6/9/05 PEUG

"The control of Electrode Impedance, Gas-Injection and Wafer-Temperature Radial Profile and their Effects on Poly-Gate Etching"

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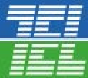

TOKYO ELECTRON

“The control of Electrode Impedance, Gas-Injection and Wafer-Temperature Radial Profile and their Effects on Poly-Gate Etching

1.Introduction (p 3 – 5)

- Dual Frequency CCP merit

2.Experimental (p 6 – 8)

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- Plasma Diagnostics

3.Results & Discussion (p 9 – 21)

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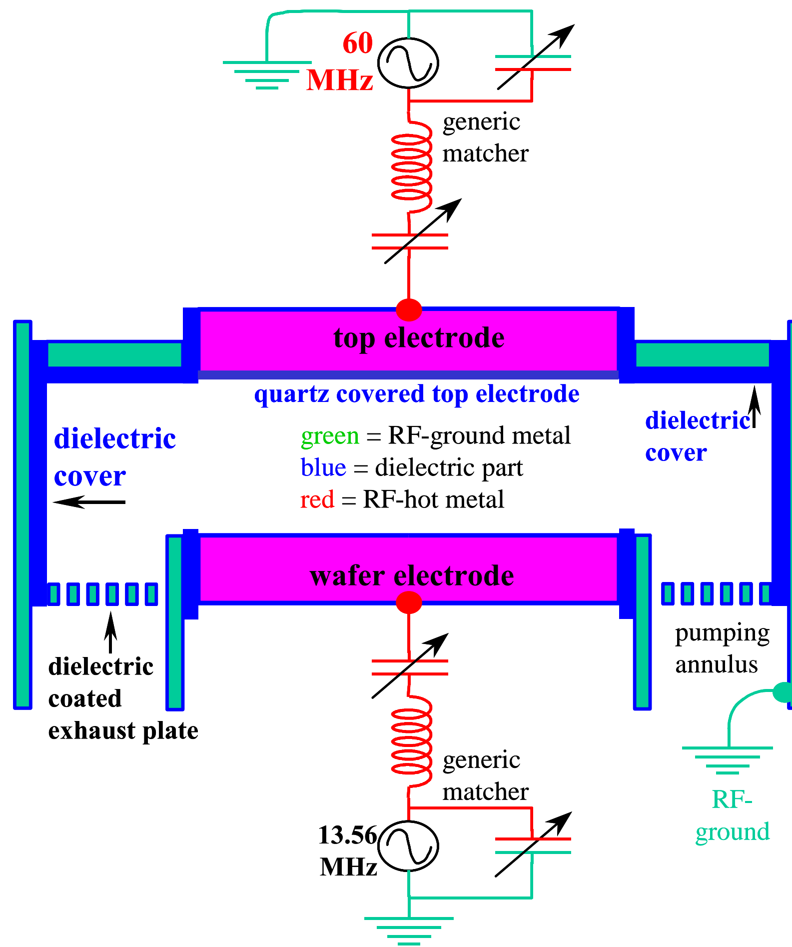
- 2-zone gas injection
- IC-Unit (Impedance Control of the wafer-electrode)
- full gate-stack etch results

4.Conclusion (p 22)

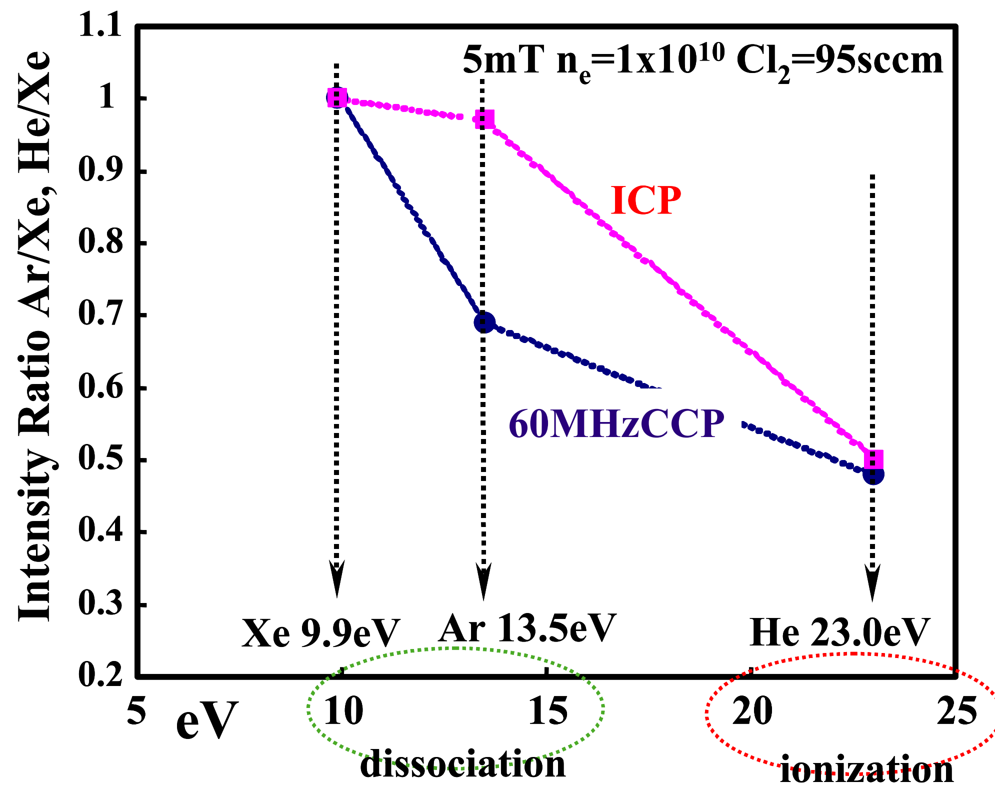
Dual Frequency Etcher with a VHF-ccp Plasma Source and a RF-bias wafer-electrode

