4th International Symposium on
Energy Challenges & Mechanics
- working on small scales

11-13 August 2015
Aberdeen, Scotland, UK

The Piezoelectronic Transistor - A nanoscale, strain-based transduction device for fast low power switching.

Glenn J Martyna[1,2*]

[1] *Physical Sciences, IBM TJ Watson Research Center, Yorktown Heights, NY 10598*
[2]*Honorary Profess of Physics, University of Edinburgh, Edinburgh, UK*

Accepted for publication on 20th February 2015

We have invented a transduction based post-CMOS device based on a piezoelectrically driven metal insulator transition [1]. An input voltage pulse activates a piezoelectric element (PE) which transduces input voltage into an electro-acoustic pulse that in turn drives an insulator to metal transition (IMT) in a piezoresistive element (PR); the transition effectively transduces the electro-acoustic pulse to voltage. Using the known properties of ***bulk*** materials, we predict using modeling that the PET achieves multi-GHz clock speeds with voltages as low as 0.1 V and a large On/Off switching ratio ($\approx 10^4$) for digital logic [1]. The PET switch is compatible with CMOS-style logic. At larger scale the PET is predicted to function effectively as a large-area low voltage device for use in sensor applications.

PET device performance is enabled by the properties of two materials, a relaxor piezoelectric for the PE and a rare earth chalcogenide piezoresistor for the PR – provided the materials exhibit bulk properties at the nanoscale. Thus it is critical to investigate materials scaling using a combined theoretical/experimental approach. The development of thin film piezoresistive and piezoelectric materials and patterned structures, and associated characterization tools is presented, along with the theoretical models that yield insight into their behavior [2-4]. Integration of these novel materials into 3 evolutionary generations of PET devices, and device characterization, is given [5] to show that a proof of concept has been achieved.

References

1. "High Response Piezoelectric and Piezoresistive Materials for Fast, Low Voltage Switching: Simulation and Theory of Transduction Physics at the Nanometer-Scale", G.J. Martyna, et al *Adv. Mat.* **24**, 3672 (2012).

2. "Giant Piezoresistive On/Off Ratios in Rare-Earth Chalcogenide Thin Films Enabling Nanomechanical Switching", G.J. Martyna et al, *Nano Lett.* **13**, 4650 (2013).

3. "Anisotropic strain in SmSe and SmTe: implications for electronic transport G.J. Martyna et al, *Phys. Rev. B.* **90**, 245124 (2014).

4. "Lateral scaling of PMN-PT thin films for piezoelectric logic", G.J. Martyna, et al *J. Appl. Phys.* **115**, 234106 (2014).

5. "Pathway to the PiezoElectronic Transduction Logic Device", *Nano Lett.* (2015).

Keywords: transistor, transduction, nanoscale, strain