BOTTOM-UP APPROACH FOR GENERATING REGULAR PATTERNS OF NANOSCALED FERROELECTRIC PEROVSKITES

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Ferroelectric materials are of growing interest in international research and development. Special attention is drawn to the integration of ferroelectric materials in non-volatile random access memory cells (FeRAMs). For future high-density FeRAMs, the scaling of the size of ferroelectric structures needs to be understood in order to elucidate possible limitations to memory densities. Various experimental studies were carried out in order to investigate scaling effects of ferroelectric nanograins on Si-wafers [1-4]. A major drawback of top-down approaches is the difficulty to achieve ferroelectric structures with lateral dimensions well below 50 nm. In addition, erosive top-down approaches [1, 3] inevitably induce damage to the fabricated capacitors as ferroelectricity is a nature of the crystal lattice. Hence, it becomes hard to distinguish between real intrinsic ferroelectric properties and the impact of production steps.

To overcome these drawbacks, we present a straightforward “bottom-up” method, using artificial TiO_2 dot templates on commonly used $Si/SiO_2/TiO_2/Pt(111)$ substrates to promote nucleation and grain growth of $PbTiO_3$ (PT) crystallites prepared by a chemical solution deposition (CSD) technique [5].

First, the TiO_2 nucleation sites were defined by electron beam lithography and transferred into patterns of small dots (diameter ~ 30 – 100 nm) by evaporating a 2nm thin Ti film and lift-off processing. 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. Some of the TiO_2 dot patterns are shown in figure 1.

The TiO_2 dot patterns were used as nucleation sites for a modified 2-butoxyethanol based CSD process. Due to very high precursor dilutions (1:20, 1:30 and 1:40), the thin as-deposited film broke up during the crystallization process yielding single crystalline PT islands as described earlier [6]. It was found, that nucleation of the PT grains predominantly took place on the TiO_2 seed structures. Characteristic arrangements of perovskite nanograins after crystallization on TiO_2 seed patterns are shown in figure 2.

The triangular shape of most grains denotes that we are dealing with (111)-oriented crystallites here, whereas square formed grains indicate a (100)-orientation. The smallest PT grains nucleated on 50nm wide TiO_2 seeds with a distance of 75 nm. It seems that initially the precursor ions are trapped mainly by the TiO_2 seeds. This assumption agrees well with the fact, that for higher degrees of precursor dilution, nucleation sites between adjacent TiO_2 dots disappeared almost completely whereas nucleation occurred at platinum grain boundaries in case of lower precursor dilutions. Nevertheless, those PT crystals were much smaller in size compared to the PT grains that were located on the TiO_2 seed structures.

Hence, the promoting influence of TiO_2 seeds on nucleation and grain growth of nanoscaled perovskites deposited by CSD was shown.

References:

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Figures:

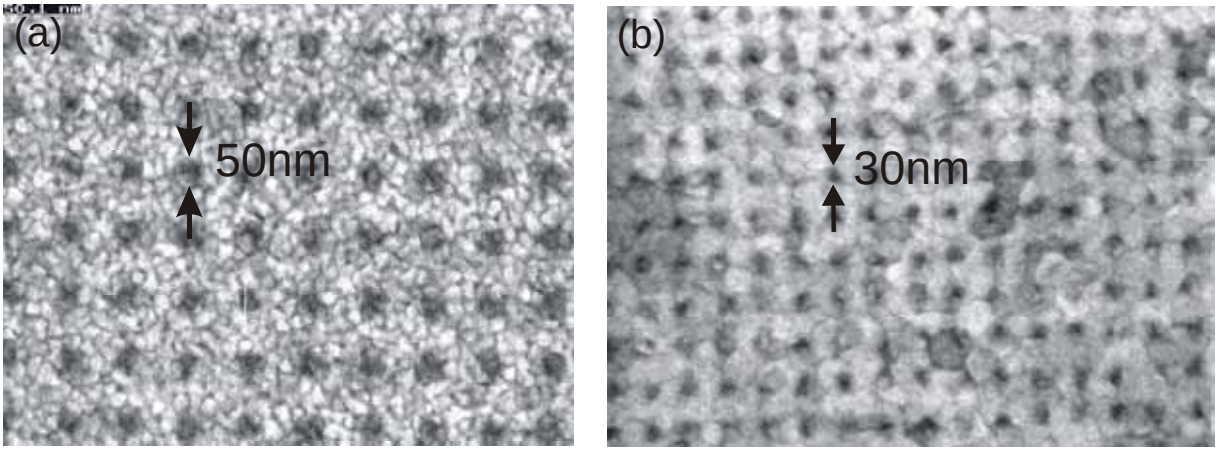

Figure 1: Scanning electron images of TiO_2 dot structures appearing as round shadows on the bright platinum substrate. The dots in (a) are 50nm in diameter and have a distance of 75nm. The smallest TiO_2 dot structures that were patterned reproducibly were 30nm in diameter with a distance of 45nm (b).

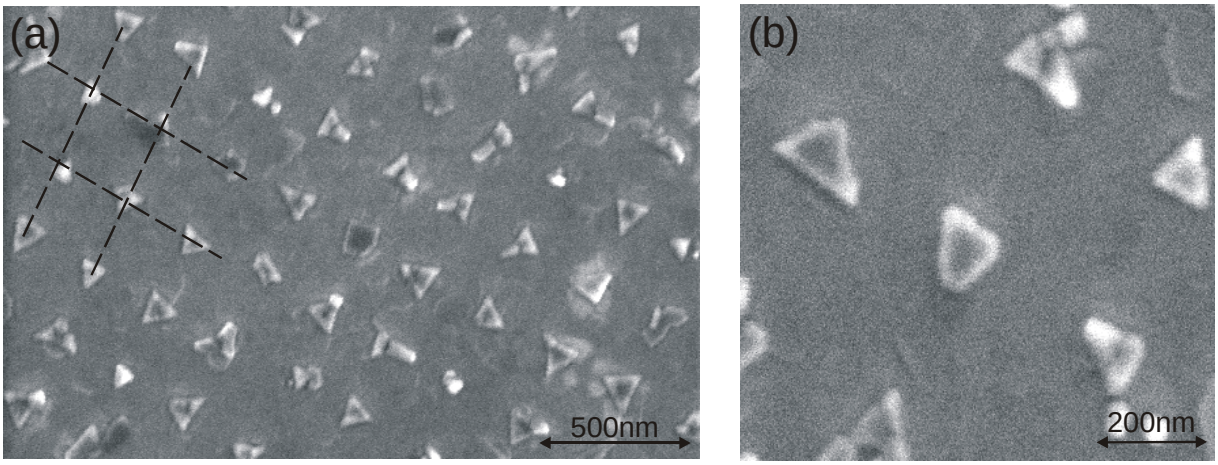

Figure 2: SEM images of separated PT nanograins deposited with a 1:30 diluted precursor solution on 100nm TiO_2 seed structures. Here, the nucleation of the PT crystals exclusively took place on the TiO_2 pattern whereas there was no crystallization at grain boundaries of the platinized substrate. To point out the alignment of the PT crystals, grid lines are plotted in (a).