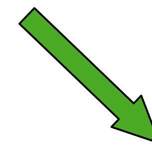


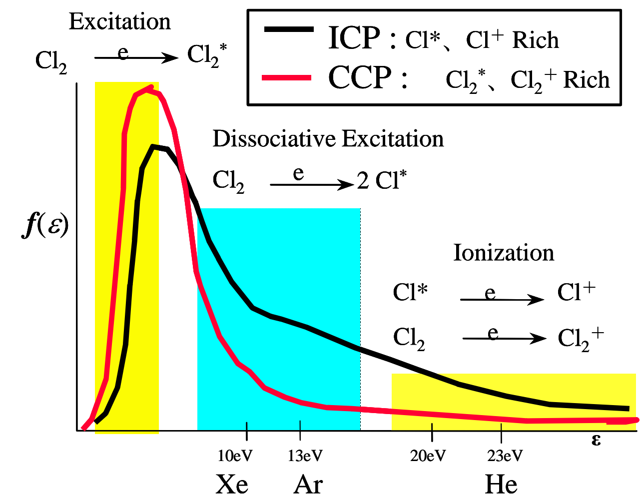
- **Simplicity and Reliability**
- **Wide pressure window**
- **Independent control of the plasma generation and Ion Energy**
- **Rich in molecular radicals**

