Supplementary Material: Modulation of $Hf_xZr_{1-x}O_2$ Thin Film Characteristics via ALD and ALE

Figure 1. (a). Alternate stacking structure confirmed by EDS depth profile measurement. (b). XPS survey spectra quantified HZO composition.

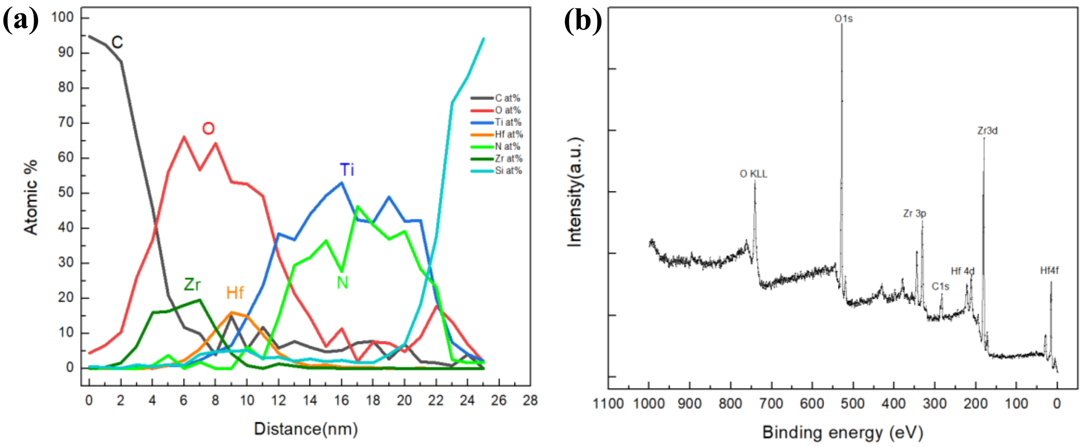


Figure 2. Measure the dielectric property of HZO film by Metal-insulator-Metal structure.

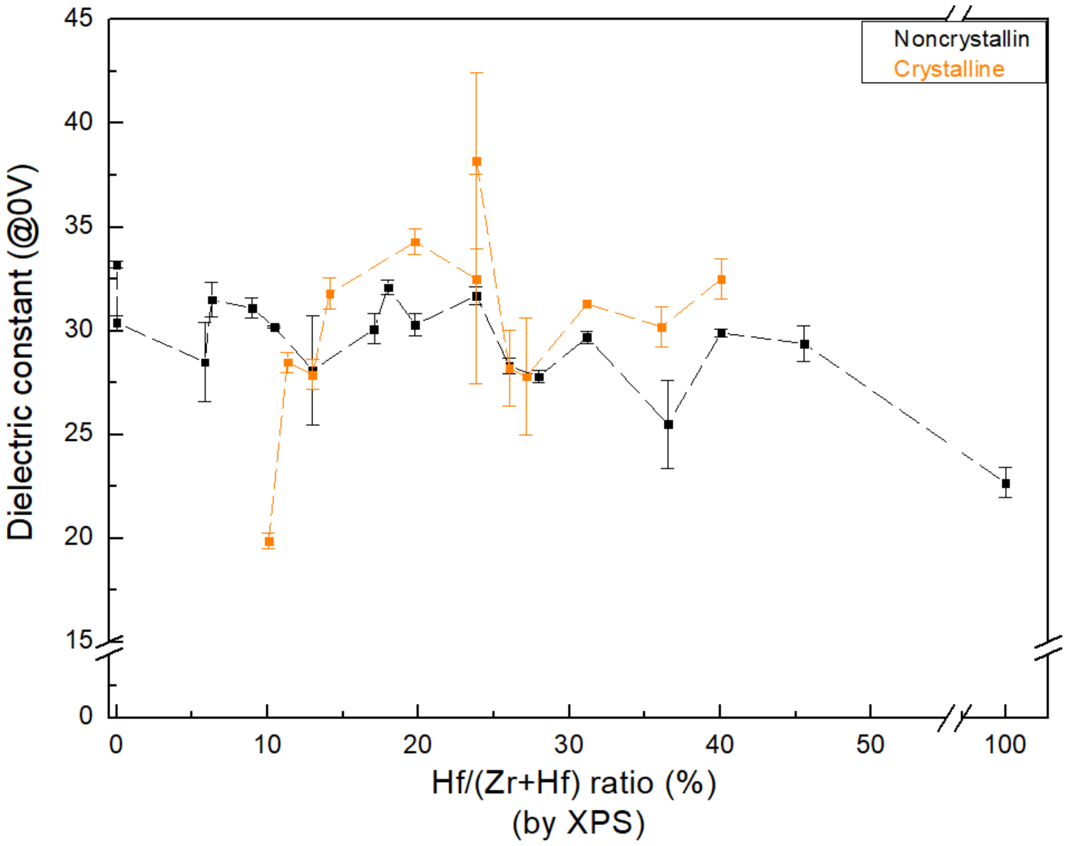
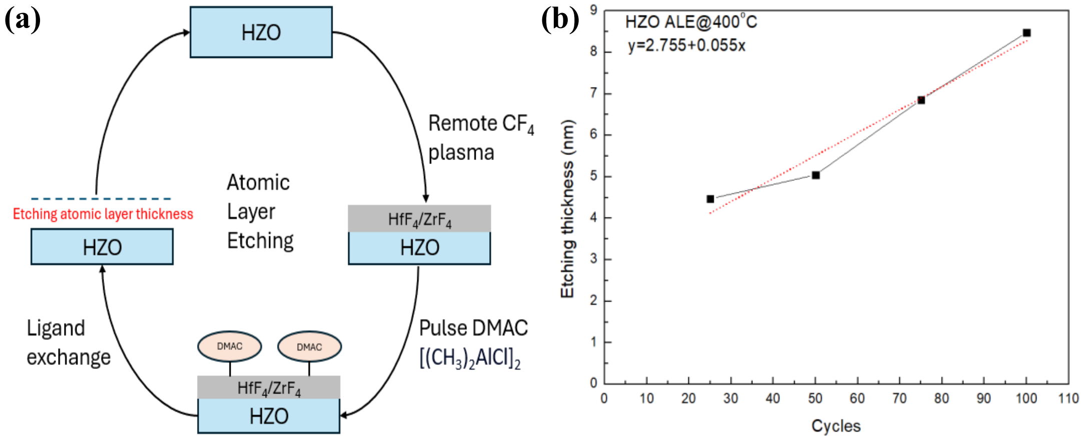


Figure 3. (a). Schematic of Atomic Layer etching of HZO film by CF_4 plasma and DMAC precursor. (b). Etching thickness vs. cycle number at 400°C.


(a)
HZO
Remote CF_4 plasma
HfF_4/ZrF_4
HZO
Pulse DMAC $[(CH_3)_2AlCl]_2$
DMAC
DMAC
HfF_4/ZrF_4
HZO
Ligand exchange
Etching atomic layer thickness
HZO
Atomic Layer Etching
(b)
HZO ALE@400°C
y=2.755+0.055x
Etching thickness (nm)
0
1
2
3
4
5
6
7
8
9
Cycles
0
10
20
30
40
50
60
70
80
90
100
110