Controlled multi-level programming of ferroelectric memristors

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Ferroelectric tunnel junctions (FTJs) are promising candidates for applications in in-memory computing (IMC), where they can be used as analog weights in a variety of architectures utilizing their inherent non-idealities, including neural networks for inference tasks[1]. However, reliability issues pose an issue for achieving a reproducible weight update in FTJs under realistic programming conditions. On example is the effect of time-dependent imprint[2] which has a significant effect on analog programming, since the coercive fields of domains shift over time depending on their polarization state. This impacts not only the fully switched ferroelectric but also partially polarized states[3] leading to write failures during reprogramming of multi-level memories[4]. In simulations of ferroelectric memristors for IMC-based classification of the MNIST dataset, it was further shown that non-linearity of analog states leads to the largest accuracy reduction[5] compared to other non-idealities such as cycle-to-cycle or device-to-device variability.

Recently, we demonstrated the use of current compliance during weight update of ferroelectric memristors based on $Hf_{0.5}Zr_{0.5}O_2$ in order to achieve a continuous weight update with identical pulses[6]. By limiting the current through the device during switching, fewer domains can switch on each pulse, and the field across the ferroelectric is self-limited up to the externally applied field E_{ext}. Simulations show that this method can be used to control the non-linearity of the weight update and to circumvent imprint effects during multi-level programming. Furthermore, this approach is generally applicable to ferroelectric films in other device architectures. The possibility of achieving a continuous, deterministic and reproducible multi-level weight update enables exploitation of the full potential of ferroelectric memories.

References

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