60MHz CCP feature

Rich in molecular radicals



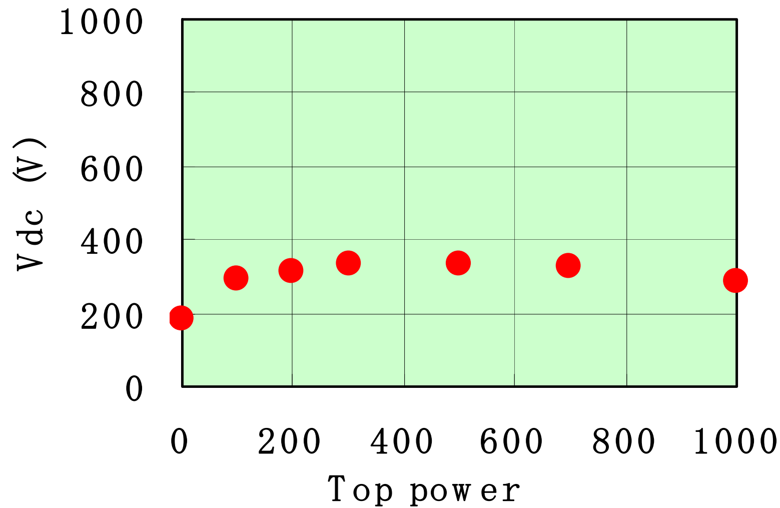


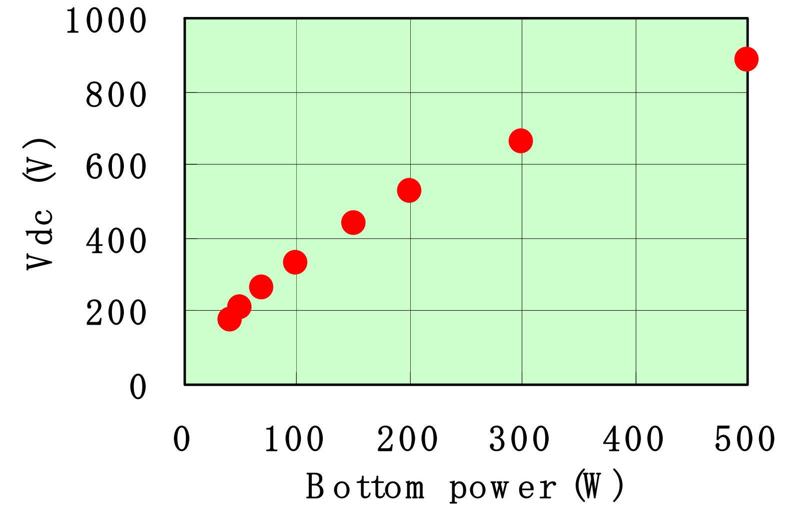


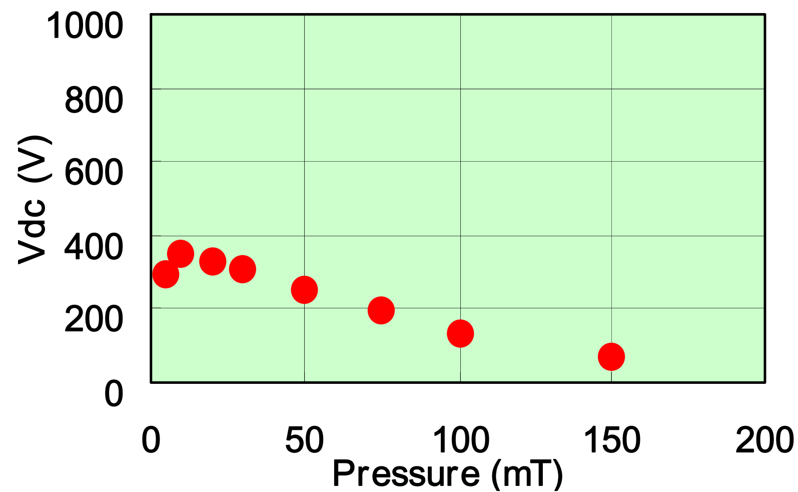
60MHz CCP source

Plasma diagnostic -Vdc on wafer Measurement

condition: 20mT, 120mm, 300/100W, HBｒ=200sccm, 1.5kV, 3/3Tr, T/B/W=80/60/60degC; Monitor Wafer: 8” bare-Si

