Carbon / high-k Trench Capacitor for the 40nm DRAM Generation

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Outline of Presentation

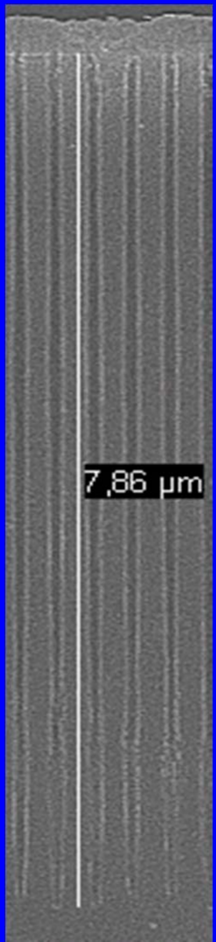
- Motivation
- Properties of Pyrolytic Carbon
- Integration for the DRAM Capacitor
- Electrical Results
- Summary

Carbon as new FEOL Material

- Alternative to metals like TiN and TaN
- Possible Applications:
  - Gate, Contacts, Interconnects,
  - Stress Layer
  - Sacrificial and Mold Material
  - …

→ **Capacitor Electrode in DRAM**

Trench Capacitor Road Map



Carbon Option

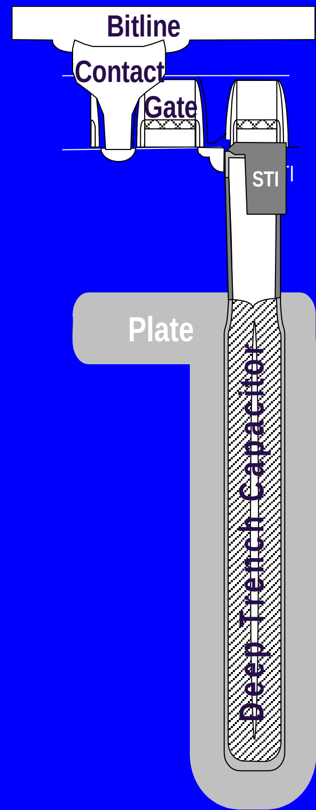
110nm	90nm	75nm	58nm	48nm
NO	NO	NON	NON / High-k	High-k
SIS	SIS	SIS	SIS / MIS	MIS / MIM

Trench Surface Enhancement

Trench Aspect Ratio

Metal

high-k



Shrink Generation →

SIS…Si Insulator Si / MIS…Metal Insulator Si / MIM…Metal Insulator Si

Benefits of Carbon

- High Conductivity
- High Temperature Stability
- Integration with NON and high-k viable
- Fills High Aspect Ratios
- Low Cost Pre-Cursors (C_xH_y)
- Easily structurable (O_2, H_2)

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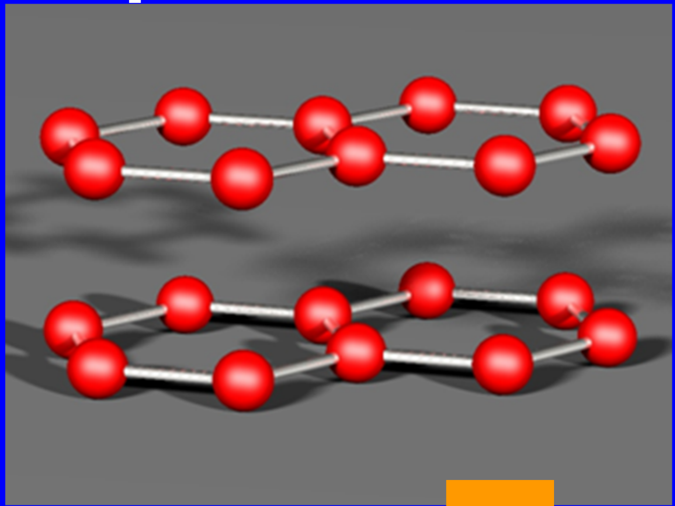
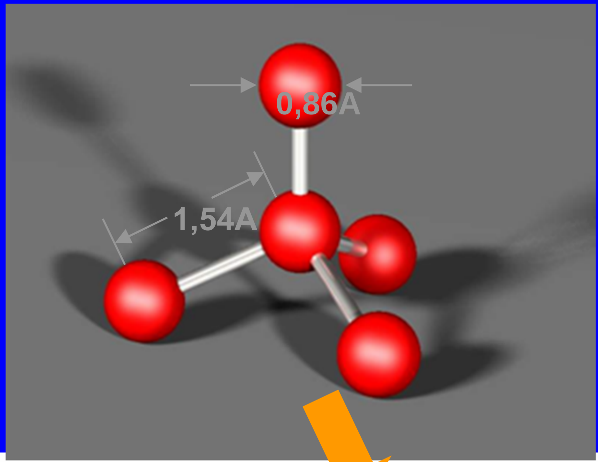
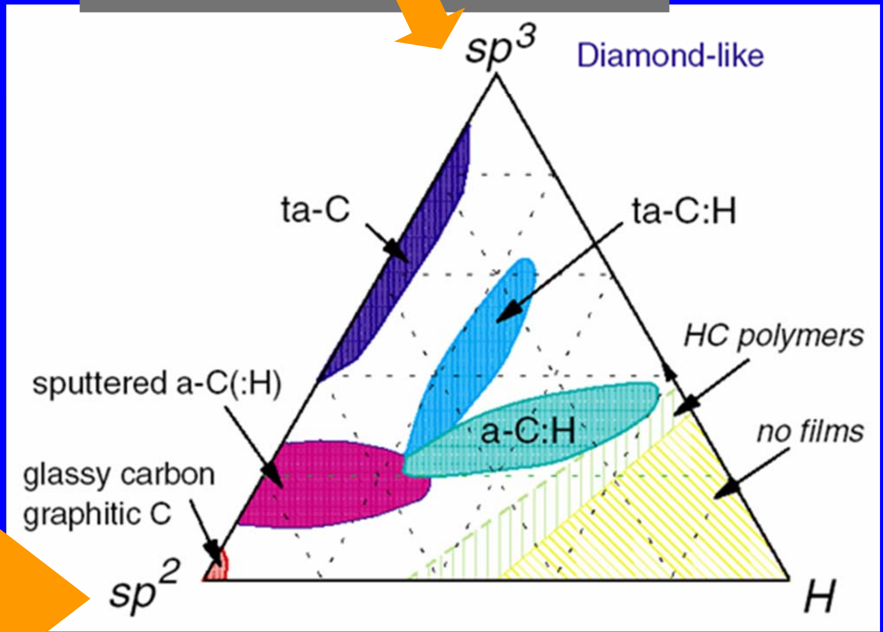
Structural

