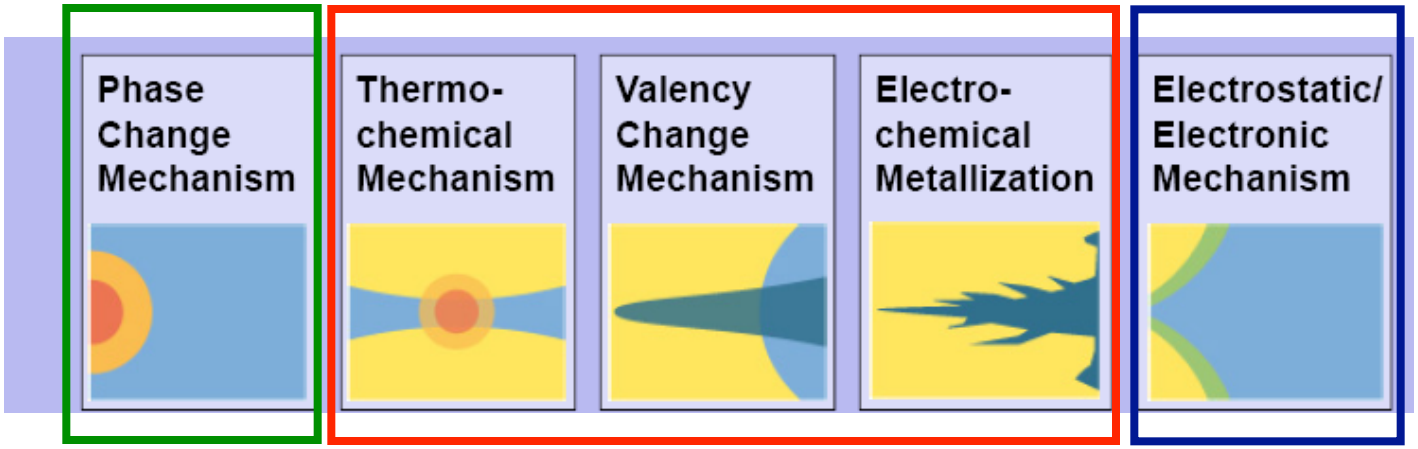


Endurance:	**> 10^7 cylces** (Flash 10^3 ... 10^7)
Resistance ratio:	**R_{OFF} / R_{ON} > 10**
Scalability:	**F < 22 nm and/or 3-D stacking**
Write voltage:	**approx. 1 ... 5 V** (Flash > 5 V)
Read voltage:	**0.1 ... 0.5 V**
Write speed:	**< 100 ns** (Flash > 10 μs)
Retention:	**> 10 yrs**

R. Waser, ISIF 2011

Resistive switching memories

classification



Waser *et al.*, Nature Materials 2007

phase change memories

Red-Ox memories

electronic effects memories

STT-RAM : Spin torque-RAM ?

FeT-RAM : Ferroelectric tunnel junctions-RAM

Technology *digital memristor*	**PCM**	**Red-Ox**	**FeT**	**STT**
Gain, Signal/Noise ratio **Non-linearity**	N/A			
Speed **Power consumption**	50 ns 6 pJ	10 ns < 1 pJ	10 ns 10 fJ	25 ns 0.02-5pJ
Architecture/Integrability (Inputs/outputs, digital, multilevel, analog, size etc.)	6 F^2	5/8 F^2	5/8 F^2	20/40 F^2
Other specific properties				
prototypes	commercial	some	---	yes
forming step	no	some	no	no
switching	unipolar	both	bipolar	bipolar
good theoretical understanding	yes	no	yes	yes
Manufacturability	CMOS compatible			
Timeline (When exploitable or when foreseen in production)	available	< 5 y	?	< 3 y

HP and Hynix to launch flash-replacement Memristor products in 2013

Posted: 09 Oct 2011 03:16 AM PDT

HP says that their two terminal memristor (Resistive RAM) technology will be launched in 18 months - and will "start to take market share from flash memory". The company has 'big plans' for the new memory technology and are working with Hynix to launch the flash replacement chip in 2013. The company also plans to go after the DRAM market in 2014/2015 and later the SRAM market as well.

HP has over 500 patents on this technology alone - but it isn't the only company working on memristor devices - in fact Samsung has an even bigger team working on a similar project.

Made in IBM Labs: IBM Scientists Demonstrate Memory Breakthrough for the First Time

- Reliable multi-bit phase-change memory technology demonstrated
- Scientists achieved a 100 times performance increase in write latency compared to Flash
- Enables a paradigm shift for enterprise IT and storage systems, including cloud computing by 2016

ZURICH, June 30, 2011 – For the first time, scientists at IBM Research have demonstrated that a relatively new memory technology, known as phase-change memory (PCM), can reliably store multiple data bits per cell over extended periods of time.

1 – memristors as analog devices

could be the key to future development of VLSI neural networks
need specific architectures, new designs

Technology *analog memristor*	**PCM**	**TCM**	**VCM**	**ECM**	**STT**	**organic**
			Red-Ox			
Gain, S/N ratio,Non-linearity	N/A					
Speed : important for // architecture ????	50 ns	←	10 ns	→	25 ns	ms
Power consumption	6 pJ		< 1 pJ		0.02-5pJ	?
Architecture/Integrability	6 F^2	←	5/8 F^2	→	20/40 F^2	?
Other specific properties						
- Forming step	No	No	Yes	No	No	No
- Roff/Ron (crossbar)	>50	?	$>10^3$	$>10^7$	> 6	?
-Operation : bipolar makes STDP synaptic change easier	unipolar	unipolar	bipolar	bipolar	bipolar	bipolar
-Retention time ???	←		10y	→		1h
- good theoretical understanding	Yes		no		yes	no
Manufacturability	CMOS compatible					
Timeline	Still research					