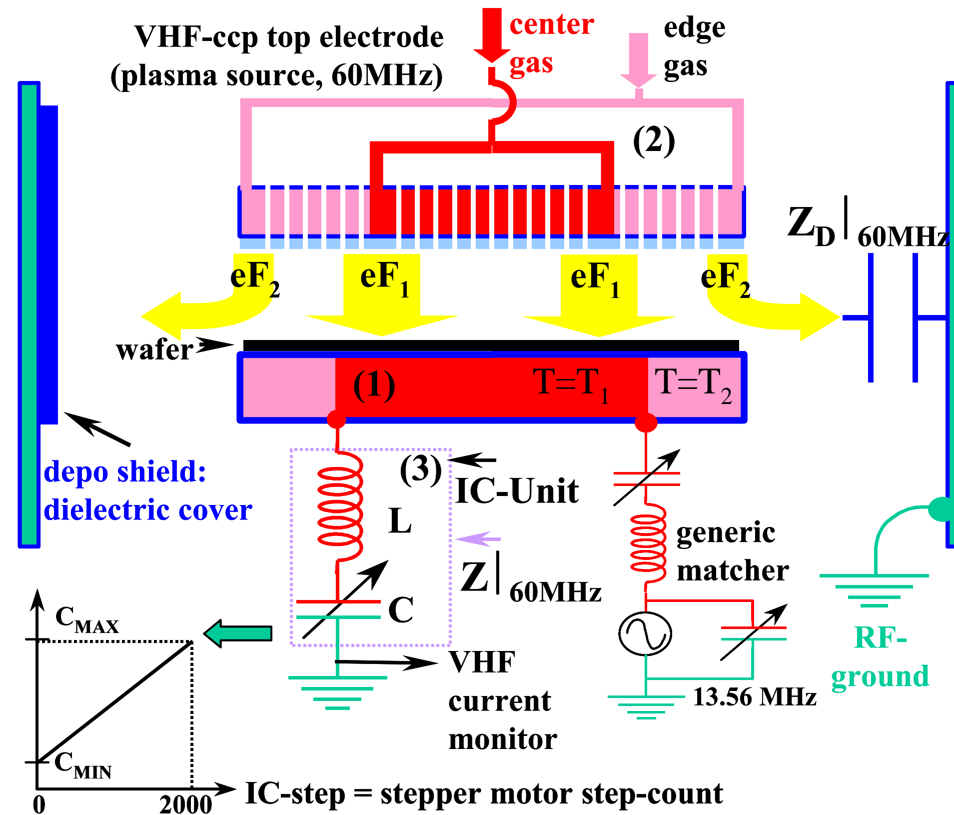






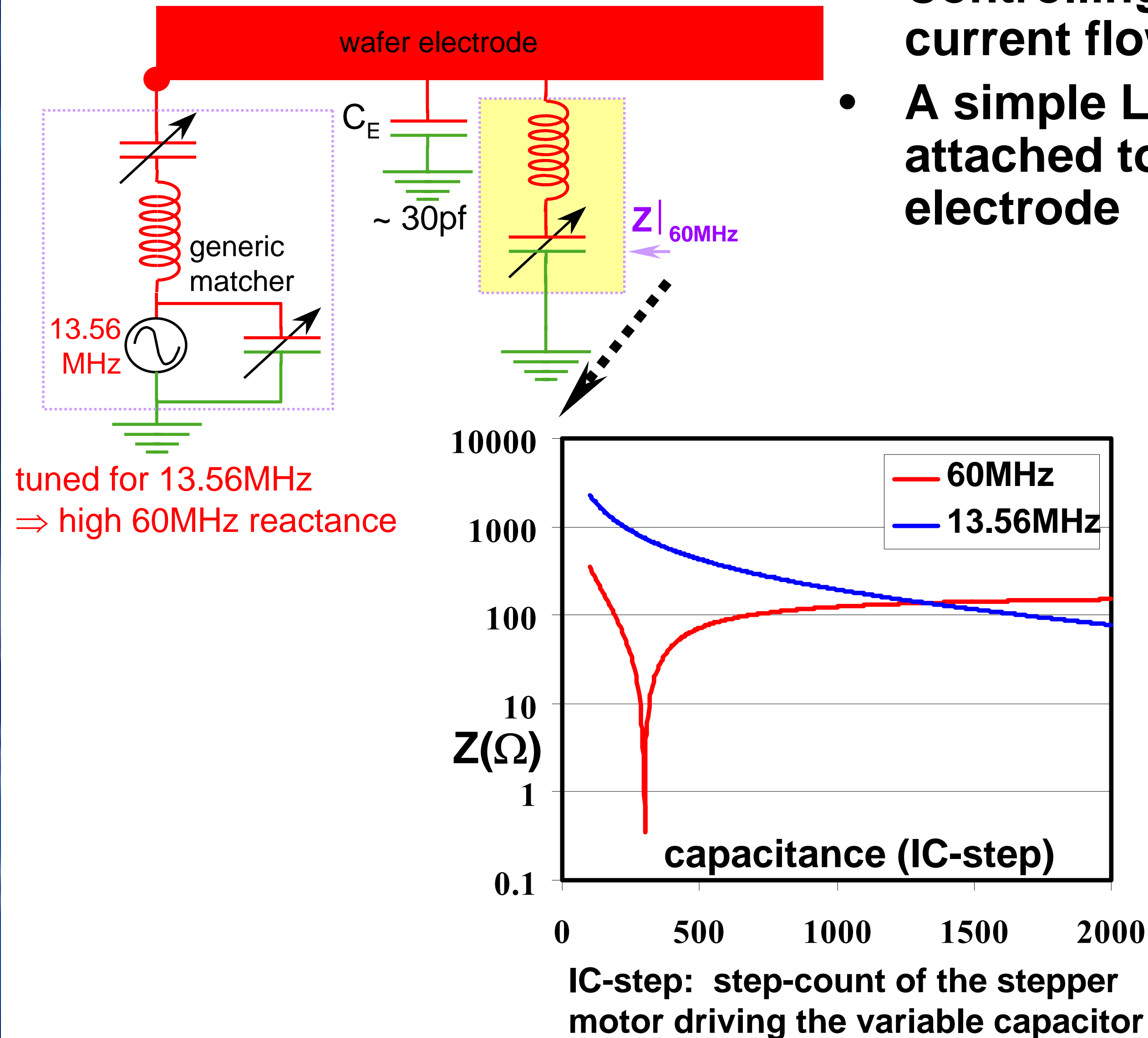
3 additional Control Knobs

1. 2-zone temperature wafer-electrode
2. 2-zone gas injection
3. IC-Unit, the Impedance Control of the wafer-electrode



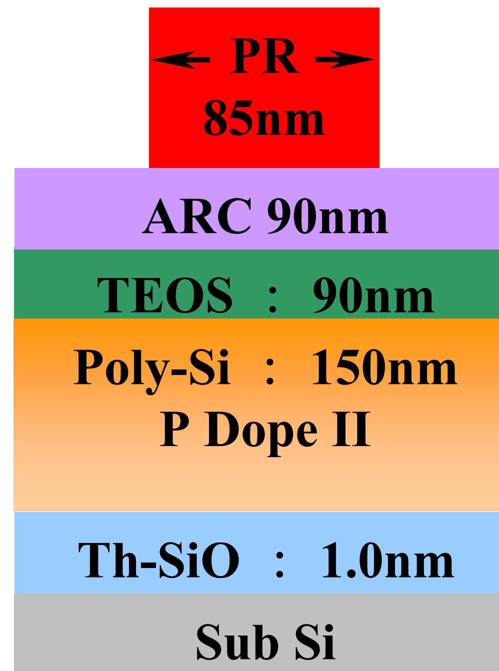
IC-Unit Functionality

- **Controlling the 60MHz current flow in the plasma**
- **A simple LC circuit attached to the wafer electrode**



