Studies of Dynamics of Memristor-based Memory Cells

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Purpose of the study

- How stable are the resistive states in the bi-stable memristor?
- What are the characteristics when DC voltages are changed with a positive and negative ramp?
- Are multi-stable devices possible and what are the switching characteristics between the stable resistance states in multi-level memristive elements?
- What are the characteristics of the pulse programming operations?
- What is the width and amplitude dependence of the switching operations?
- What are the best characteristics for write-in and readout?

Tested devices

- Each element implemented on the wafer consists of two crossing lines of Pt with a width ranging from 2u m to 10 um.
- The bottom 100nm-thick lines of Pt were deposited by sputtering in a Pfeiffer SPIDER600 sputtering tool from a Pt target with 1000 W DC power.
- The bottom electrode is then patterned by optical lithography using AZ ECI 3007 resist and etched by chlorine plasma.
- Then, a 10 nm thick HfO2 layer is deposited by ALD with a BENEQ TFS200 from TEMAHf precursor and H2O reactant, followed by a 10 nm-thick Ti layer deposited by sputtering from a Ti target with 1000 W DC power.
 - Subsequently, the top Pt electrodes are deposited with a similar recipe like for the bottom electrodes.
 - Finally, both Pt and oxides are etched by chlorine plasma from STS dry etching tool, the end of oxide layer is detected by a built-in reflectometer





	Type 1 and 3	Туре 2	Type 1		Type 1	
	Type 2	Type 1 and 3	Type 4	Type 1		Type 1
	Type 1		Type 1 and 3	Туре 2	Type 1	
		Туре 1	Type 2	Type 1 and 3	Туре 4	Type 1
	Type 1		Type 1	Type 4	Type 1 and 3	Type 2
		Type 1		Type 1	Туре 2	Type 1 and 3

DC and sinusoidal forcing

Open problems:



DC forcing



Switchings appear at different non-repeatable voltage levels

Siusoidal responses







Programming with pulses

- G.E. Ning, Jianhua Yang, A. L. Ghozeil, B. Buchanan: Regulating memristor switching pulses, Patent Application WO 2015167551 A1, <u>https://www.google.com/patents/</u> WO2015167551A1
- I. Salaoru, A. Khiat, Qingjiang Li, R. Berdan, T. Prodromakis: "Pulse-induced resistive and capacitive switching in TiO2 thin film devices", Applied Physics Letters 103, 233513 (2013)
 - B. Srinivasan, G.S.Sandhu: Methods of reading and using memristor memory cells with a short read pulse, US Patent 9,135,995, 2015, https:// www.google.com/patents/US9135995







Conclusions

- The memory cells tested are not very good candidates for binary (two-state) memories
- The energy needed for switchings between stable states is relatively high
- After a number of switchings the cells become worn-out

Patents

US8634225 B2 (2014), Samsung Electronics Co. Ltd. Method and apparatus managing worn cells in resistive memories US9412445 B1(2016) Resistive memory apparatus and reading method thereof

Thank you!