Electron Beam Lithography Patterning of Magnetic Nanostructures for Neuromorphic and In-Memory Computing

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Short Summary:

We will present our results showing how stochastic domain walls integrated into magnetic tunnel junctions can act as logic elements as well as artificial synapses and neurons. We will show that leveraging these dynamical behaviors can benefit many areas of unconventional computing. Challenges in fabricating the devices will be analyzed.

Abstract:

Future unconventional computing systems will require computers that have high energy efficiency, low compute-memory bottleneck, can be immersed in harsh conditions, are adaptive to sensory inputs, and perform analog computations on the edge. A leading material class to tackle these needs are ferromagnetic materials and associated devices based on magnet tunnel junctions (MTJs). Devices made from magnetic materials also have dynamical behaviors that can be leveraged for these new computing paradigms, such as neuromorphic computing, for real-time training and inference on the edge.

We will present our results on electron beam lithography patterning of ferromagnetic materials to leverage domain walls (DWs) and stochasticity for these applications. We will show results on how DWs integrated into MTJs (DW-MTJs) can act as computing elements [1-2] and artificial synapses and neurons [3]. We will show our results applying the devices to neural networks, as well as to a nearer-term application of analog content addressable memory (aCAM) [4]. We will show how the stochasticity of the DW motion aids in online learning without forgetting, and how the combination of both stochastic DWs and stochastic MTJs can be used to implement efficient Bayesian neural networks [5]. The challenges for patterning devices that integrate with magnetic tunnel junctions will be analyzed through transmission electron microscopy. These results elucidate the wide design space for using ferromagnetic materials for unconventional computing.

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