2013 Transfer-to-Excellence (TTE) Program

Mechanical Switches as Selectors in ReRAM Cells

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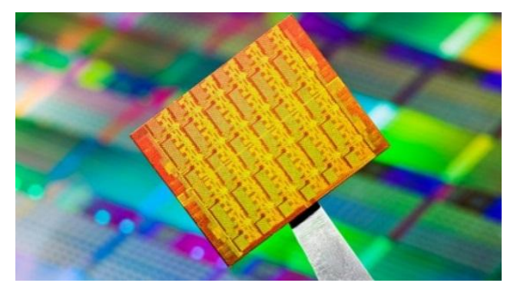
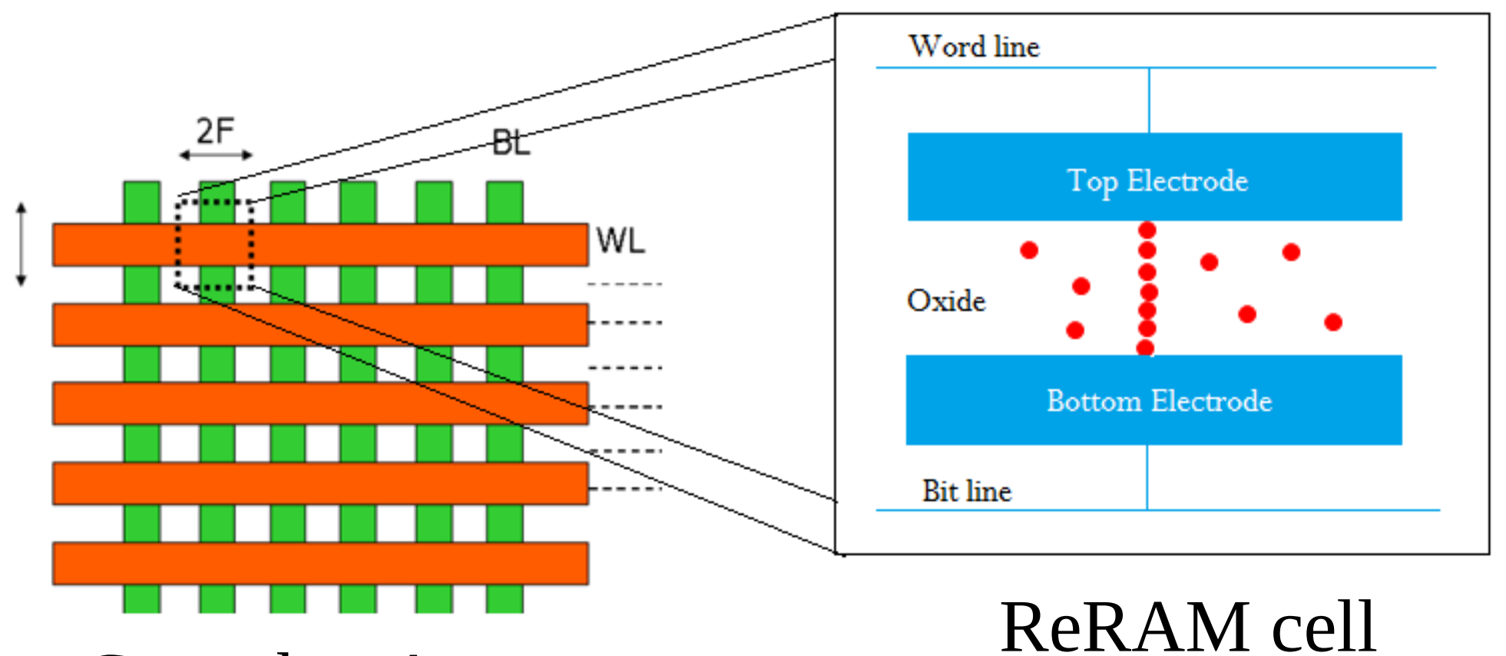
Abstract

In recent years, ReRAM (Resistive Random Access Memory) has become one of the most promising nonvolatile memories. It is well-known for its high speed and low power consumption. However, ReRAM with high sneak-path leakage current is hindering the efficiency. A mechanical switch (MS) was proposed as a selector in a ReRAM cell to reduce the leakage current. Dimensions and materials of the beam were investigated to achieve the low pull-in and pull-out voltages. Tungsten, which has high melting point, was considered as a good material to be used in mechanical switch structure. In this project, many tests on MS were made to find the best dimension of word line beam (WL) to get both pull-in and pull-out voltages.