IC-step: step-count of the stepper motor driving the variable capacitor

Wafer gate-stack structure used for the experiment



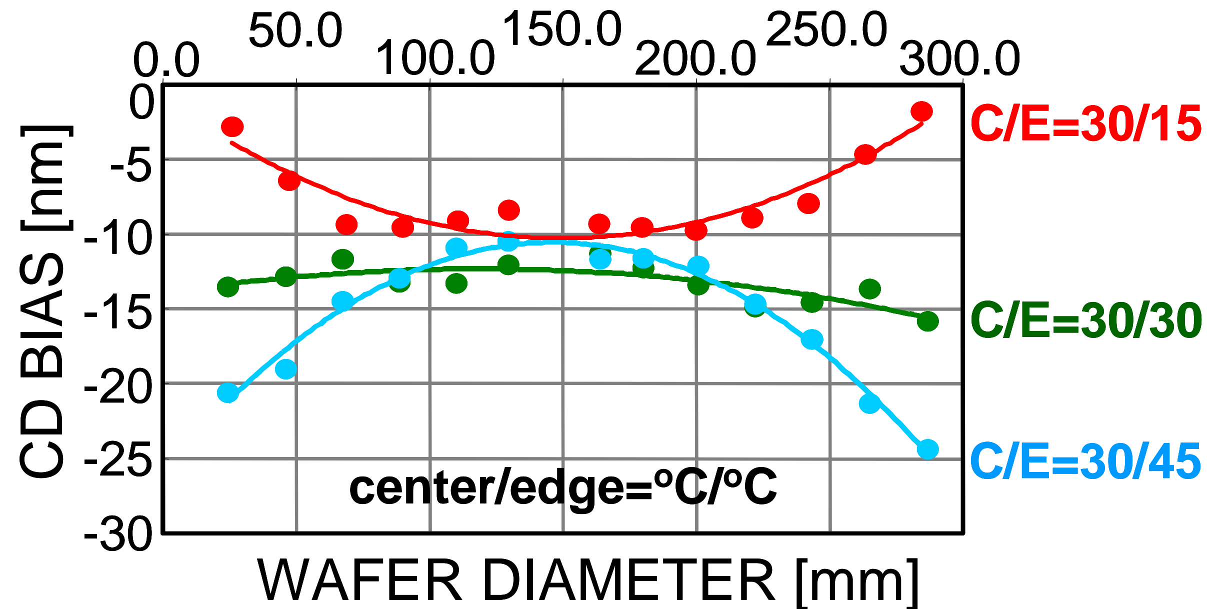
Main effect summary

plasma ⟵ | ⟶ etch result

response / factor	$n_e(r)$	neutral dist.	radical dist.	vertical ER unif.	horizontal ER unif.	CD-bias unif.
2-zone temperature wafer-electrode	L	L	H	M	H	H
2-zone gas injection	M	L	L	M	L	L
Impedance Control Unit	H	L	M	H	L	M
traditional factors: P, Q, RFs, etc.	--	--	--	--	--	--

2-zone temperature effect on BARC+TEOS combination

- **A significant change in the CD uniformity is obtained**
- **C/E=30/30 case is a reasonable condition in this recipe**



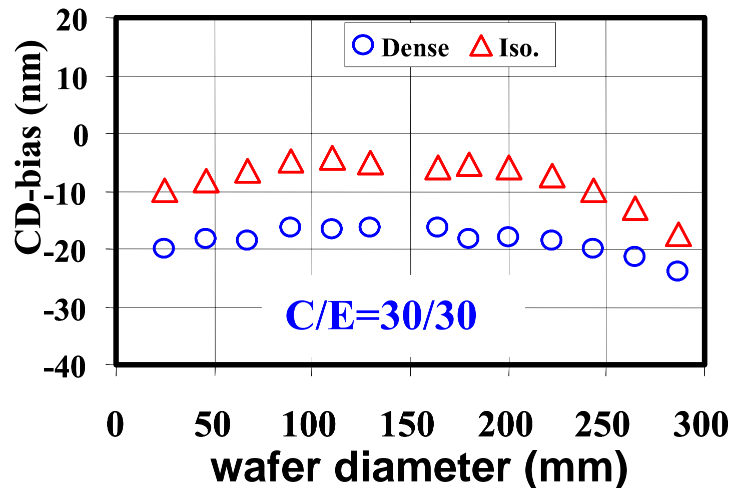
CF_4+O_2 chemistry for BARC; CF_4+CHF_3 chemistry for TEOS

C/E temp fine-tune

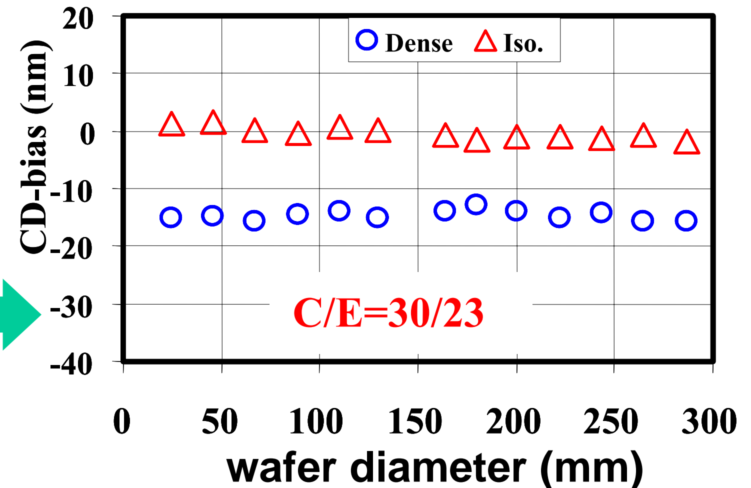
- **BARC+TEOS+n+-poly**

$CF_4+O_2 \Rightarrow$ BARC; $CF_4+CHF_3 \Rightarrow$ TEOS; fluorocarbon $\Rightarrow n^+$-poly

C/E=30/30 (29 points CDSEM)
Ave Iso CD-bias = –8.2nm; 3σ=10.7nm
Ave Den CD-bias = –18.9nm; 3σ=5.8nm

