SPIKING NEURON CIRCUITS IN ULSIC VS TFT TECHNOLOGIES

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Recent advances on computing systems have enabled increasing success of algorithms using artificial intelligence. Researchers are now exploring new computational paradigms and materials to enable computing at the level of the device, allowing increased privacy and also reduction in energy. One of the most promising techniques is to realize circuits that imitate how neurons in biological brains function. Spike-based neural networks have been shown to hold more computational power than other neuromorphic architectures and their integration into mainstream computing is projected to herald a new age of computational power. Integrating neuron circuits with the functionality of materials used in flexible electronics is likely to open up a large field of applications, most notably for sensors for continuous health monitoring. In traditional MOFET technologies, spiking neuron circuits are typically operated in the deep subthreshold in order to take advantage of the exponential dependence of V_g to achieve the spiking action and also to optimize energy consumption. Nevertheless, this gives rise to some challenging problems when implemented in flexible technologies where the desire for using low cost and low temperature processes leads to lower mobility and much greater variability in device processing.

Explorations of spiking neuron circuits in TFT technologies are still rare and comparison with those in conventional ULSIC have not been thoroughly investigated. In this presentation we explore LTSPICE simulations comparing the axon-hillock circuit in realistic conventional silicon, oxide and organic TFT technologies. Biologically, the axon hillock is where the membrane potentials from the synaptic inputs are summed before being transmitted to the axon. The axon-hillock circuit, first proposed by Mead in 1989 [1] is a self-resetting circuit that is very simple to realize and therefore amenable to realizations in organic and oxide TFT technologies. Spiking is determined by a voltage threshold that is dependent on the geometry of the transistors and their properties. While more complex implementations of neurons can overcome these dependencies, it is interesting to compare the properties of these relatively simple circuits in these different technologies to understand their limits.
Axon-hillock circuits have been demonstrated many times in Si CMOS technology. We use as our basis of comparison a very low consuming implementation [2], where we have benchmarked the device performance with LTSPICE compact modeling. We then implement CMOS, pMOS and nMOS implementations of this circuit. Our first observation is that the firing rate range of the CMOS circuit is larger compared to the nMOS and pMOS implementations for a given set of circuit parameters but through careful design the single flavor versions are able to attain the same frequencies as CMOS.

Axon-hillock circuits have recently been realized and modeled in an organic CMOS technology [3]. The main drawback of the demonstrated circuits is that the large difference in mobility of n-type organic and p-type organic neuron prevent device operation in the deep sub-threshold as in conventional Si CMOS. In addition, the firing rate is much slower than that observed in biological neurons and in the CMOS circuits. Implementing a level 3 model in LTSPICE [4], we show that better performance can be obtained using single flavor pFET devices. Finally, we use a level 3 model in LTSPICE to consider single flavor nFET devices based on oxide devices [5]. We find that the oxide based devices can achieve higher spiking rates compare to the organic pFET circuits. Finally, we explore how the restricted spiking range in the single flavor neurons can impact a classification task.

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