High Temperature Non-Volatile Memory

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High temperature electronics are being considered to provide new levels of awareness, control, and stability in systems at the extremes of environmental conditions, from the inside of turbine engines to the surface of Venus. Advances in ultra-wide bandgap semiconductors laid the foundation for high temperature electronics, particularly SiC and III-V nitrides, but assembling a whole capability: sensor, package, logic, passives, memory, remains elusive. Generally, the memory is considered the least mature among the constituents of a high temperature electronic capability.

Non-volatile memory in the context of high temperature electronics likely serves as a data buffer, a look-up table to adjust sensor output values, or start-up instructions, therefore the memory density requirements are very modest, generally considered to be < 1 Mb for a system. The challenge comes from entering uncharted territory in terms of materials and integration. Where FLASH and DRAM are composed of the suite of known Si-CMOS materials, the high temperature non-volatile memories will have to integrate with the back-end-of-the-line (BEOL) considerations for SiC-based logic, experiencing much harsher processing conditions and new materials compatibility requirements.

Ferroelectric materials, particularly the wurzite nitrides discovered in 2019 [1], are promising candidates as the basis for high temperature non-volatile memory (HT-NVM). The wurzite structure is highly polar and inherently stable, requiring > 3 MV/cm electric fields to induce polarization switching. This arduous switching process is likely why it took so long to discover ferroelectricity in these materials and also what gives them inherent temperature stability. Ferroelectric Random Access Memory (FRAM) is a commercial NVM based on Pb(Zr,Ti)O3 ceramic films and upcoming HfO2 materials. At the DEVCOM Army Research Laboratory, we are using the lessons learned from the commercialization of PZT FRAM and applying them to the wurzite nitrides to arrive at a new high temperature memory capability, filling the gap towards a high temperature electronics capability.

Reference:

1. S. Fichtner, N. Wolff, F. Lofink, L. Kienle, and B. Wagner, J. Appl. Phys. 125, 114103 (2019)