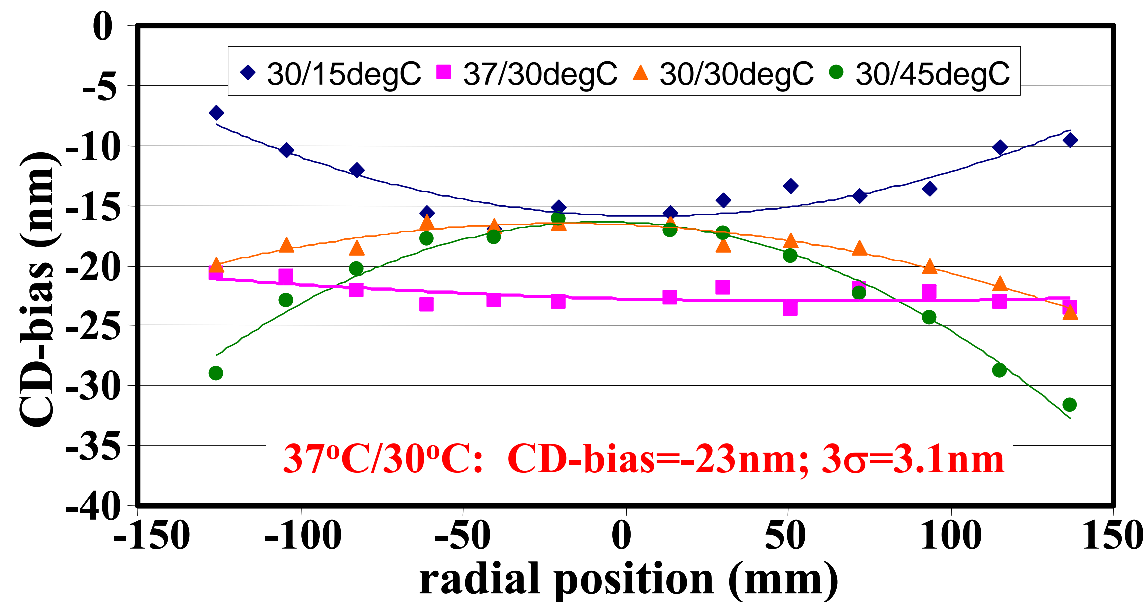


C/E=30/23 (29 points CDSEM)
Ave Iso CD-bias = –0.5nm; 3σ=2.9nm
Ave Den CD-bias = –14.8nm; 3σ=2.9nm



2 zone temperature wafer-electrode can increase CD-bias uniformly

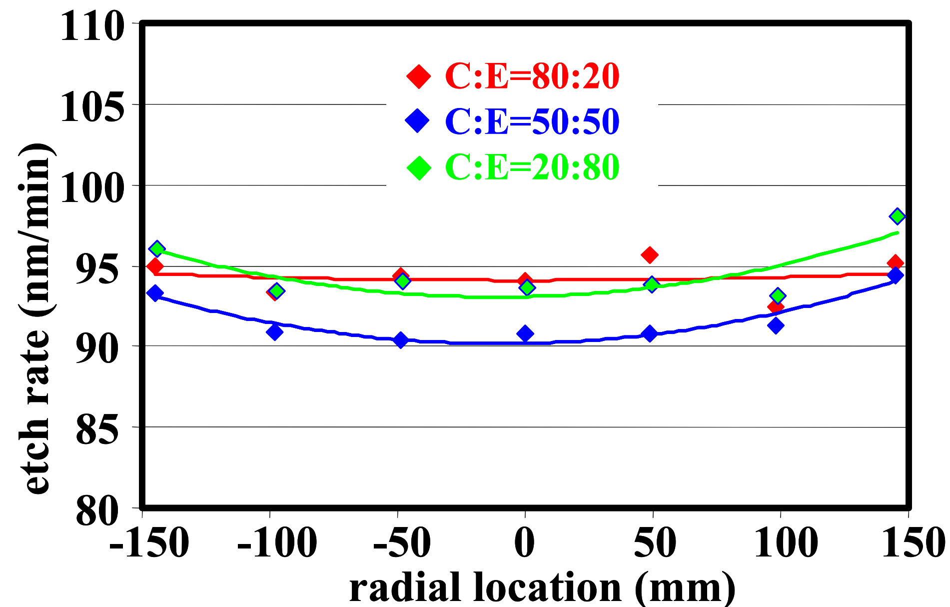
30oC/23oC → 37oC/30oC: increases CD-bias uniformly



BARC+TEOS+n+-poly CD-bias=-23nm with 3σ=3.1nm

2-zone gas effect on BARC etch rate

- **2-zone gas can improve BARC E.R. uniformity**



C:E=80:20 gives the best etch-rate uniformity of BARC

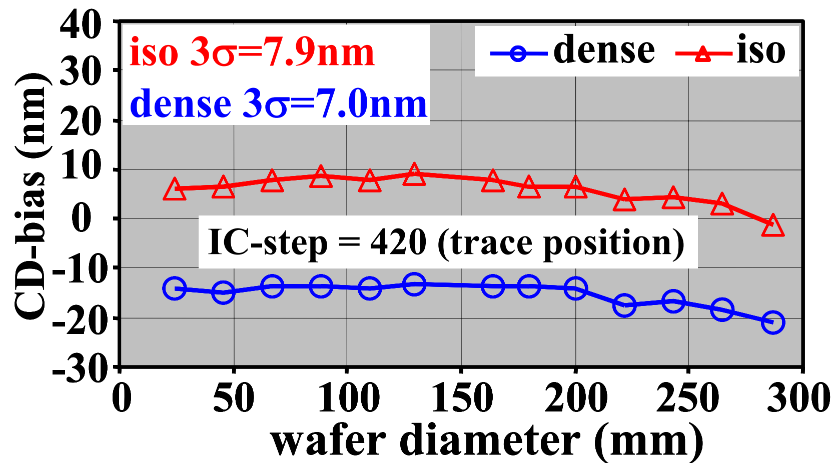
note: 2-zone gas has weak effect on CD uniformity due to large (e.g., 170mm) electrode-gap

