



Perovskite Superlattices as Tunable Microwave Devices

Interfacial interactions between paraelectric materials induce quasi-ferroelectric behavior.

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Experiments have shown that superlattices that comprise alternating epitaxial layers of dissimilar paraelectric perovskites can exhibit large changes in permittivity with the application of electric fields. The superlattices are potentially useful as electrically tunable dielectric components of such microwave devices as filters and phase shifters.

The electrically tunable materials heretofore used in some microwave devices exhibit strong temperature dependences of dielectric properties and high microwave losses. Previous efforts to overcome these undesired effects have involved the addition of various dopants to SrTiO₃, BaTiO₃, and Sr_xBa_{1-x}TiO₃. Despite the amount of research in this area, results have been disappointing.

The present superlattice approach differs fundamentally from the prior use of homogeneous, isotropic mixtures of

base materials and dopants. A superlattice can comprise layers of two or more perovskites in any suitable sequence (e.g., ABAB..., ABCDABCD..., ABCABACA...). Even though a single layer of one of the perovskites by itself is not tunable, the compositions and sequence of the layers can be chosen so that (1) the superlattice exhibits low microwave loss and (2) the interfacial interaction between at least two of the perovskites in the superlattice renders either the entire superlattice or else at least one of the perovskites tunable.

The perovskites investigated experimentally for use in superlattices include SrTiO₃, SrCeO₃, SrZrO₃, BaTiO₃, BaZrO₃, CaZrO₃, and LaAlO₃. Superlattices for the experiments were fabricated by pulsed laser deposition onto mostly LaAlO₃ substrates; a few specimens were prepared on SrTiO₃ substrates. Microwave filters containing superlattices were also fabricated. The

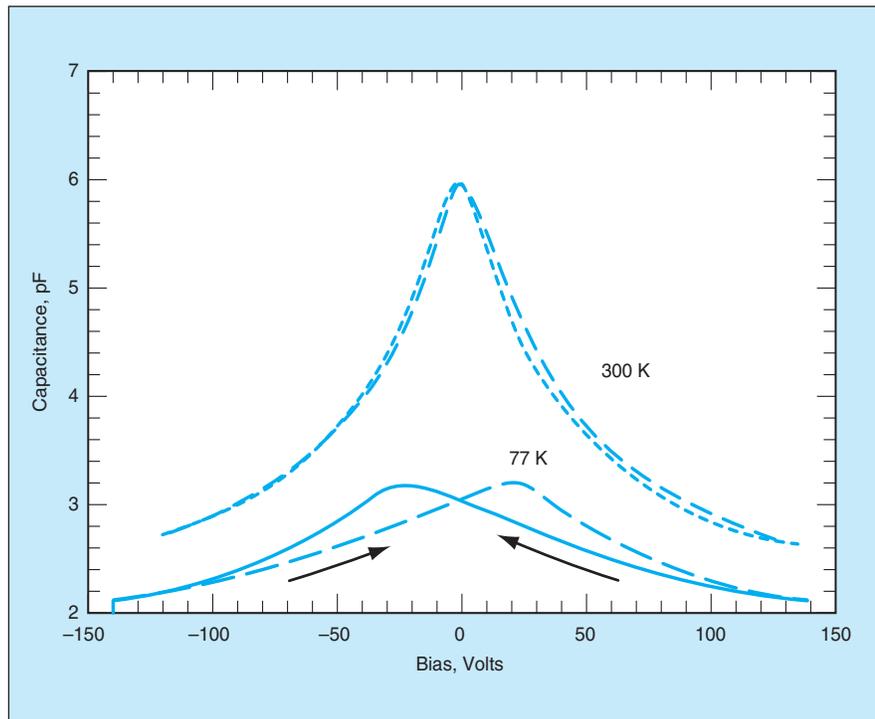
superlattices were evaluated with respect to structure, composition, and dielectric properties.

Analysis of the observations made in the experiments led to the following conclusions:

- Large tuning was observed in capacitors made from some superlattices (see figure). Ferroelectricity induced by lattice-mismatch strain in superlattices has been tentatively identified as the cause of tunability in the otherwise nontunable paraelectric perovskite constituents.
- Some of the superlattices exhibited positive $d\epsilon/dE$, where ϵ is permittivity and E is the magnitude of an applied electric field. This stands in contrast to the negative values of $d\epsilon/dE$ typically observed in perovskites.
- Superlattices can be made to exhibit weak temperature dependences of tunability. For example, one SrTiO₃/BaZrO₃ superlattice was found to exhibit a tunability of 33 percent at both room temperature and at 77 K. In contrast, a typical ferroelectric material is tunable in only a narrow temperature range near a phase transition. Superlattices with weak temperature dependence of tunability could be attractive materials for situations in which precise control of temperature would be either impossible or too expensive.
- In tests on coplanar-waveguide microwave filters containing perovskite superlattices of a given total thickness, dielectric losses were found to be smaller than those in filters containing single SrTiO₃ films of the same total thickness.

This work was done by H. M. Christen and K. S. Harshavardhan of Neocera, Inc., for Glenn Research Center. Further information is contained in a TSP (see page 1).

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Tunability in Excess of 50 Percent was observed in a capacitor in which the dielectric was a superlattice of SrTiO₃/CaZrO₃ with layer thicknesses chosen for large tunability at room temperature.