Graphene Sheets



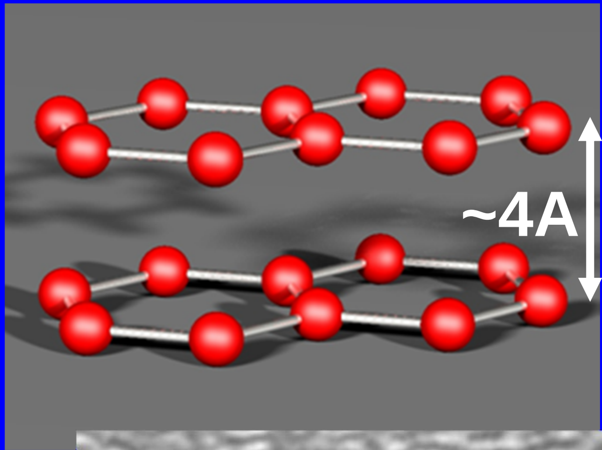
Diamond



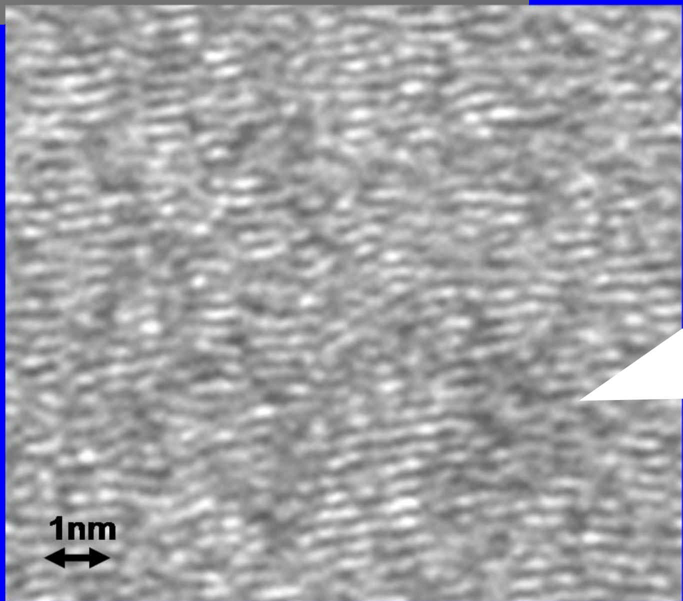


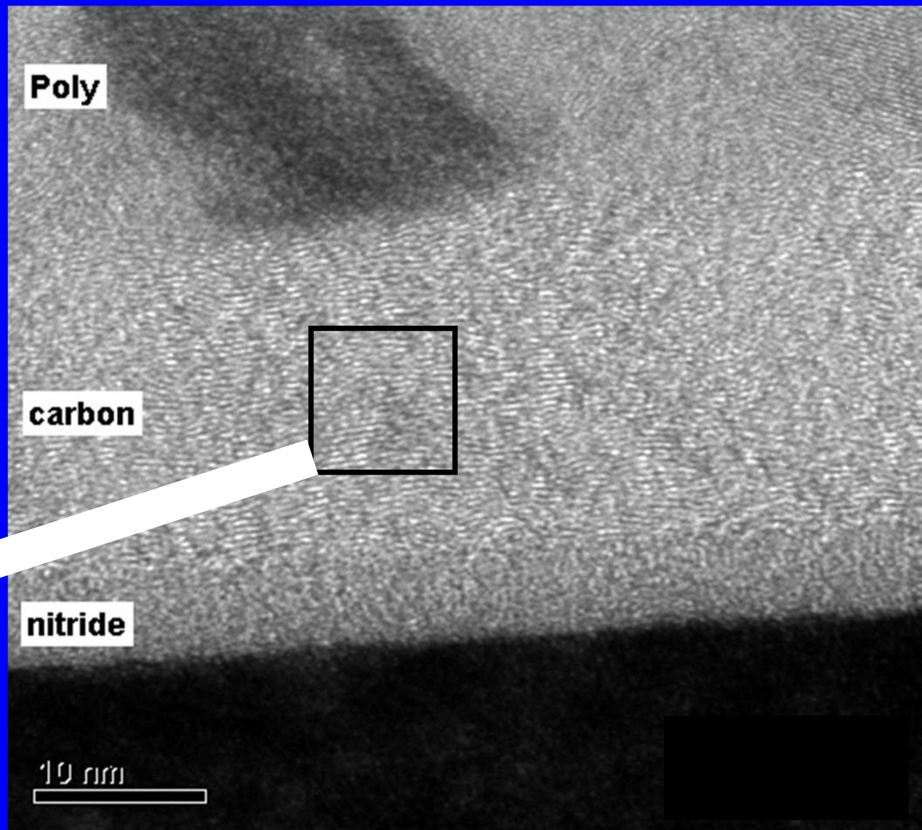
Desired material is the highly conductive Graphene

