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Electrical Characteristics of Ferroelectric HfO_2 Directly Deposited on Si Substrates

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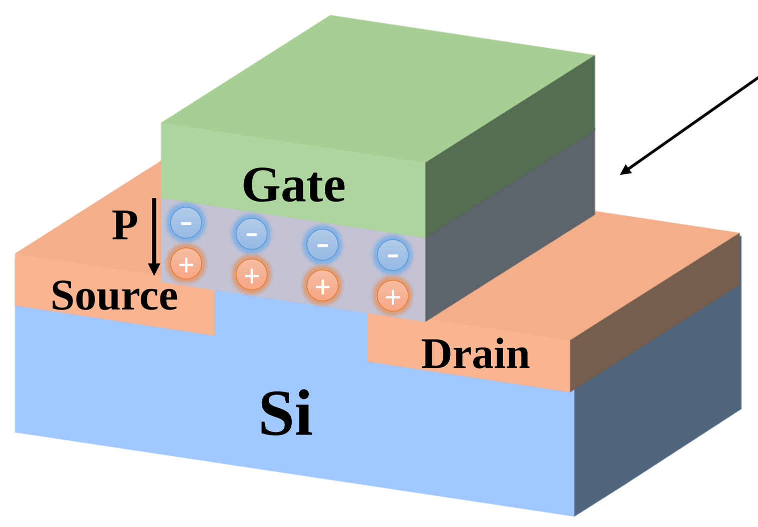
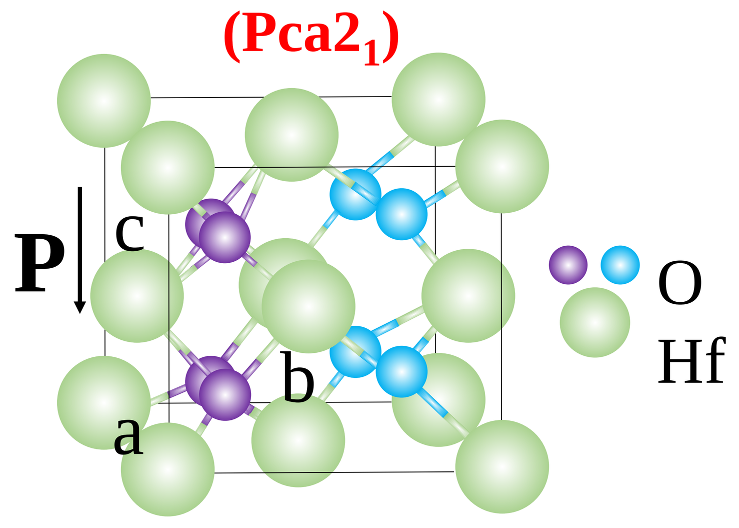
1. Introduction

1T-FeRAM with Orthorhombic HfO_2

Metastable Orthorhombic HfO_2 ($Pca2_1$)





Advantages of HfO_2
- Scalability
- Compatibility with Si

[1]

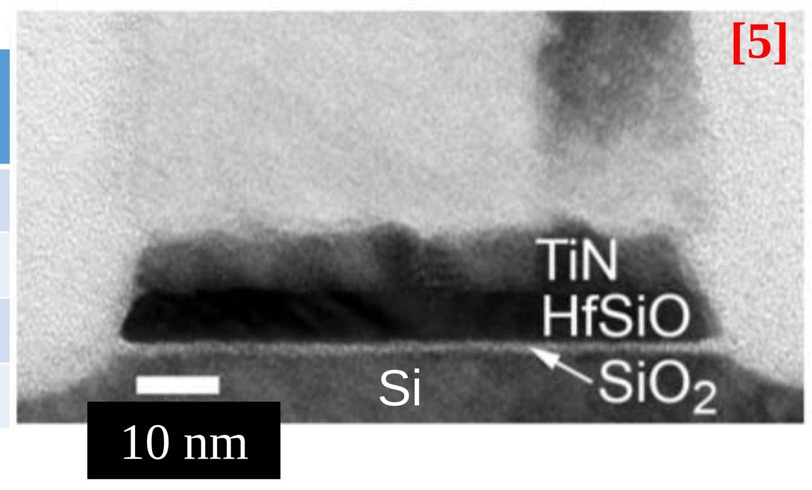
Phase	a (Å)	b (Å)	c (Å)
Monoclinic (M)	5.09	5.16	5.26
Orthorhombic (O)	4.90	5.11	4.92

[1] Q. Zeng, et al., Acta Crystallogr. C, 70(2), 76-84 (2014).