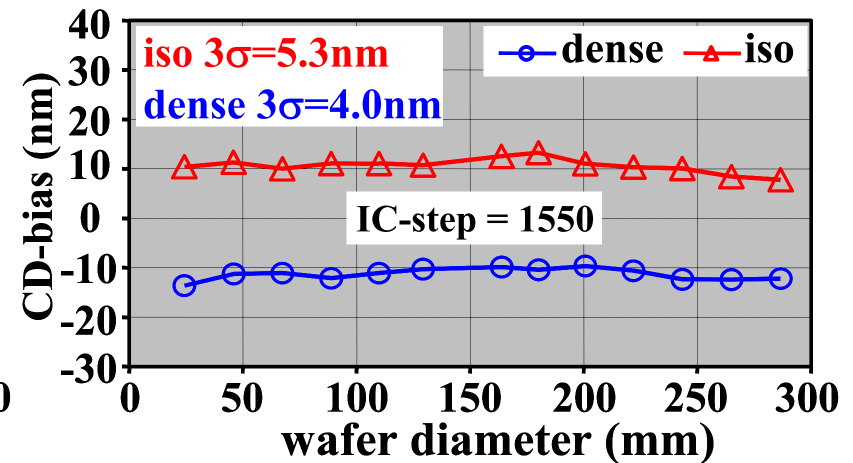
IC-unit effect on CD uniformity

- **TEOS case has a slightly stronger correction-effect than the n+-poly case**

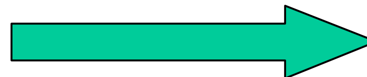
TEOS alone:

BARC is etched at the trace condition





Effect of IC step alone

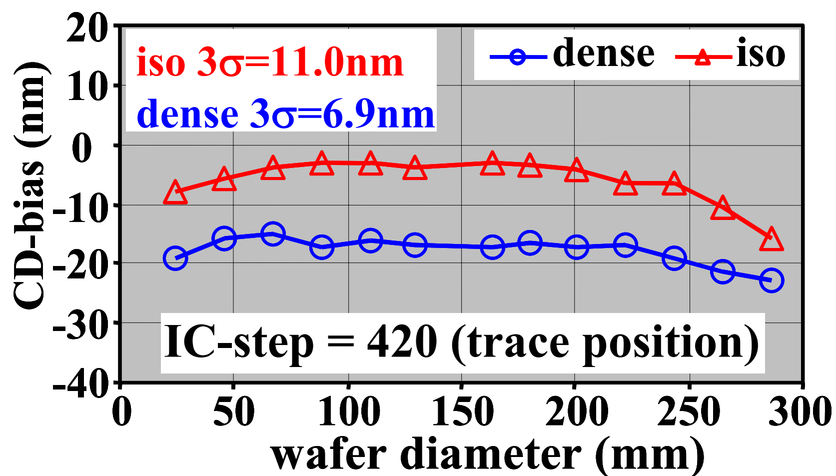


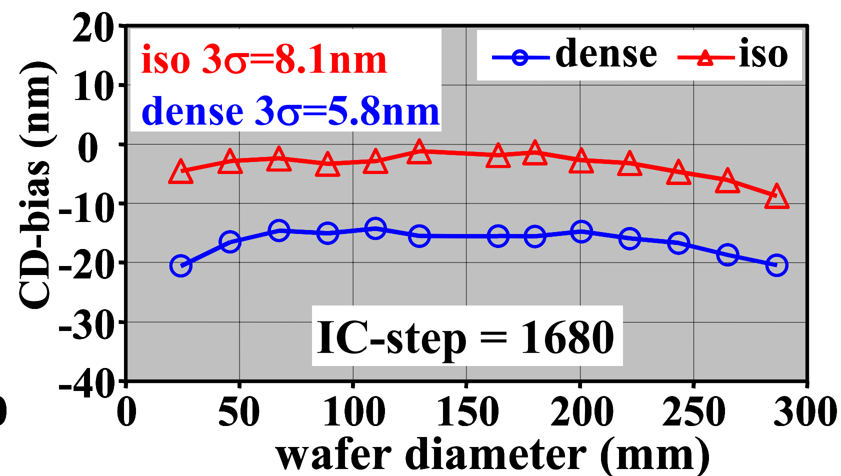
IC-unit effect on CD uniformity

- **TEOS case has a slightly stronger correction-effect than the n+-poly case**

n^+-poly alone:

