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A nanoscale, strain-based device for fast low power switching, RF applications and memory

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We have invented a transduction based post-CMOS device based on a piezoelectrically driven metal insulator transition in a piezoresistive element embedded in a nanoscale device structure termed the Piezoelectronic Transistor (PET) [1]. In action, 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). Using the known properties of bulk materials, we predict using modeling that the PET can achieve (a) at VLSI scale, multi-GHz clock speeds with voltages as low as 100 mV and a large On/Off switching ratio ($\approx 10^4$) for digital logic, (b) at larger area, 200mV operation at clock speeds of 2 GHz with a 10^4 On/Off ratio—ideal for on–board computing in sensors, (c) at the mico-scale, the device is predicted to operate as a fast (250 ps) radio frequency (RF) switch exhibiting high cyclability, low On resistance and low Off capacitance, resulting in a robust switch with a RF figure of merit of 4 fs. These performance benchmarks cannot be approached with CMOS which has reached fundamental limits.

In this lecture, the PET electro-acoustic device properties and function are described and a multi-scale model PET device performance developed and used to model it for VLSI, sensor and RF applications. Progress towards realization of the device is presented by showing scaling of films of a relaxor piezoelectric for the PE and a rare earth chalcogenide piezoresistor for the PR [3,4]. 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. Last, progress towards a fast, low power memory, PET-MEM is presented which makes Piezoelectronics a complete technology.

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); “The piezoelectronic stress transduction switch for very large-scale integration, low voltage sensor computation, and radio frequency applications”, *Appl Phys. Lett.* **107**, 073505 (2015).
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.* **15**, 2391 (2015).

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