Issue for Hf-based Ferroelectrics on Si Substrate

Dopant	t_{ox} (nm)	T_{anneal} (°C)	Substrate	Ref.
Zr	30	950	SiO_2/Si(100)	[2,3]
Si	9	1050	Si(100)	[4]
Si	10	1000	Si(100)	[5]
Y	N/A	700	YSZ/Si(100)	[6]

t_{ox}: Thickness of HfO_2 T_{anneal}: annealing temperature



Interfacial layer formed by high temperature annealing
→ Formation of depolarization field

Direct deposition on Si substrates with low temperature annealing process is necessary to suppress interfacial layer formation

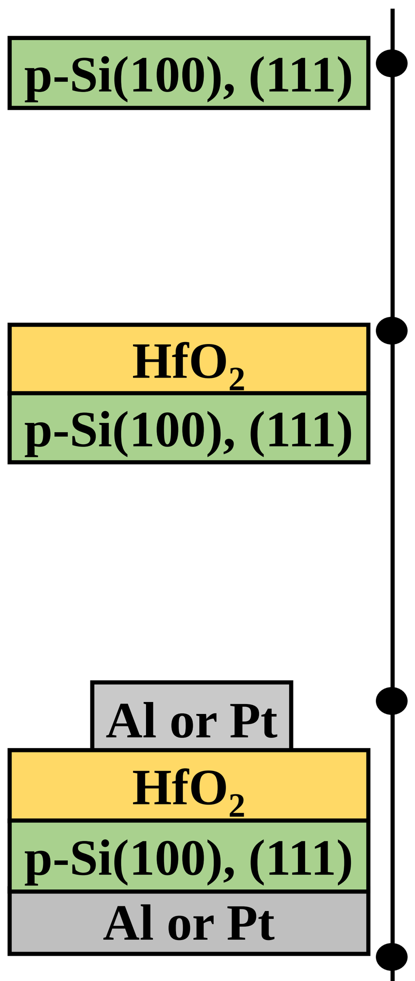
[2] C. H. Cheng, et al., IEEE Electron Dev. Lett., 35, 138-140 (2014).
[3] Y. C. Chiu, et al., Phys. Status Solidi RRL, 11, 1600368 (2017). [4] J. Muller, et al., 2012 VLSIT (2012).
[5] T. S. Boscke, et al., IEDM11-550 (2011). [6] K. Lee, et al., Appl. Phys. Lett. 112, 202901 (2018).

2. Objective

❖ **Si substrate orientation dependence on the formation of undoped HfO_2 with metastable orthorhombic phase**

➢ Direct deposition of ferroelectric HfO_2 on Si substrates with relatively low annealing temperature.