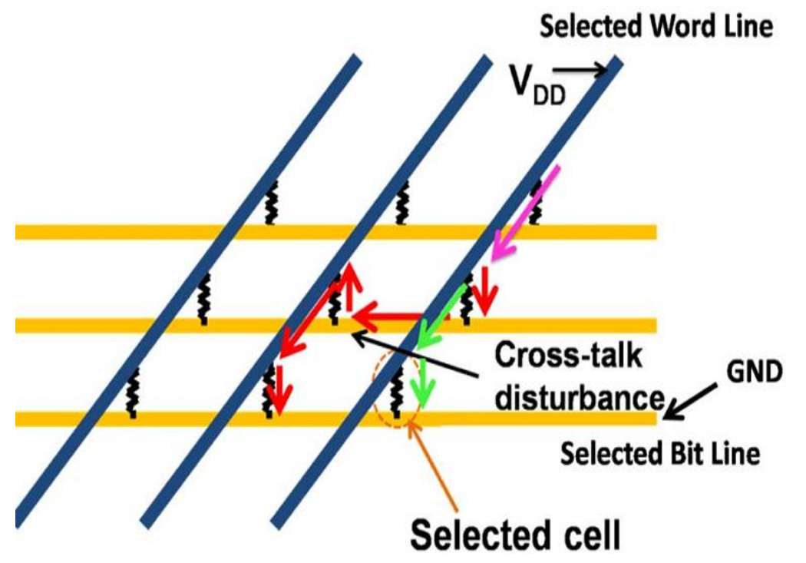
ReRAM Structure and its Challenge





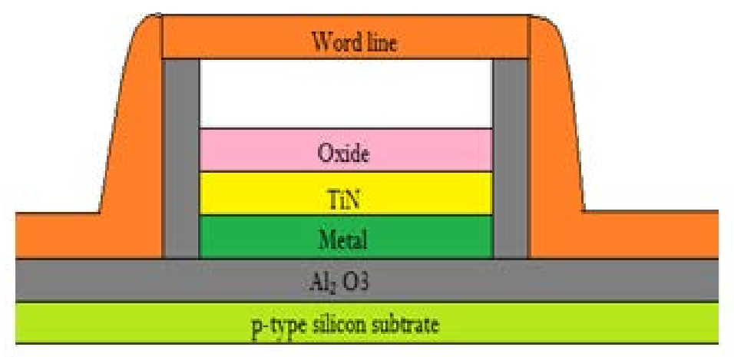
Cross-bar Array

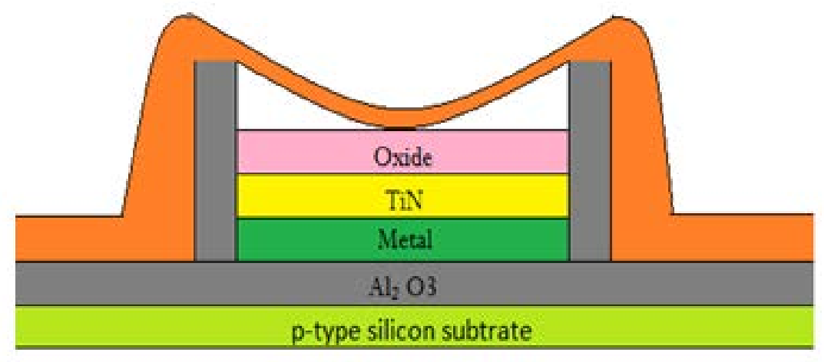
ReRAM cell



Challenge – "Sneak leakage"
- Programming failure
- Output signal degradation

Mechanical Switch Structure





When a voltage is applied: $F_e > F_s$

$$F_e = \frac{V^2 \varepsilon A}{2g^2}$$

F_e : electrostatic force (N)
V: voltage (V)
A: area of the beam (m^2)
g: gap (m)
ε: permittivity