Structural



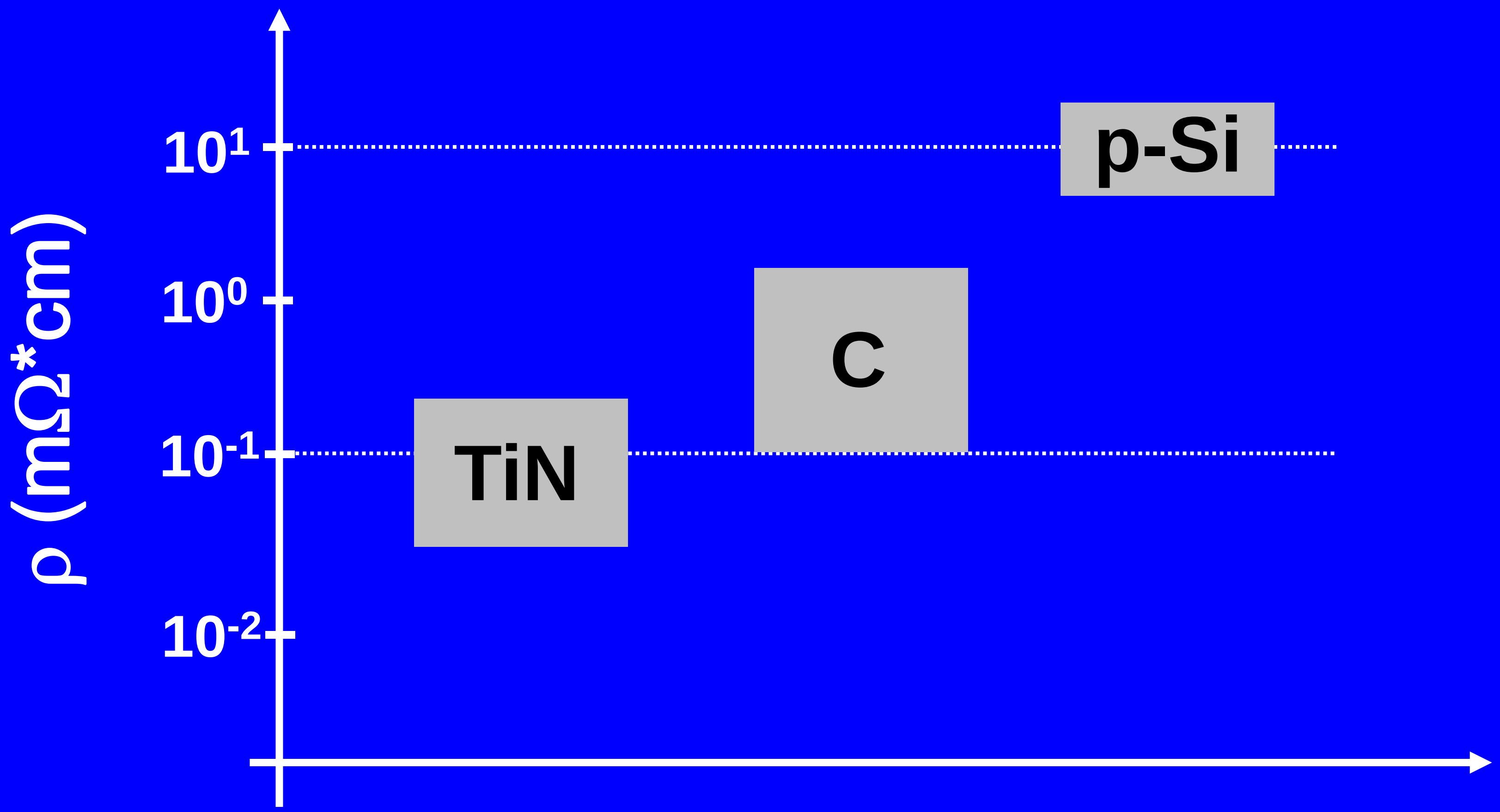
Crystallites with layered structure





High conductivity along the layers

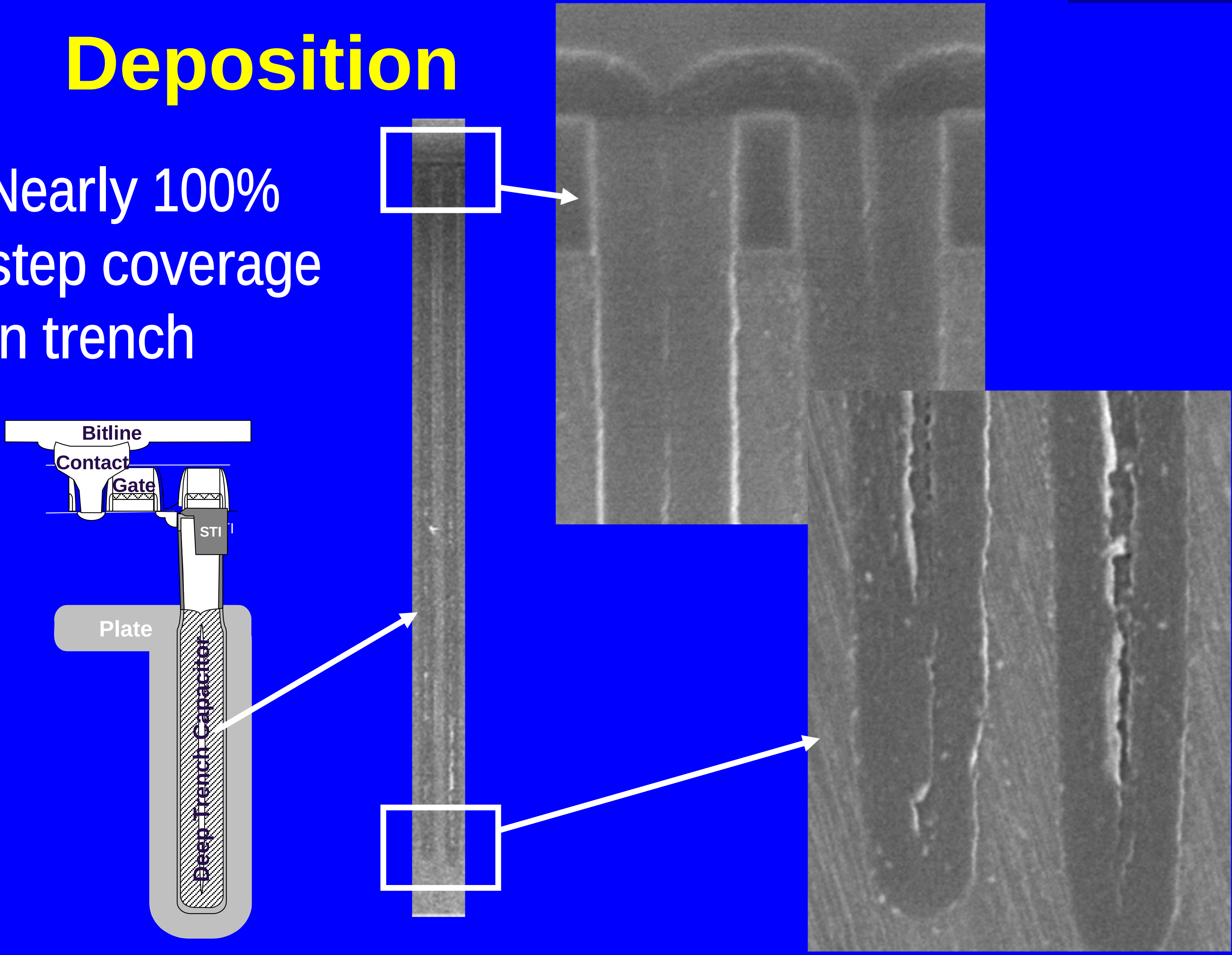
Electrical Resistivity



Carbon resistivity can be as low as that of TiN

Deposition

Nearly 100% step coverage in trench



Carbon vs. TiN

	Metal (TiN)	Carbon
ρ (μΩ*cm)	50-200	120-2000
Max. AR shown	1:120	1:430
Step coverage	>85%	>95%
Process	pulsed CVD	LPCVD / RTP
Precursor	$TiCl_4$	C_xH_y
Rate (nm/min)	1-2	0.2 - 120
Thermal stability	>1200°C	>1200°C