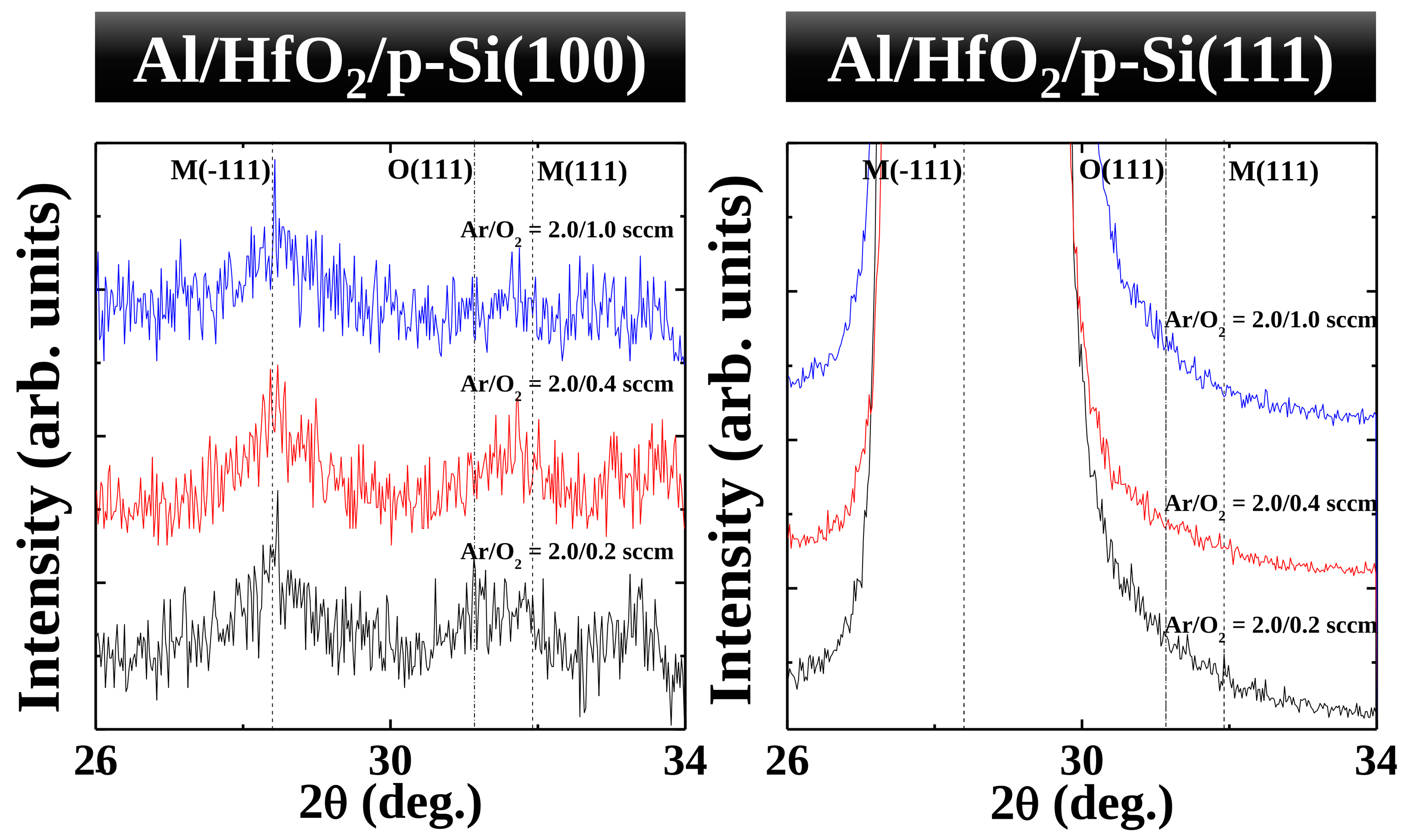
3. Experimental Procedure



- **Cleaning p-Si(100), p-Si(111)**
  SPM / DHF
- **HfO_2 deposition (24 nm) @ RT**
  RF Magnetron Sputtering: 100W
  Ar/O_2 = 2.0/0.2-1.0 sccm (0.35Pa -0.4 Pa)
  Hf target
- **Post deposition annealing**
  600°C / 30 s in N_2 (1 SLM)
- **Al or Pt evaporation**

