Supplementary Materials

Micro-electromechanical system-based cryogenic and heating *in situ* transmission electron microscopy for investigating phase transitions and domain evolution in single-crystal $BaTiO_3$

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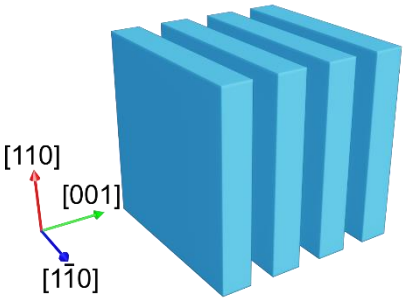
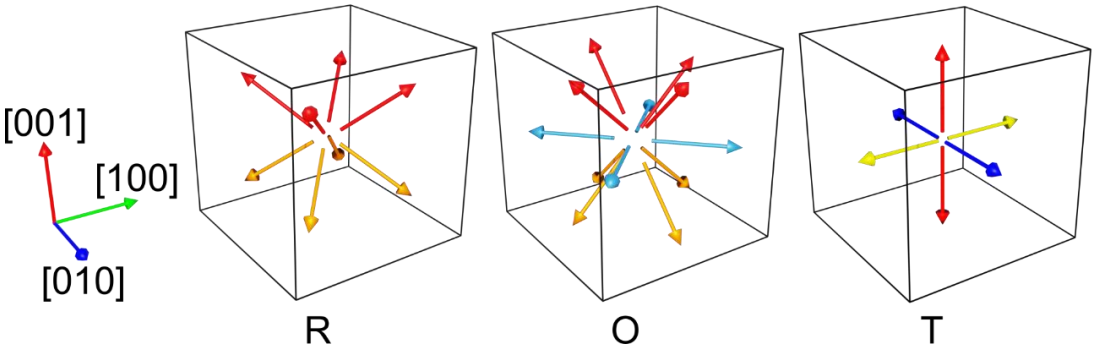
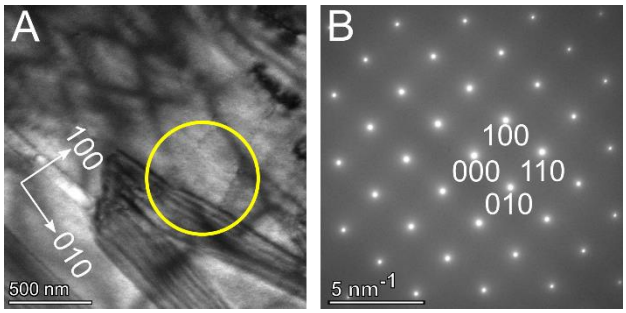


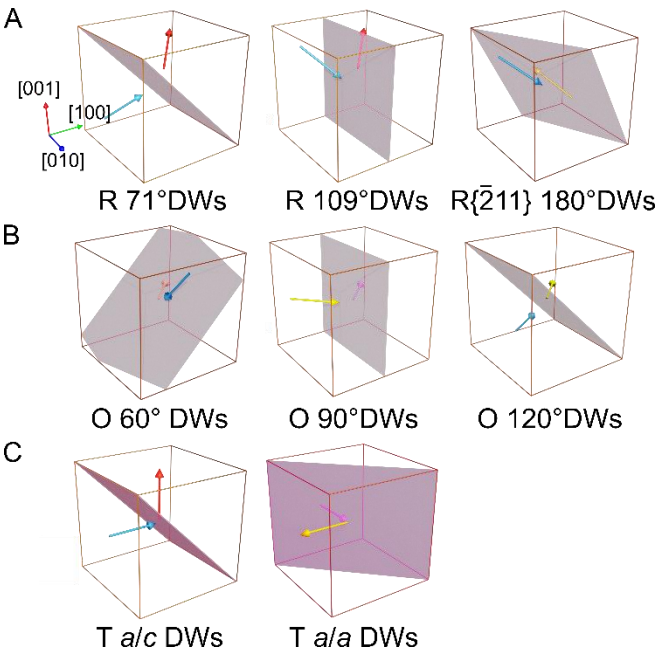
Supplementary Figure 1. Schematic of FIB-prepared TEM specimen along the (001) plane of [110]-orientated sing-crystalline BTO.