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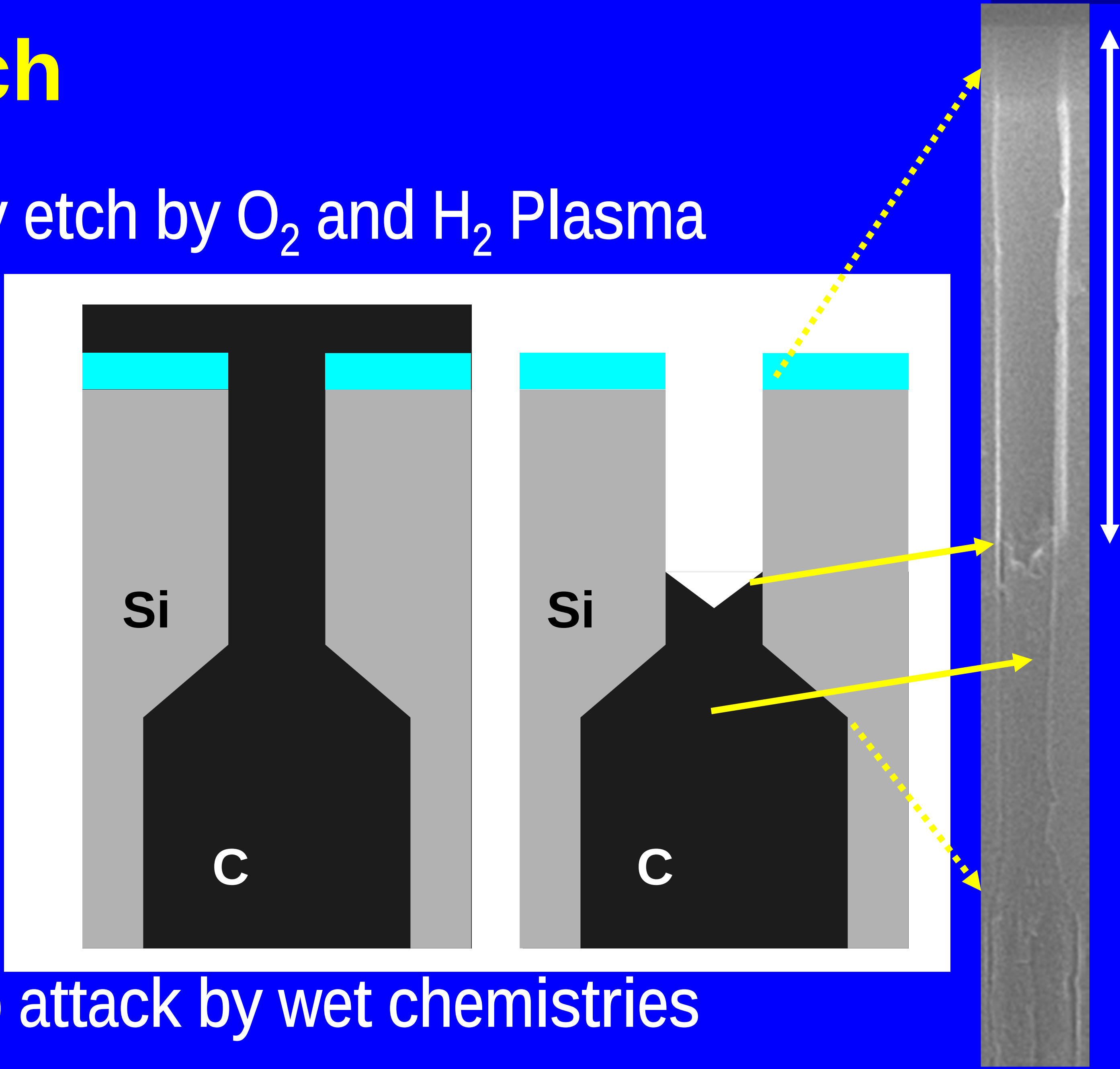
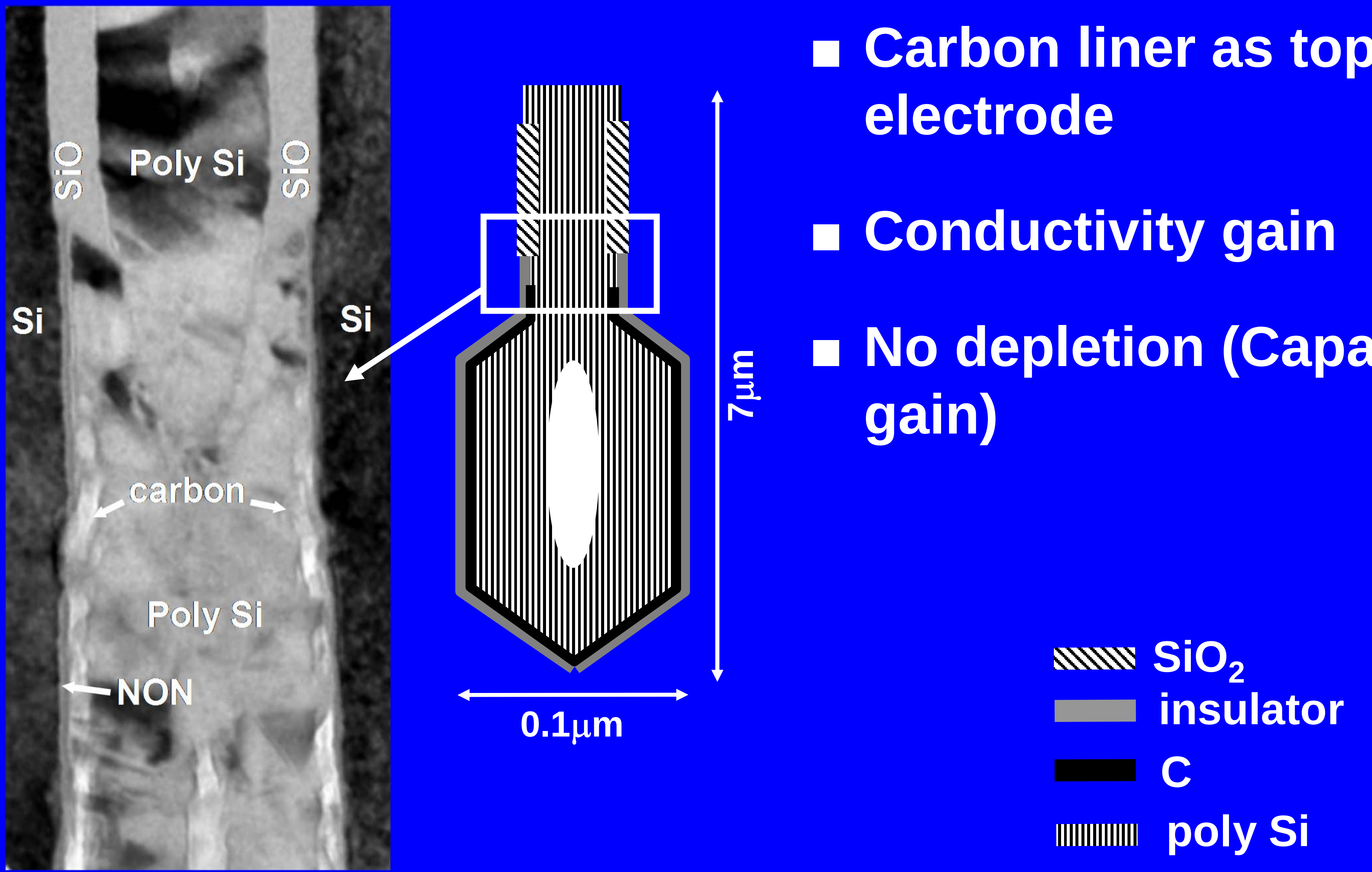
Etch