$$F_s = k(g_0 - g)$$

F_s : restoring force (N)
k: spring constant (N/m)
g_0 = initial gap (m)

$$V_{pull-in} = \sqrt{\frac{8kg_0^3}{27\varepsilon A}}$$

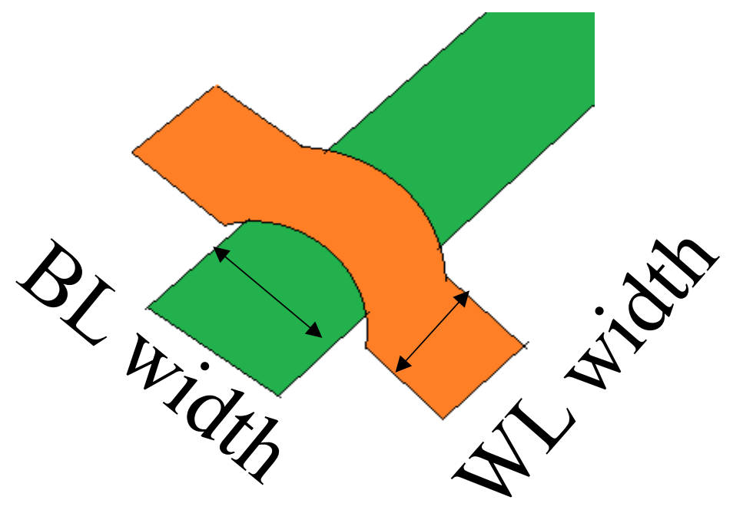
k: spring constant (N/m)
g_0: initial gap (m)
A: area of the beam (m^2)

Material of the word line:
Tungsten:
- High melting point
- High spring constant

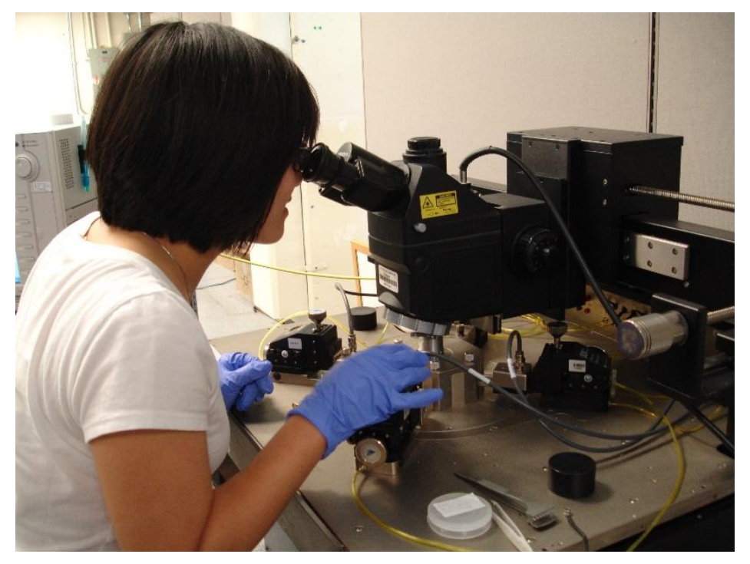
Gap: 20nm

Experimental method

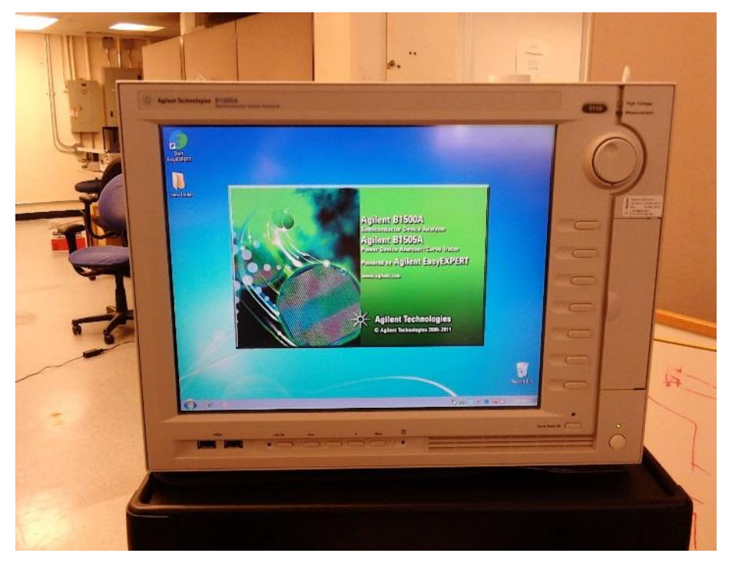
Dimension:
Bit line width: 0.35 μm - 4μm
Word line width: 0.30μm - 8μm