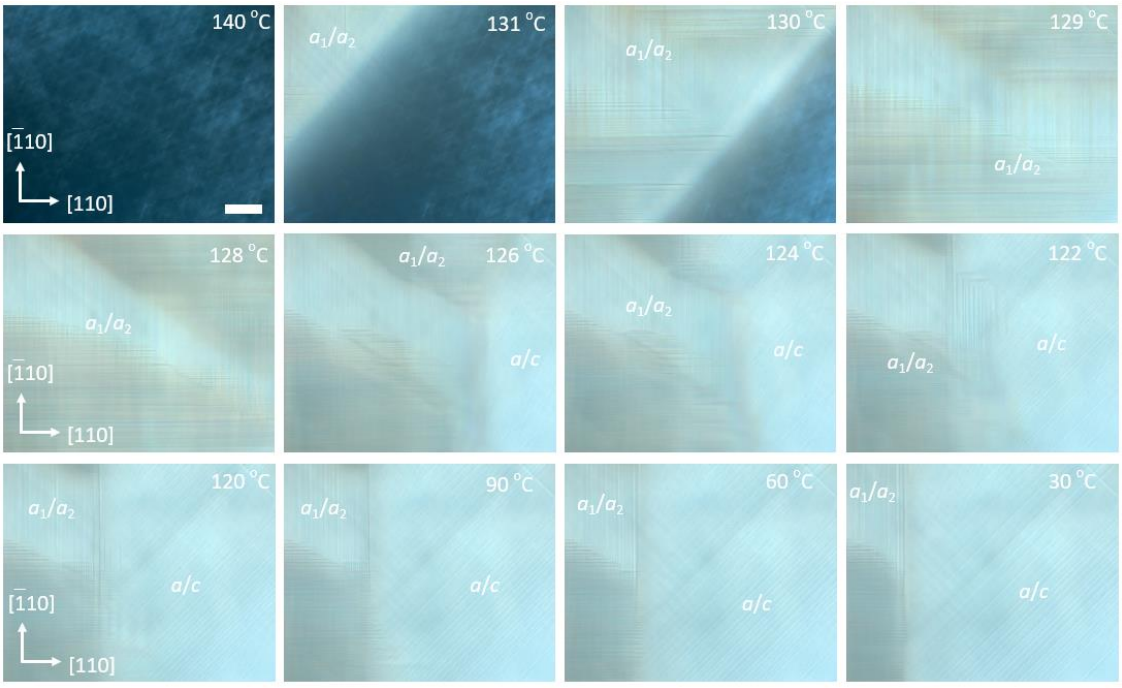
Supplementary Figure 2. Spontaneous polarizations in rhombohedral (denoted as R), orthogonal (O), and tetragonal (T) phases of $BaTiO_3$, respectively.



Supplementary Figure 3. (A) BF-TEM image obtained at -160 °C. (B) SAED pattern corresponds to the area highlighted by the yellow circle in (A). Scale bars are (A) 500 nm and (B) 5 nm^{-1}, respectively.



Supplementary Figure 4. The observed domain wall configurations in (A) rhombohedral (denoted as R), (B) orthogonal (O), and (C) tetragonal (T) phases of $BaTiO_3$, respectively.



Supplementary Figure 5. Optical images obtained from the cooling process at different temperatures. The scale bar is 50 μm.

Supplementary Table 1. Material parameters of $BaTiO_3$ for bulk free energy calculation

Parameters	Symbol	Value	Ref.
Landau-Devonshire potential coefficients	α_1	$4.124 \times 10^5 (T - T_C)$ Nm^2/C^2	[1]
	α_{11}	-2.097×10^8 Nm^6/C^4	
	α_{12}	7.974×10^8 Nm^6/C^4	
	α_{111}	1.294×10^9 Nm^{10}/C^6	
	α_{112}	-1.950×10^9 Nm^{10}/C^6	
	α_{123}	-2.500×10^9 Nm^{10}/C^6	
	α_{1111}	3.863×10^{10} Nm^{14}/C^8	
	α_{1112}	2.529×10^{10} Nm^{14}/C^8	
	α_{1122}	1.637×10^{10} Nm^{14}/C^8	
	α_{1123}	1.367×10^{10} Nm^{14}/C^8	

REFERENCES

1. Li YL, Cross LE, Chen LQ, A phenomenological thermodynamic potential for $BaTiO_3$ single crystals. *J Appl Phys* 2005; 98: 064101.