- Dry etch by O_2 and H_2 Plasma



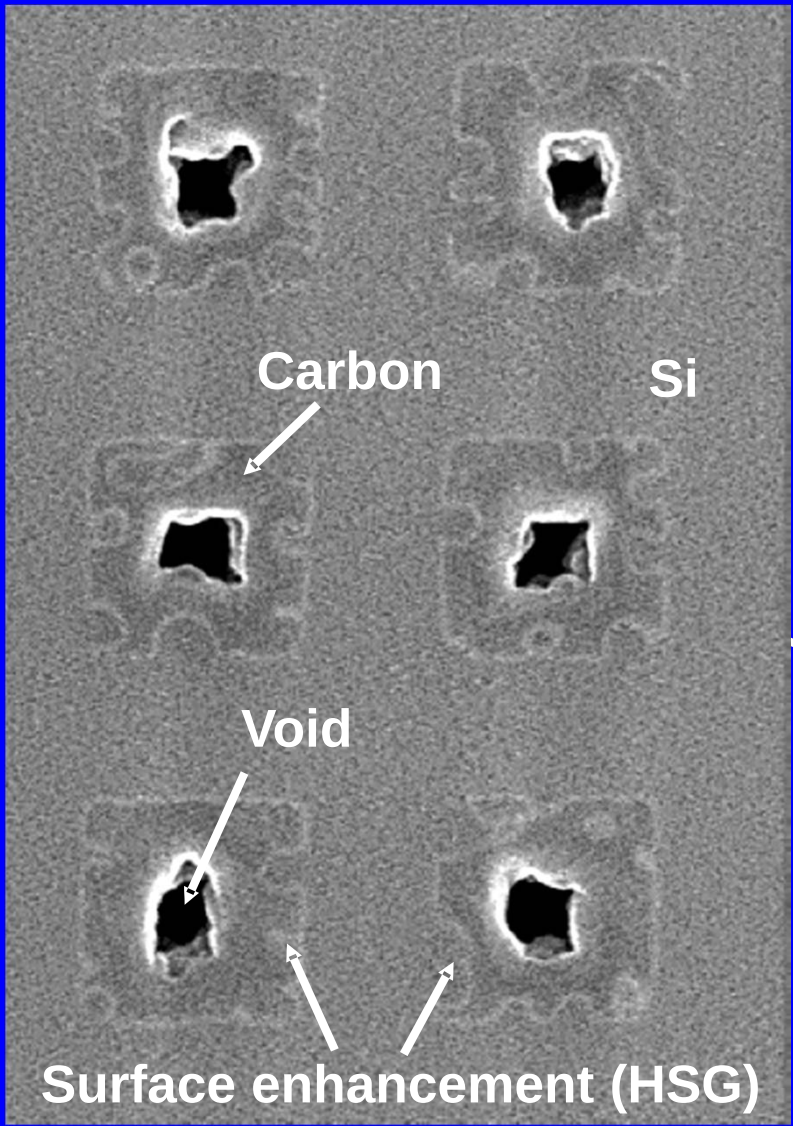
- No attack by wet chemistries

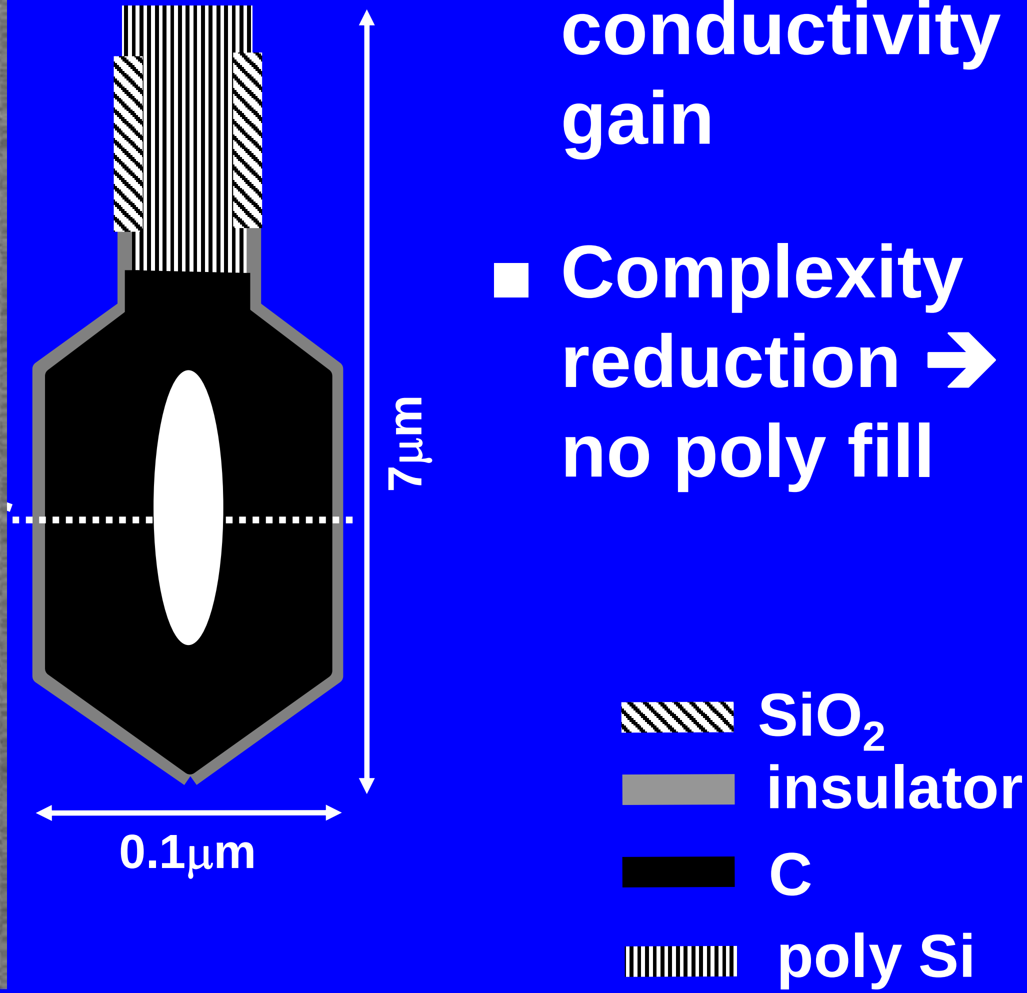
Liner Top Electrode



- Carbon liner as top electrode
- Conductivity gain
- No depletion (Capa gain)