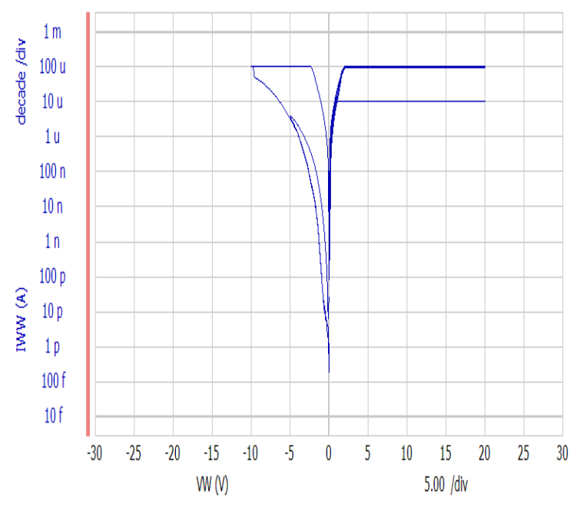
Method:



Cascade 4 Probe Station



Semiconductor Device Analyzer

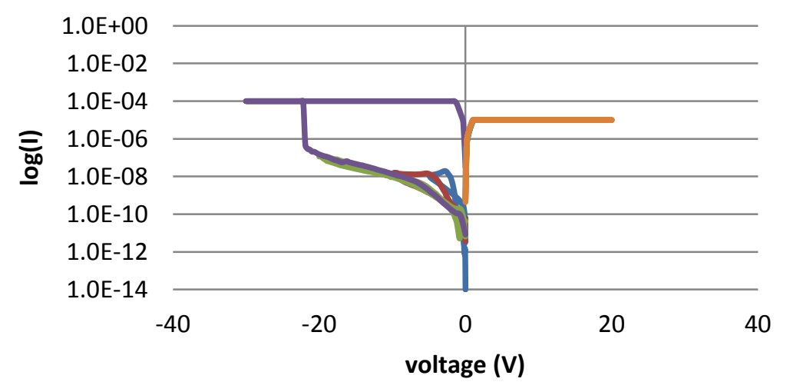


IV curve

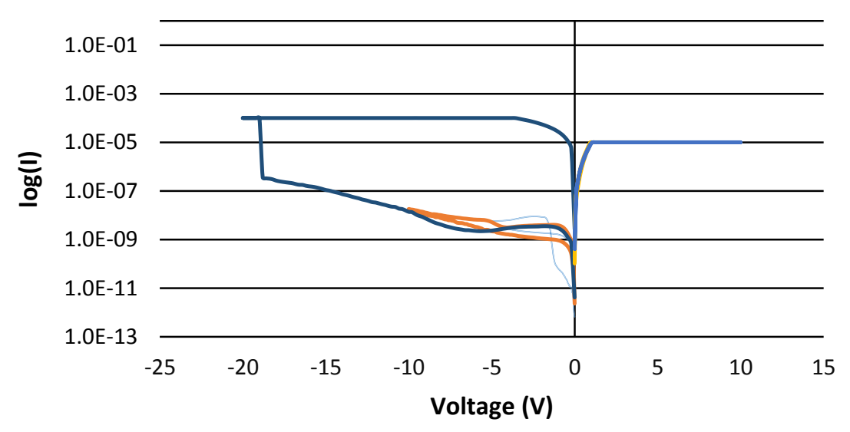
Results

Without TiO_2

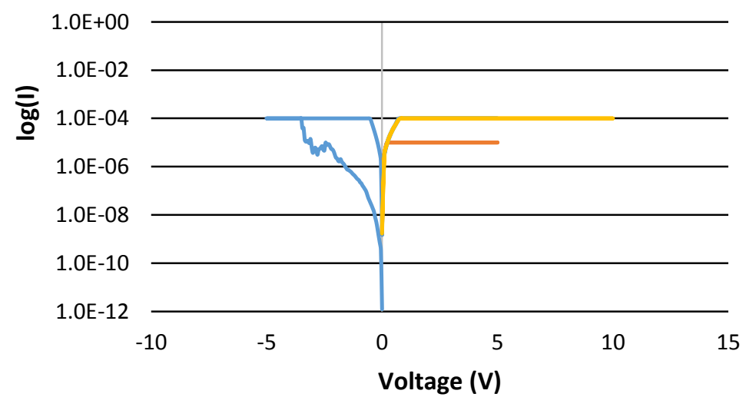
B600W400: Pull-in Voltage -21.3V

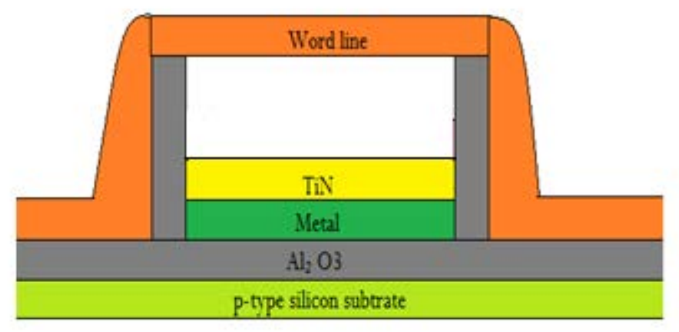


B800W400 - Pull-in Voltage: -19V



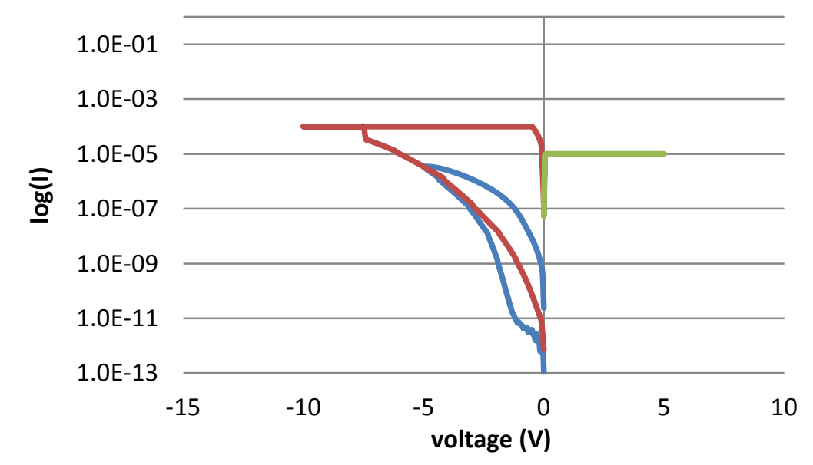
B2W400 – Pull-in Voltage: -3.4



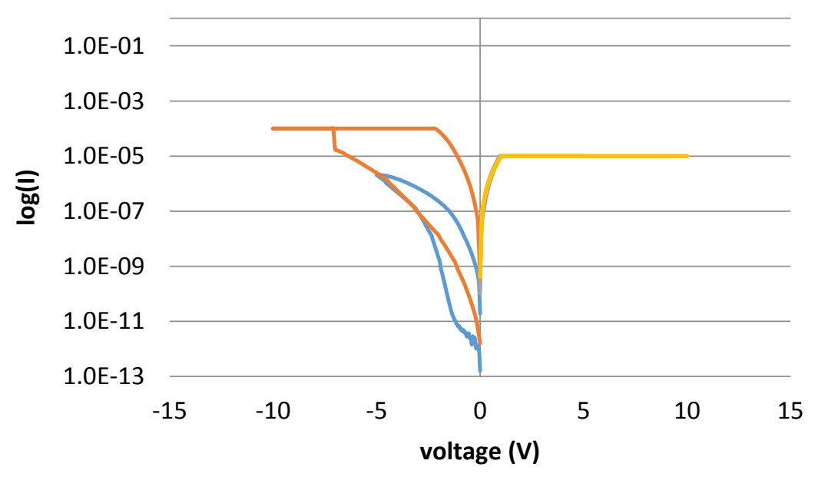


With TiO_2

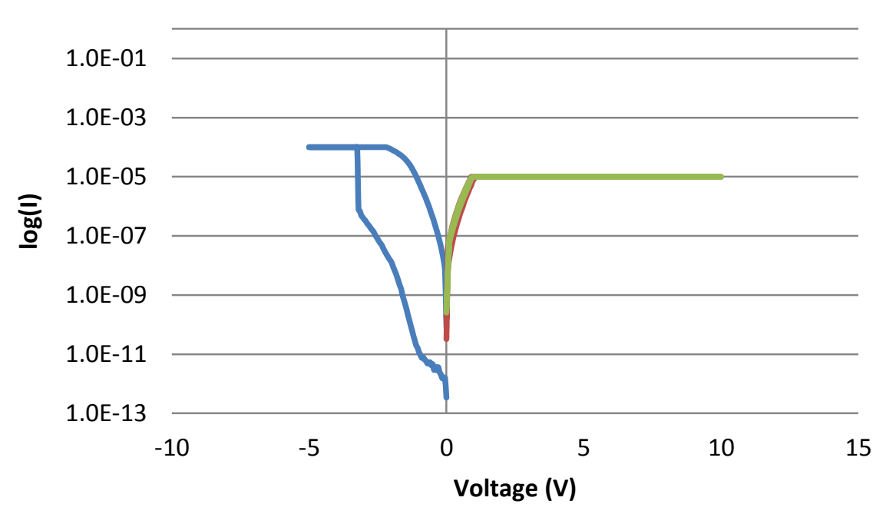