C-V, J-V, XRD

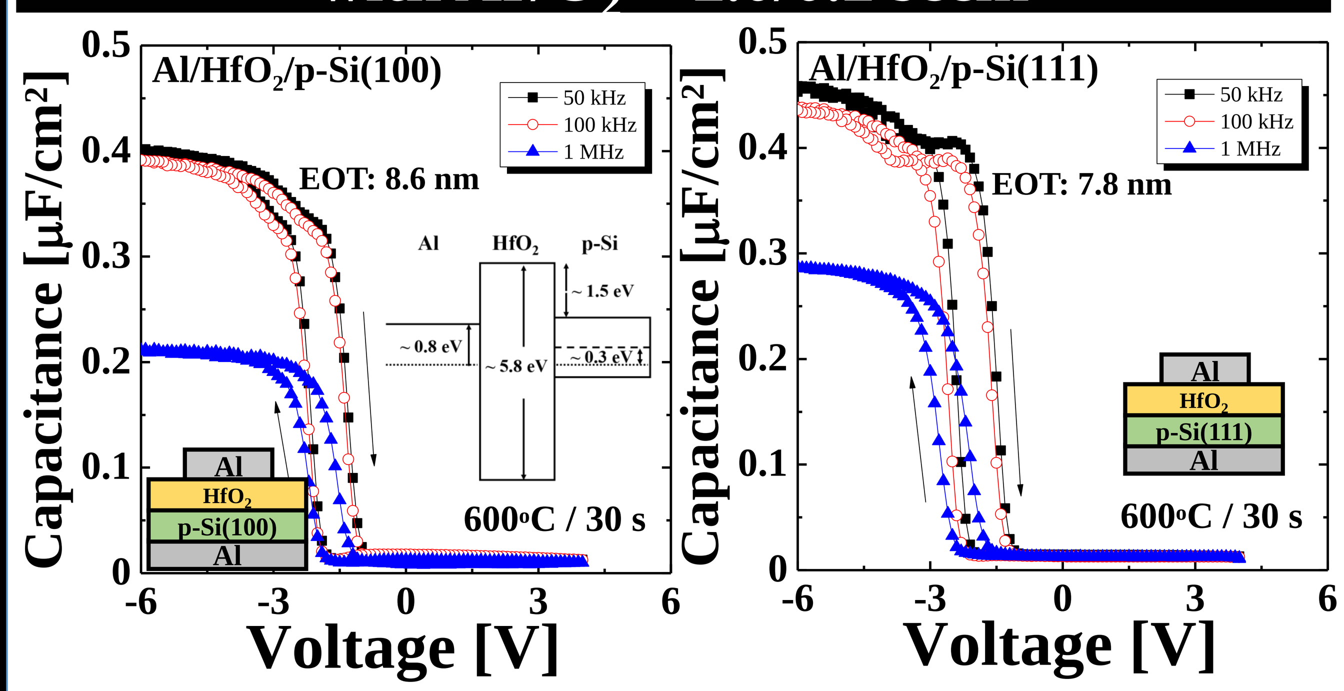
4. XRD Patterns



➢ **Low oxygen flow was effective to induce orthorhombic phase.**

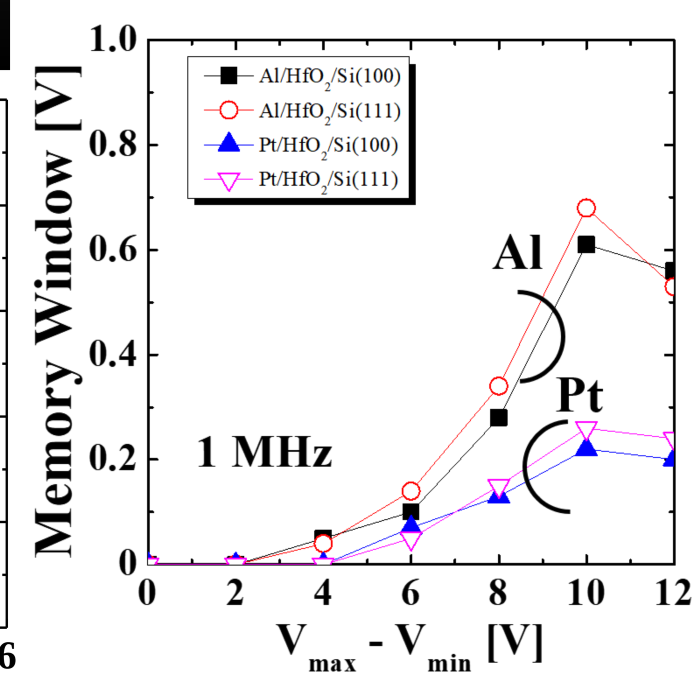
5. Electrical Characteristics

C-V characteristics of MFS diode with Ar/O_2 = 2.0/0.2 sccm

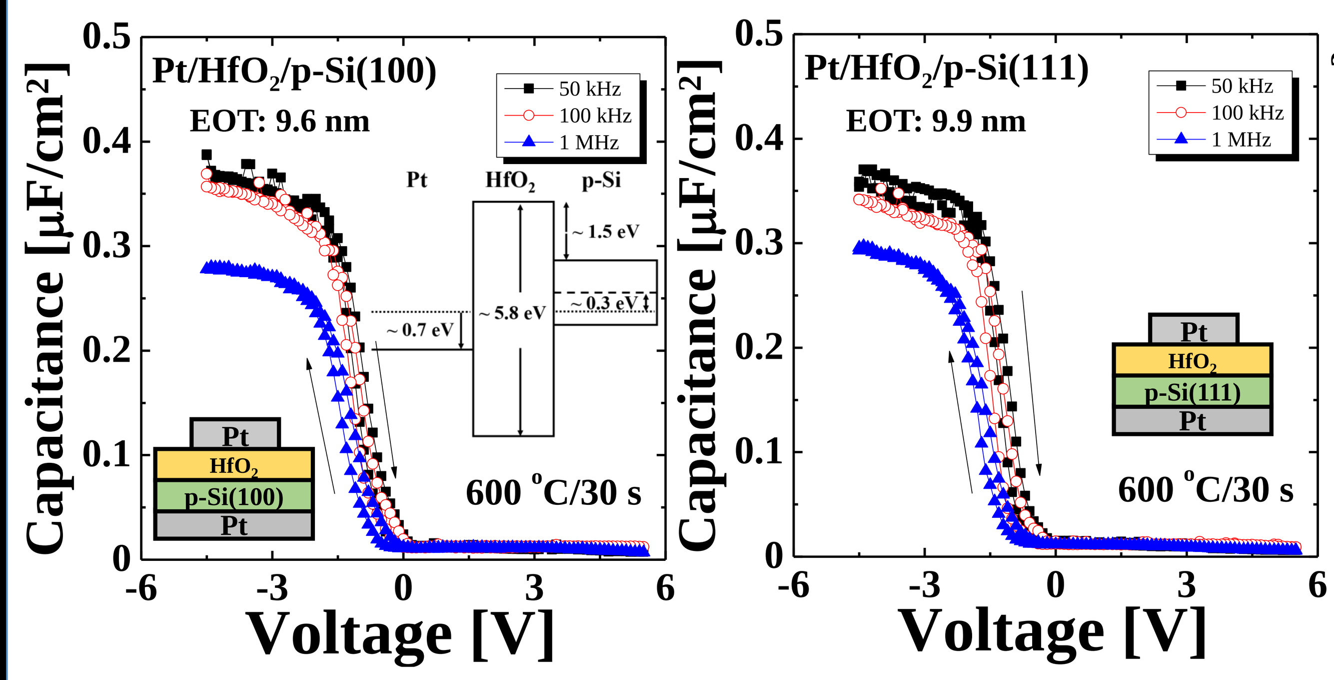


➢ **MW of 0.61 V and 0.67 V was obtained on p-Si(100) and p-Si(111) substrate.**
➢ **Hump in accumulation region was observed in the Al/HfO_2/Si(111) diode with low frequency.**

Memory Window

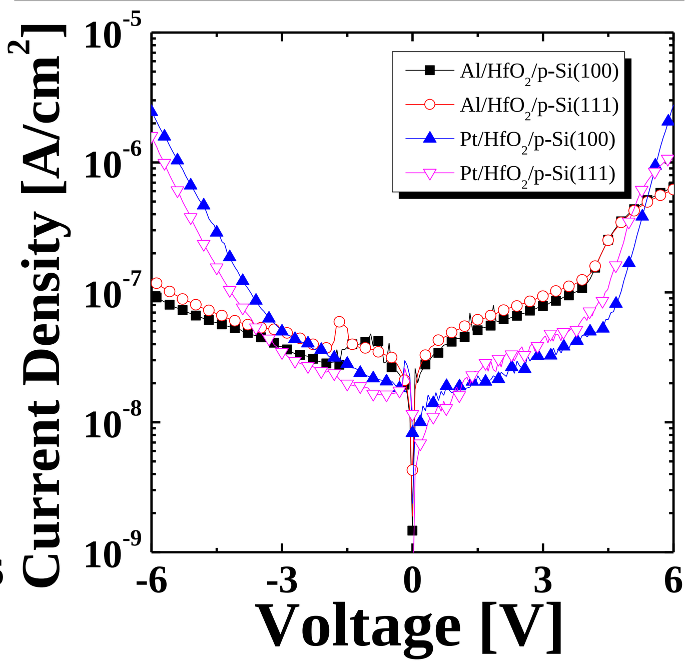


➢ **Regardless of gate electrode, the diode on Si(111) showed larger memory window than Si(100) substrate.**



➢ **Hump was not observed by replacing Al to Pt electrode.**
➢ **MW was decreased to 0.22 V and 0.26 V in case of the Pt/HfO_2/Si(100) and Pt/HfO_2/Si(111) diodes.**

J-V Characteristics



➢ **Breakdown voltage was increased with Al top electrode**

5. Conclusion

❖ **Si substrate orientation dependence of undoped ferroelectric HfO_2 was investigated for the first time.**

➢ Low temperature annealing at 600 °C induced ferroelectricity of HfO_2 directly deposited on Si substrates.
➢ Si(111) induced larger memory window than Si(100) probably because of improvement of the crystallinity.

Acknowledgement

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