Bulk Top Electrode

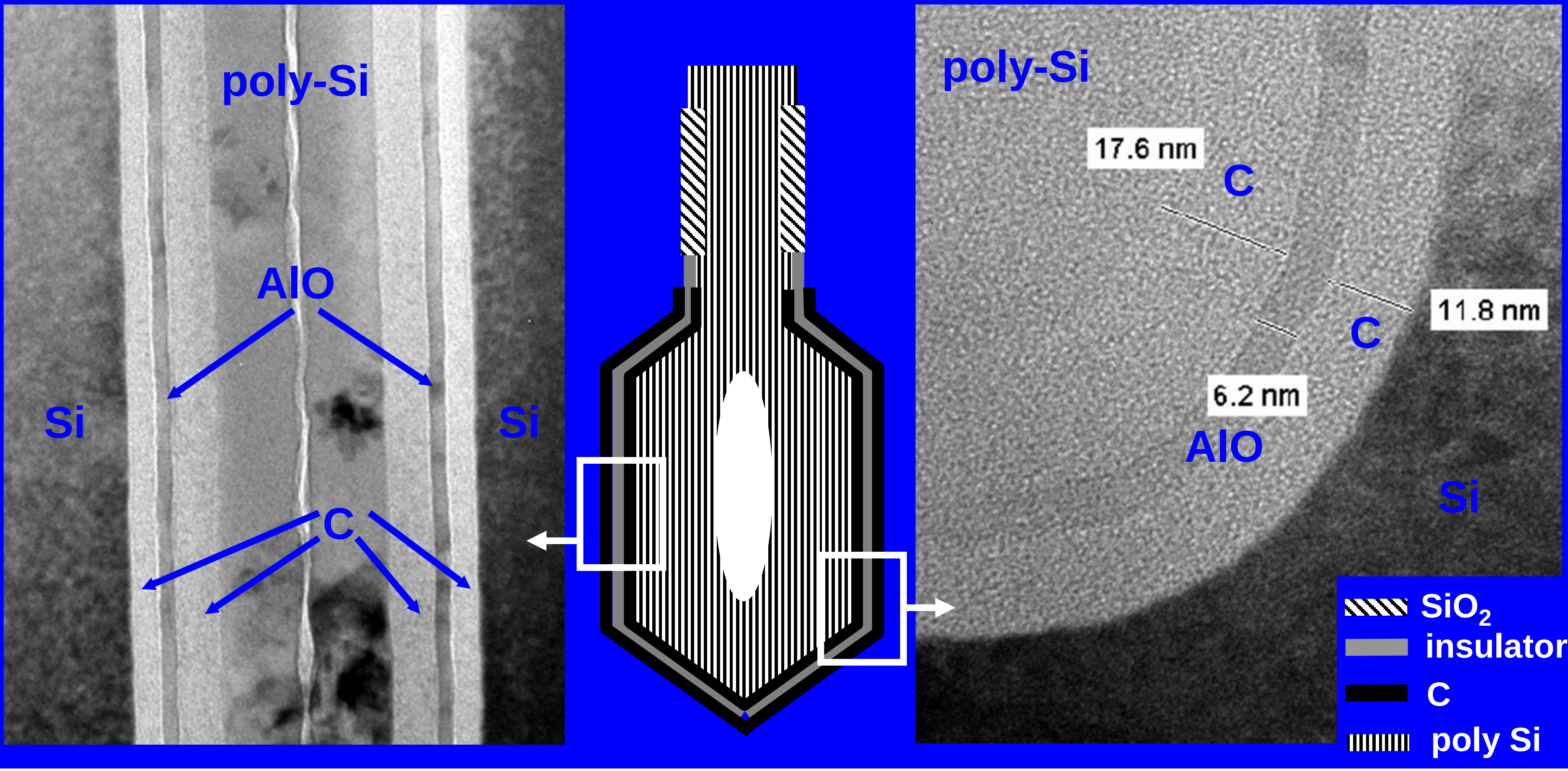




- Maximum conductivity gain
- Complexity reduction → no poly fill

MIM Application

- C liner top and bottom electrode with high-k
- No depletion for pos. and neg. polarity



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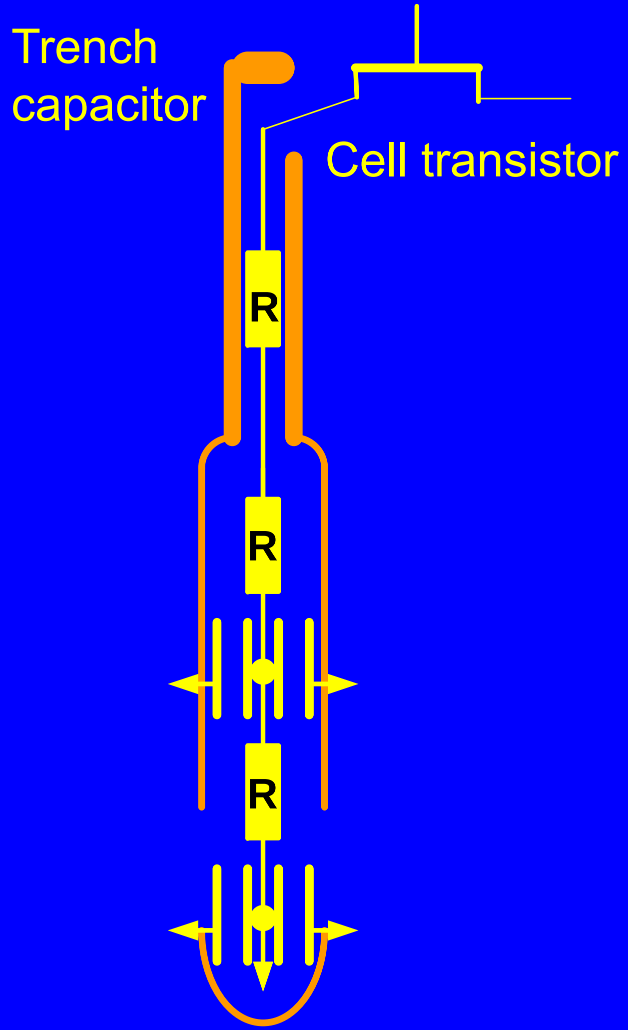
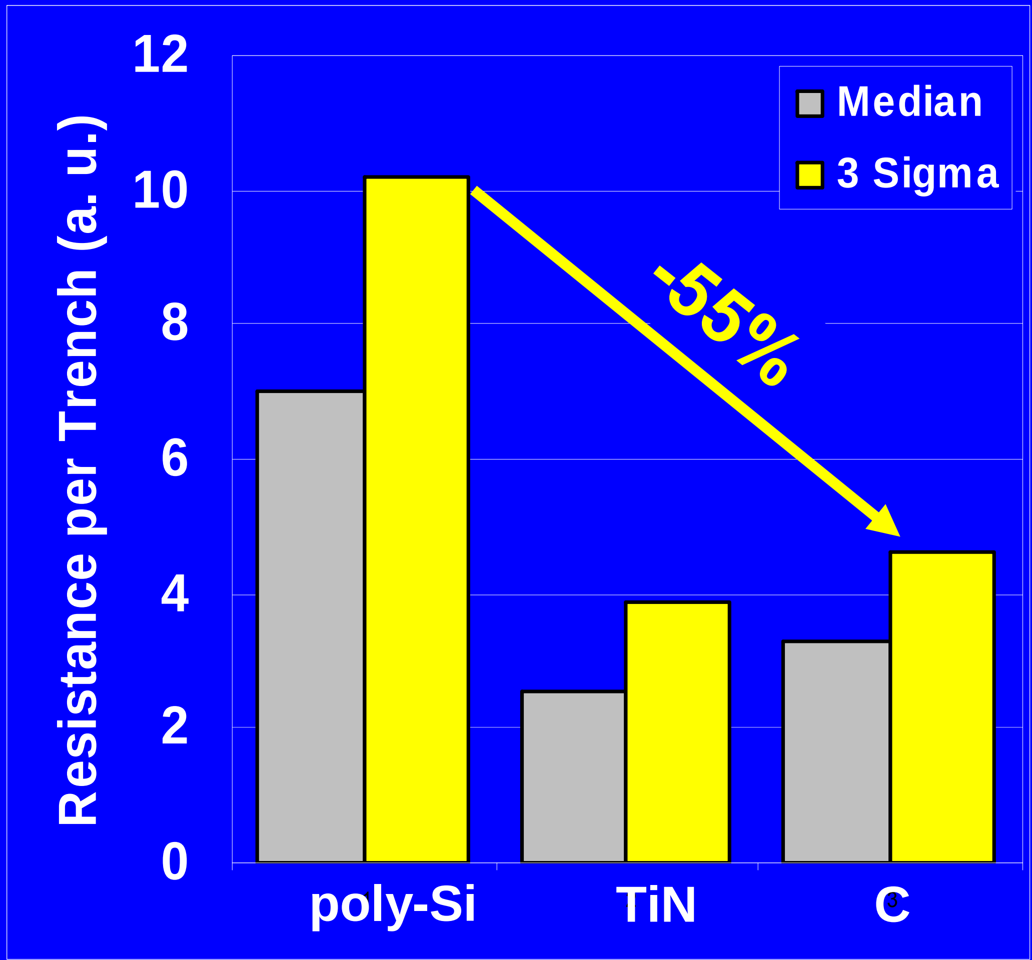
Electrical Resistivity

