ARTICLE

Supporting information

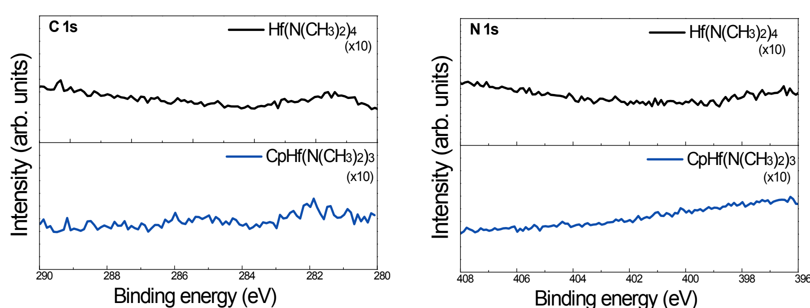

Figure S1. C and N contents of ALD HfO_2 films deposited on Si using $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$ precursors at 250 ℃.

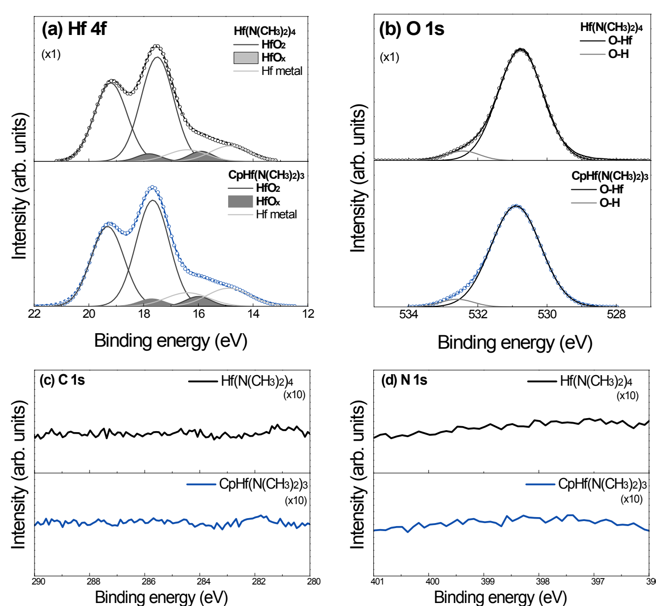

Figure S2. XPS spectra of 20 nm-thick ALD HfO_2 films deposited on Si at 350 ℃: (a) Hf 4f, (b) O 1s, (c) C 1s and (d) N 1s for $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$, respectively

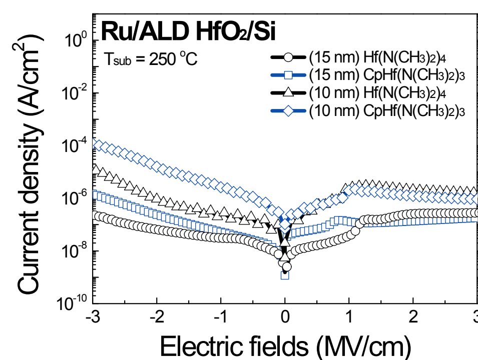

Figure S3. I–V curves of MOS capacitors deposited using 10 nm and 15 nm-thick ALD HfO_2 using $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$ precursors at 250 ℃

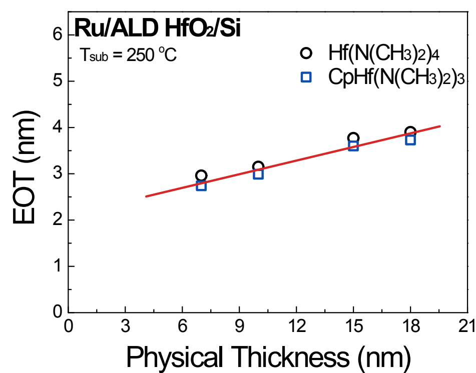

Figure S4. EOT variation as physical oxide thickness of ALD HfO_2 deposited using $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$ precursors at 250 ℃

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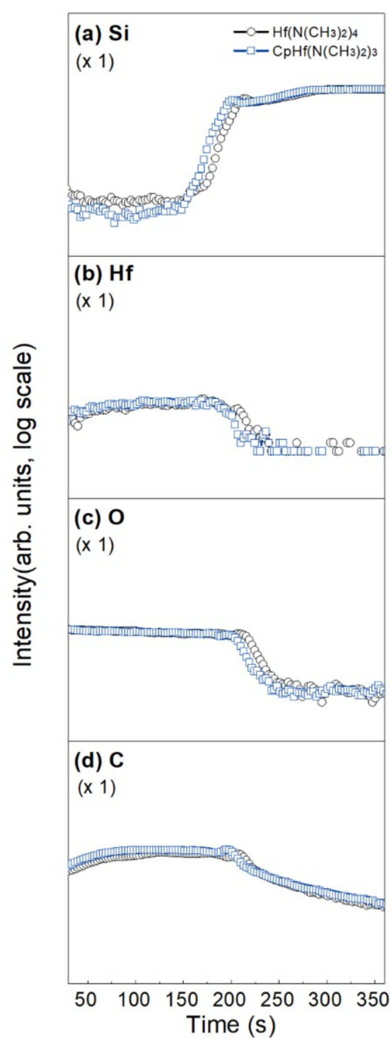

Figure S5. ToF-SIMS profile of 15 nm-thick ALD HfO_2 deposited using $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$ precursors at 250 ℃: (a) Si, (b) Hf, (c) O and (d) C.

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Table S1. Chemical compositions of ALD HfO_2 films deposited on Si using $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$ precursors at 350 ℃.

	Hf		O		C	N
	HfO_2	HfO_x	O-Hf	O-H		
$Hf(N(CH_3)_2)_4$	28.0 %	1.9 %	60.9 %	3.7 %	2.7 %	2.8 %
$CpHf(N(CH_3)_2)_3$	29.6 %	2.5 %	61.0 %	3.0 %	1.5 %	2.0 %

Table S2. The estimated *k*-value from EOT-Physical oxide thickness (fig S4) of HfO_2 films using $Hf(N(CH_3)_2)_4$ and $CpHf(N(CH_3)_2)_3$ precursors at 250 ℃.

	Physical oxide thickness of HfO_2			
	7 nm	10 nm	15 nm	18 nm
$Hf(N(CH_3)_2)_4$	12.7	13.9	17.9	21.2
$CpHf(N(CH_3)_2)_3$	13.6	14.7	18.7	21.2

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