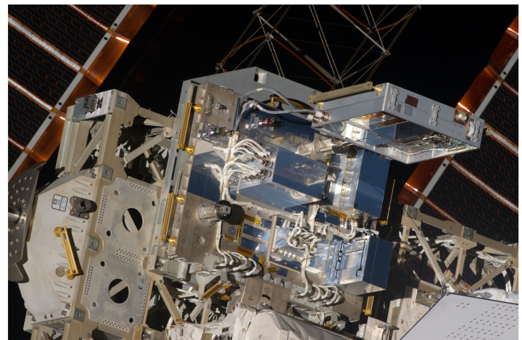
Sandia Ferroelectric Thin Films Fly on MISSE 8

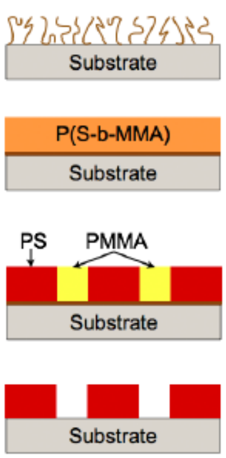
Challenge

Ferroelectricity is a collective phenomenon that emerges from the interactions of neighboring unit cells of certain polar crystalline materials. Because of this inherent property, ferroelectric materials are attractive candidates for nonvolatile random access memory (NVRAM). Additionally, they are also under consideration as materials for compact sensors because they can piezoelectrically harvest energy from their environments, thus potentially rendering themselves self-powered. Two significant challenges for this research arena are the fabrication of ferroelectrics with areal bit densities equivalent to competing technologies, and the demonstration of resistance to extreme environments.



Exterior of the international space station, showing the MISSE experiments being secured by an astronaut.

Research



Schematic of the use of block copolymers for nanoscale patterning.

The most-common and best-performing ferroelectric materials for NVRAM are those in the lead, zirconium, titanium oxide family ($Pb(Zr,Ti)O_3$, or simply PZT), and one focus of this research has been to investigate block copolymer patterning in order to control feature size at the nanoscale and to determine the minimum size at which ferroelectric properties will be retained. Block copolymers (BCP) consist of chemically different polymer blocks that are driven to phase separate by their chemical incompatibility (roughly akin to the separation of oil and water), but such phase separations are constrained by the fact that the blocks are covalently linked to one another. A thin film is deposited on a substrate and subsequently separates into a nanoscale pattern, for example alternating “stripes of the two polymers. Thereafter, one polymer is removed, leaving a pattern of the other with sub-100 nm features. Controlling the patterning of such features is a key research area for ferroelectrics.

Sandia National Laboratories

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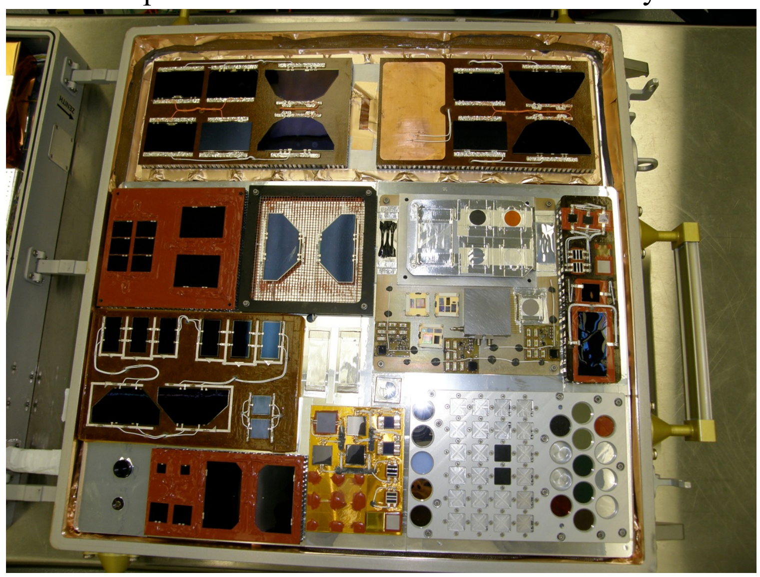
A second major focus is the investigation of the resistance of these materials to extreme environments. To this end, Sandia researchers were able to field some ferroelectric materials on the final Materials International Space Station Experiment (MISSE), a collection of experiments flown into space on the space shuttle and mounted on the exterior of the International Space Station, then subsequently retrieved to assess the effect of the extreme-radiation environment of space.

Impact

Ferroelectrics have the potential to serve as compact nonvolatile random access memory (NVRAM), such as in satellite payloads, but must be validated in terms of their radiation hardness (rad hard). In addition, because of their ferroelectric/piezoelectric properties, they have myriad potential capabilities as miniature self-powered sensors for DOE, DHS, and DoD applications, for example, as unattended, unobtrusive sensors for monitoring transit of illicit radioactive materials. They may also be applicable to chemically corrosive situations such as marine environments and petrochemical operations.



Closeup of one of the MISSE8 modules that includes some of the ferroelectric thin film experimental structures.

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