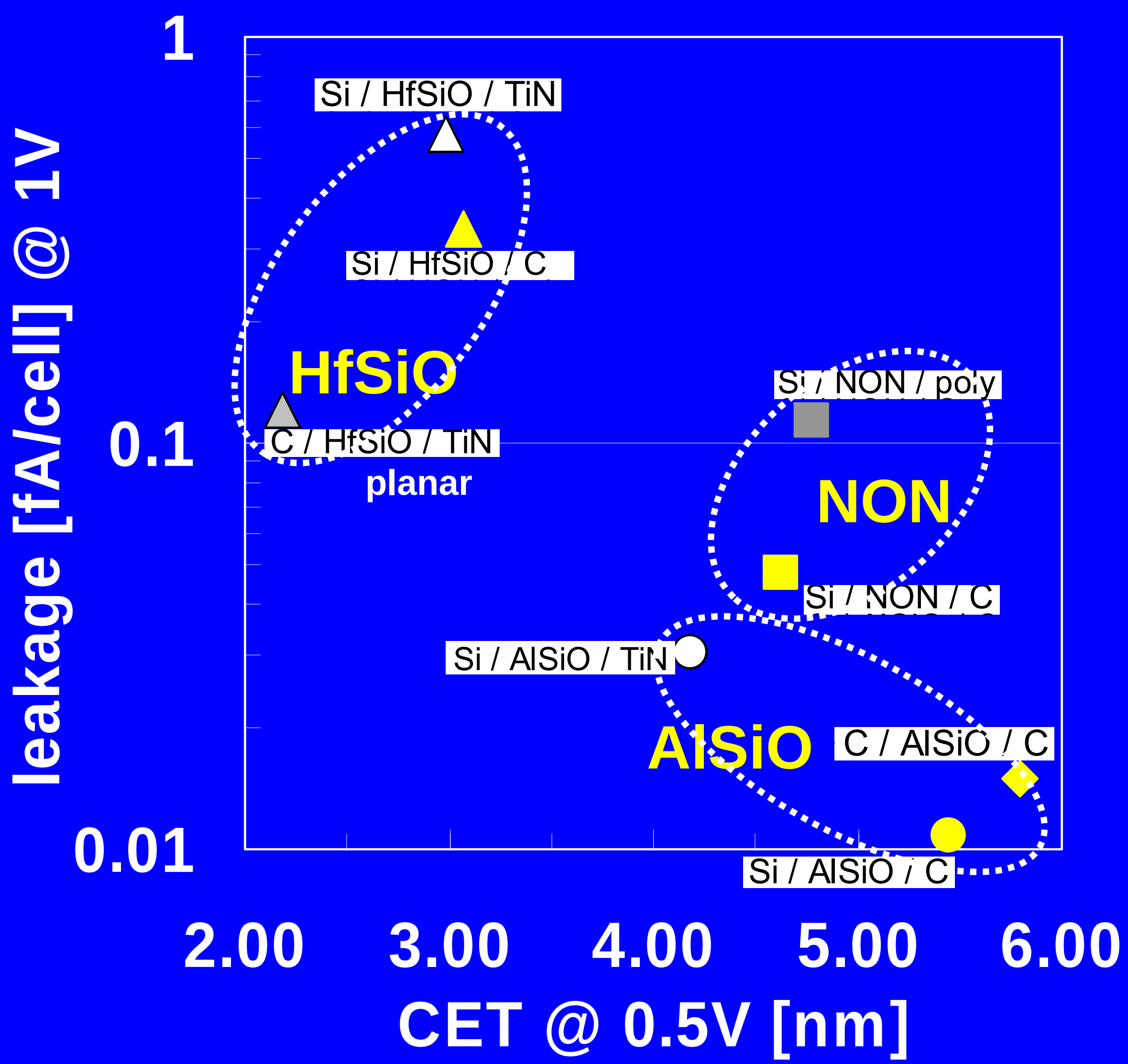




>50% resistance benefit with Carbon liner application

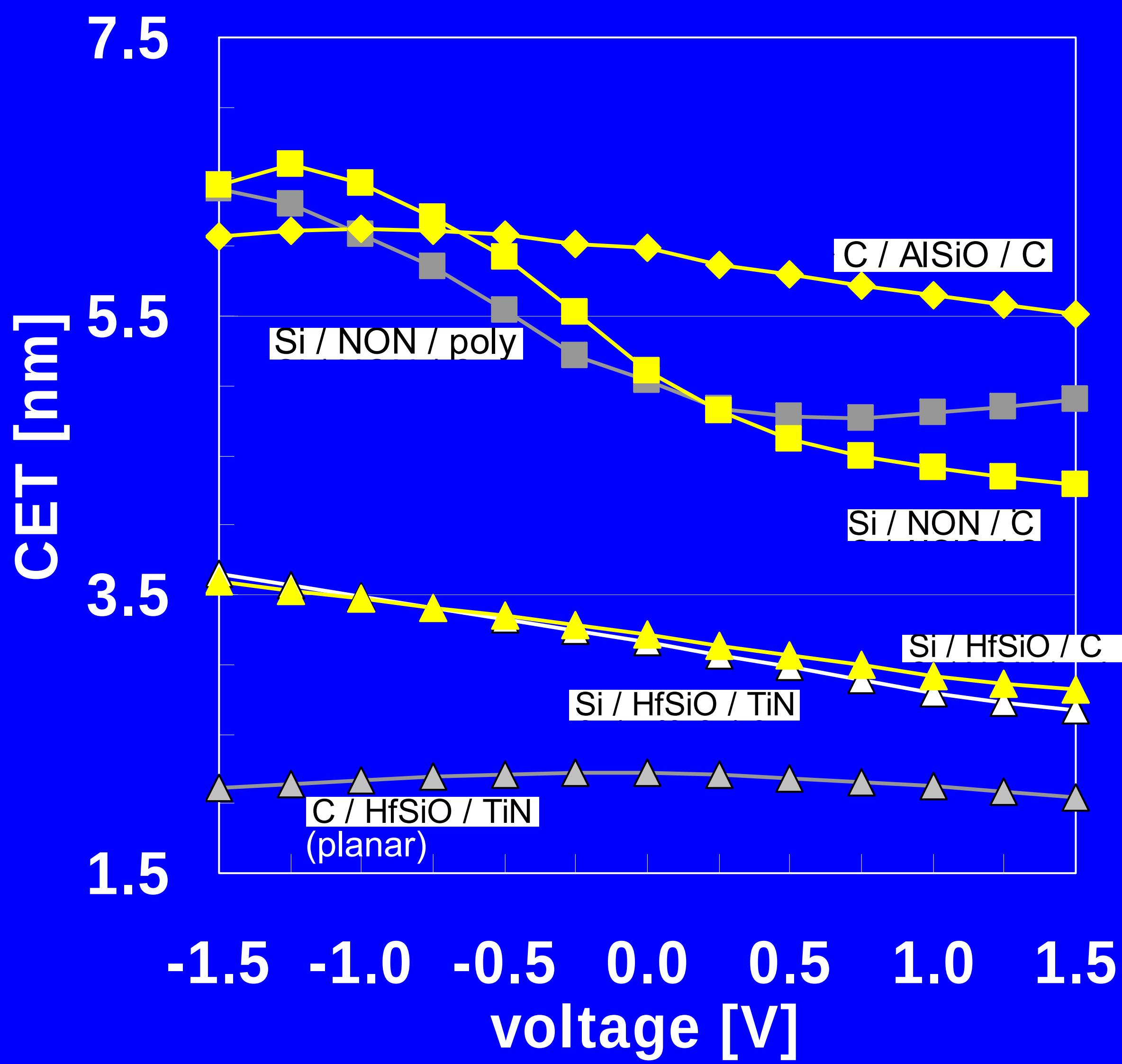
Electrical

CET Performance after 1050℃



- CET ~2 w/ planar C/HfSiO/TiN MIM structure
- CET ~3 with C trench top electrode
- NON/C has lower leakage than NON/Si

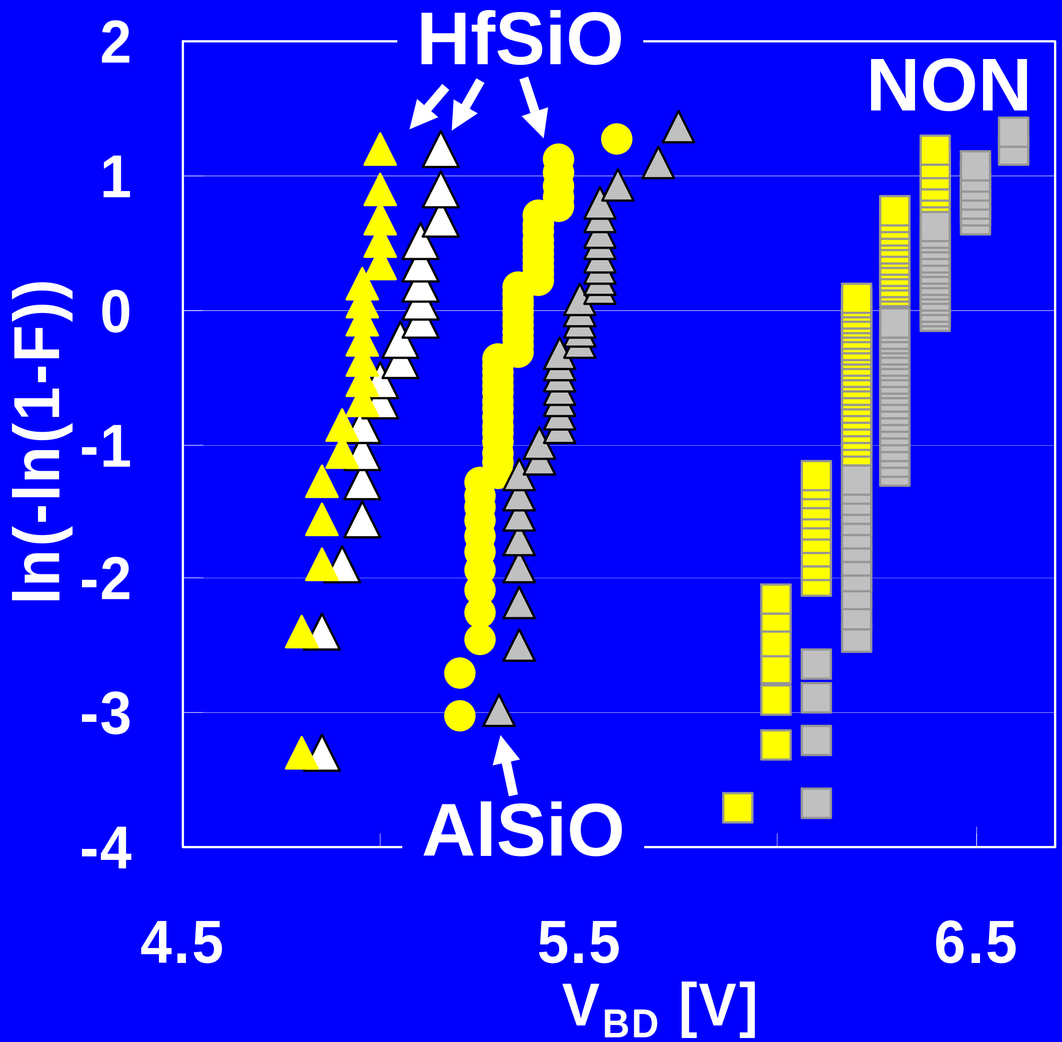
CET vs. Voltage



- Carbon MIS and MIM application is equivalent to TiN
- Carbon with NON shows capacitance benefit to poly-Si

Electrical

Breakdown Voltage - Reliability after 1050℃



- Carbon on NON has same V_{BD} as w/ poly
- High-k V_{BD} similar with C and TiN
- All options pass reliability

Summary

- Successfull integration of Carbon as a cost effective enabler of sub 60nm DRAM generations has been demonstrated
- Carbon is employed as metallic top and bottom electrode in the Deep Trench Capacitor
- Using standard NON or high-k dielectrics at thermal budgets exceeding 1000℃

Acknowledgements

- Thanks to all the co-workers at Qimonda Dresden and Munich who greatly contributed to the success of this work

- This work was supported by the Ministry of Education and Research of the Federal Republic of Germany (project number 01M3171A)

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Federal Ministry of Education and Research