Template-based bottom-up fabrication of regularly patterned nanosized ferroelectric grains

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For future high-density ferroelectric random access memories (FeRAMs) a further decrease of the feature size is essential to further follow Moore's Law. In addition the scaling of the ferroelectric structures needs to be understood in order to elucidate possible limitations of this memory concept. Here we present a straightforward "bottom-up" method, using artificial TiO_2 dot templates on standard $Si/SiO_2/TiO_2/Pt(111)$ substrates to promote nucleation and grain growth of $PbTiO_3$ (PT) crystallites prepared by chemical solution deposition (CSD) [1]. Compared to the usually applied subtractive methods based on lithography and etching or focused ion beam (FIB) this method avoids damaging the prepared ferroelectric nanostructures. First, the TiO_2 nucleation sites were defined by electron beam lithography and transferred into patterns of small dots (diameter $\sim$30 – 100 nm) by evaporating a 2 nm thin Ti film followed by lift-off. A two layer resist system based on PMMA and PMMA/MAA was applied for obtaining an undercut resist profile. The smallest dots that were fabricated reproducibly were 30 nm in diameter and had a distance of 45 nm. Subsequently the TiO_2 dot patterns were used as nucleation sites in a CSD process applying highly diluted PT precursor solutions. During the crystallization process the thin as-deposited film broke up yielding well defined single crystalline PT islands indicating the promoting influence of the initial TiO_2 seed structures. Characteristic arrangements of perovskite nanograins after crystallization on TiO_2 seed patterns are shown in figure 1.

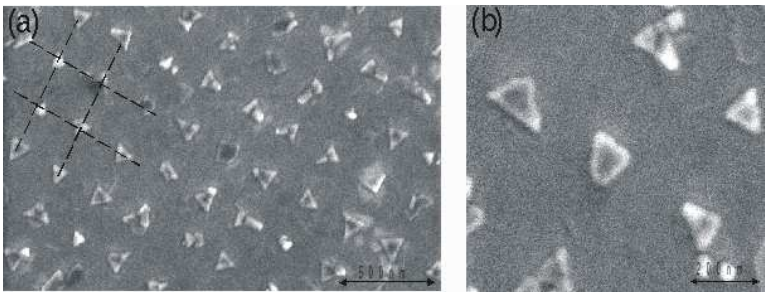

Figure 1: SEM images of separated PT nanograins deposited with a 1:30 diluted precursor solution on 100 nm TiO_2 seed structures. Here, the nucleation of the PT crystals exclusively took place on the TiO_2 pattern, whereas there was no crystallization at grain boundaries of the platinized substrate. To point out the alignment of the PT crystals, grid lines are plotted in (a).

The triangular shape of most grains points to a (111)-orientation of the crystallites here, whereas square formed grains indicate a (100)-orientation. The smallest PT grains nucleated on 50 nm wide TiO_2 seeds with a distance of 75 nm. PFM measurements were carried out to prove ferroelectricity.

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