B600W400 - TiO2
Pull-in Voltage: -7.1V

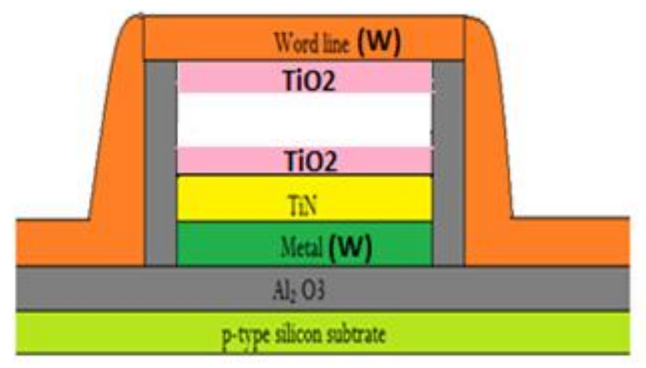


B800W400 - TiO2
Pull-in Voltage: -6.7V



B2W400 - TiO2
Pull-in Voltage: -3.2V





Conclusion and Future Directions

* As increasing the bit line width (length of the beam), the pull-in voltage is smaller.
* Adding TiO_2 to surfaces of word line and bit line helps to reduce pull-in voltage.
* In the future, the thickness of the word line beam needs to be increased to get pull-out voltage.
* To reduce the pull-in voltage, the gap needs to be reduced.

Acknowledgement

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References:

[1] W. Kwon, J. Jeon, L. Hutin, and T.-J.K. Liu, "Electromechanical Diode Cell for Cross-point Nonvolatile Memory Arrays", Proc. IEEE, vol. 33, no. 2, pp. 131-133, Feb. 2012
[2] Y. Deng, P. Huang, B. Chen, X. Yang, B.Gao, J. Wang, L. Zeng, G. Du, J. Kang, and X. Liu, "RRAM Crossbar Array With Cell Selection Device: A Device and Circuit Interaction Study," Proc. IEEE, vol. 60, no. 2, pp. 719-726, Feb. 2013

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