Enhancing permittivity of $SrTiO_3$ thin film via intermediate $AlFeO_3$ layers incorporation

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Key words: Terahertz Spectroscopy, Strontium Titanate, Thin Films

Strontium titanate is a quantum paraelectric used in novel energy storage, memory and microwave optical devices for its high permittivity and low losses in a broad frequency range from radio to sub-terahertz [1,2]. In bulk crystalline form, real permittivity of $SrTiO_3$ reaches values as high as 24000, and more than 99% of it is contributed by the TO1 phonon soft mode (SM) associated with a potential ferroelectric phase transition. In polycrystalline films, however, the dielectric strength $\Delta\varepsilon$ and the central frequency of the SM are significantly lower and higher, respectively. Petzelt *et al*. showed that the SM dielectric strength decreases as the film thickness grows [3]. A natural question arises, how to preserve high values of permittivity in thicker films to enable their use in electronics. In this study, we investigated structural and dielectric properties of polycrystalline $SrTiO_3$ thin films (50 nm and 250 nm thick) and $SrTiO_3/AlFeO_3$ multilayer heterostructure. The films were grown by pulsed laser deposition on (0001) Al_2O_3 substrates. Formation of perovskite type lattice was observed *in situ* by reflective high energy electron diffraction (RHEED), while lattice constants, crystallite sizes and microstrains in them were determined after the deposition using X-ray diffraction (XRD) measurements. We employed terahertz time-domain spectroscopy to measure the spectra of real and imaginary parts of dielectric permittivity of the prepared samples. Broad absorption band centered at 2-3 THz is associated with $SrTiO_3$ ferroelectric soft mode. Temperature dependencies of its parameters show that $SrTiO_3$ remains in a quantum paraelectric state in all samples at temperatures down to 5 K. However, the values of the SM dielectric strength $\Delta\varepsilon$ are different: in thin $SrTiO_3$ single layer and $SrTiO_3/AlFeO_3$ multilayer they reach $\Delta\varepsilon = 450$, while for the thick $SrTiO_3$ single layer these values are lower, $\Delta\varepsilon = 320$. In agreement with the Lyddane-Sachs-Teller relation, the measured soft mode central frequency in the thick film is higher than in thin film and heterostructure, which indicates an intrinsic mechanism of the observed soft mode stiffening.

The study was supported by the Ministry of Science and Higher Education of Russia (contract No. 075-15-2025-010, THz spectroscopy) and Russian Science Foundation (project No. 25-42-00058, theoretical analysis).

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