TABLE I. Processing steps for the MIM and MOS experimental samples.

		Technology steps		
		Separate annealing		Simultaneous annealing
Type of structure	Sample #	Bottom TiN	HfO_2/Al_2O_3	Bottom TiN + HfO_2/Al_2O_3
MIM (structure A)	1	No	No	Yes
	2	Yes	Yes	No
	3	Yes	No	No
MOS (structure B)	4	—	No	—
	5	—	Yes	—

TABLE II. Electrical parameters of the MIM and MOS experimental structures, showing the EOT, dielectric constant (*k*-value), BDV, and breakdown electric field.

		Electrical parameter of high-*k* layer			
Type of structure	Sample #	EOT (A)	*k*-value	BDV (V)	Breakdown electric field (MV/cm)
MIM	1	19.0	28.7	≥7.0	5.0
	2	21.0	26.0	≥8.1	5.8
	3	31.2	17.5	≥4.6	3.3
MOS	4	31.5	17.3	—	—
	5	17.5	31.2	—	—

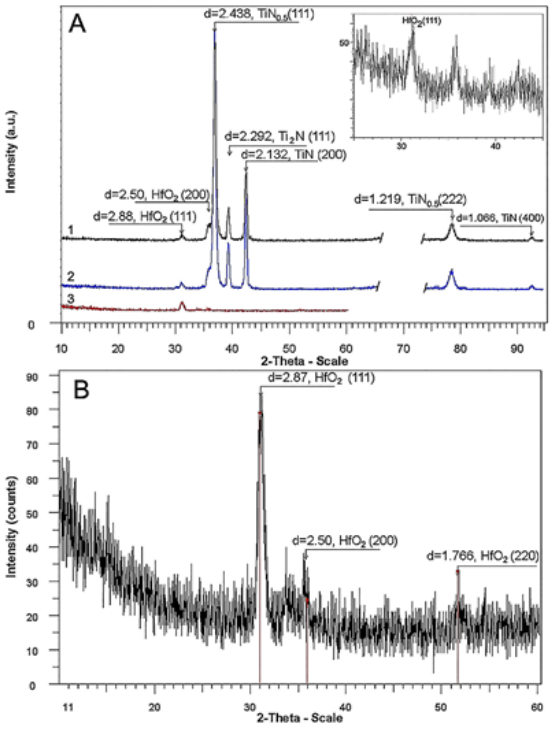

FIG. 3. XRD characterization data: (a) Patterns acquired from samples #1 (curve 1), #2 (curve 2), and #5 (curve 3). (Inset) GIXRD pattern acquired from sample #1. Peaks of identified phases are labeled with the d-spacing, phase name, and hkl indices. Peaks of the hafnia aluminate phase are indexed as cubic HfO2. The strong peak of Si(400) at 69° is excluded from all the patterns to emphasize the diffraction from top layers. (b) Detail of XRD patternacquired from sample #5.

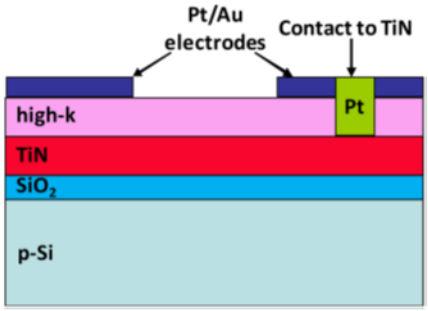

FIG. 1. Schematic view of the MIM capacitor containing a hafnia aluminate dielectric layer.

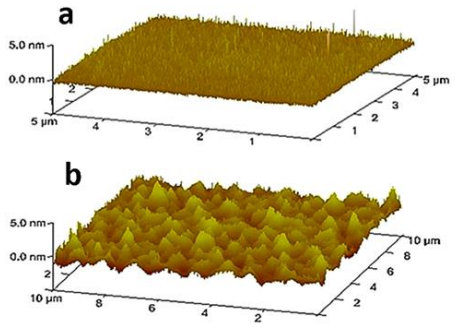

FIG. 4. AFM topography map of a bottom TiN electrode: (a) as-deposited, prior to annealing (Rq = 0.264 nm, Ra = 0.198 nm); (b) after predeposition annealing at T > 600 °C for 30 s in N2 environment (Rq = 0.636 nm, Ra=0.498 nm).

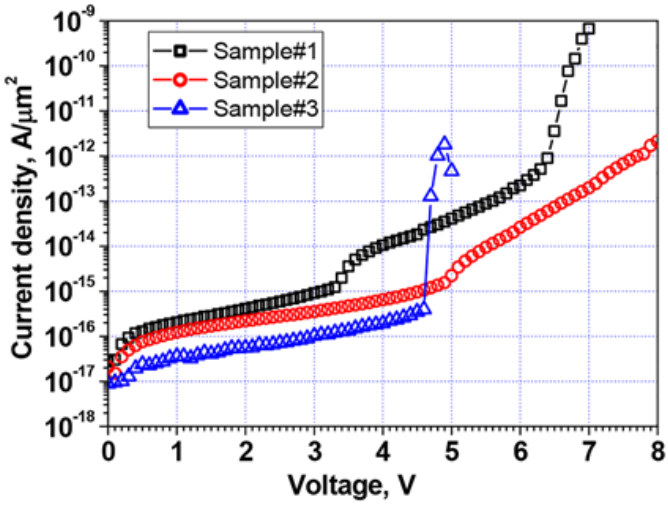

FIG. 2. I–V characteristics of MIM capacitors (structure A samples): samples #1 and 2 (HfAlOx dielectric layer underwent PDA > 600 °C), sample #3 (as-grown HfAlOx dielectric film). All measurements performed with negative bias on a top electrode (Pt/Au).

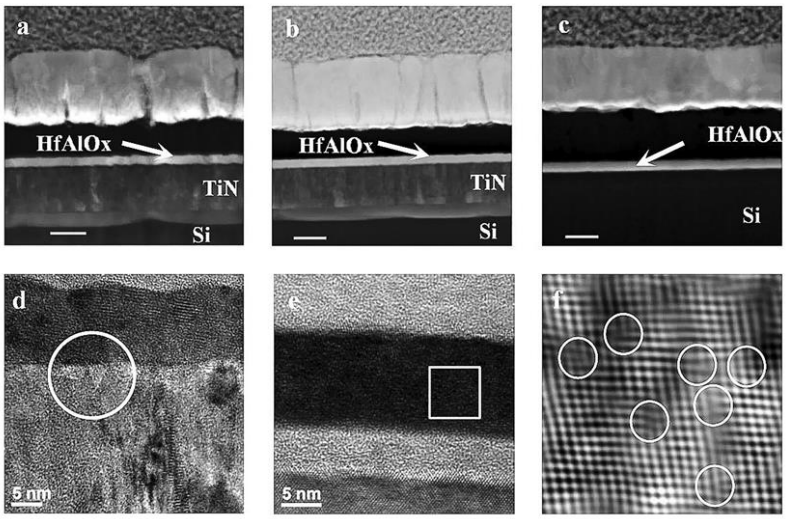

FIG. 5 STEM cross-sectional images: [(a)–(c)] HAADF STEM images of samples (a) #1, (b) #2, and (c) #5; HfAlOx, TiN, and Si layers are labeled, scale bars = 50 nm. [(d) and (e)] High-resolution TEM images of samples (d) #1 and (e) #5, where voids at TiN/HfAlOx interface are circled in (d). (f) Fourier filtered image of HfAlOx taken from the white box in (e), where some of the dislocation cores are circled.

References:

[1] J. H. Choi, Y. Mao, and J. P. Chang, Mater. Sci. Eng. R. 72, 97 (2011).

[2] A. Toriumi and K. Kita, Material Engineering of High-k Gate Dielectrics, edited by M. Baklanov, M. Green, and K. Maex (Wiley, Chichester, 2007), pp. 298–336.