BARC + TEOS are etched at their trace conditions



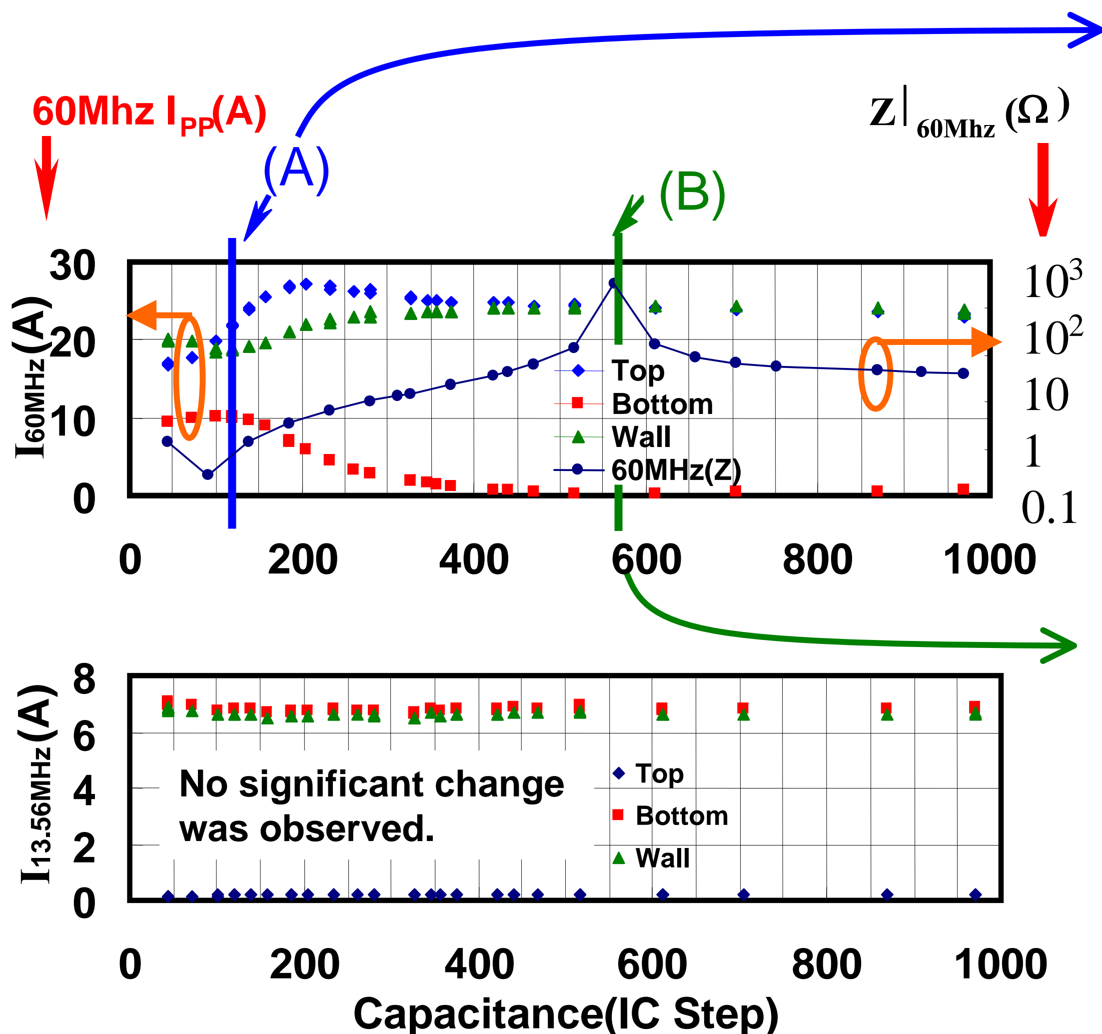


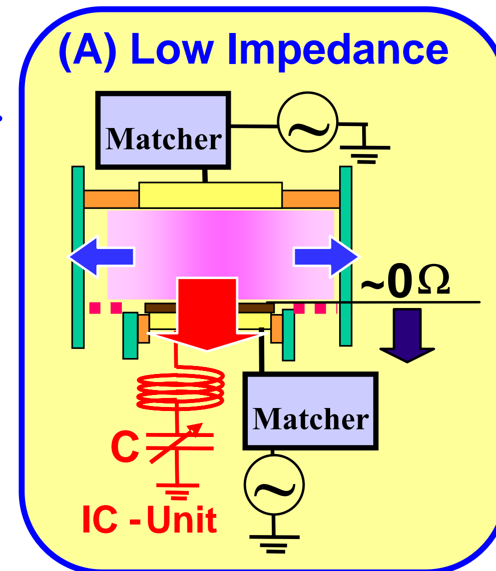
Effect of IC step alone

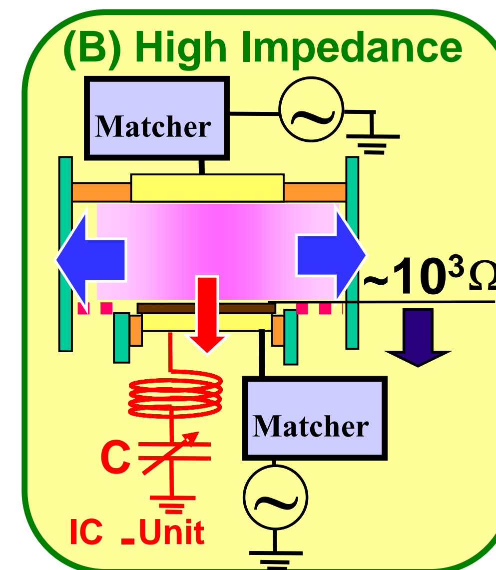
IC-Unit electrical characterization

- IC-Unit controls the 60MHz current flow in the plasma
- IC-Unit do not interfere with the 13.56MHz Bias

(low-pressure HBr-based chemistry – ME Case)



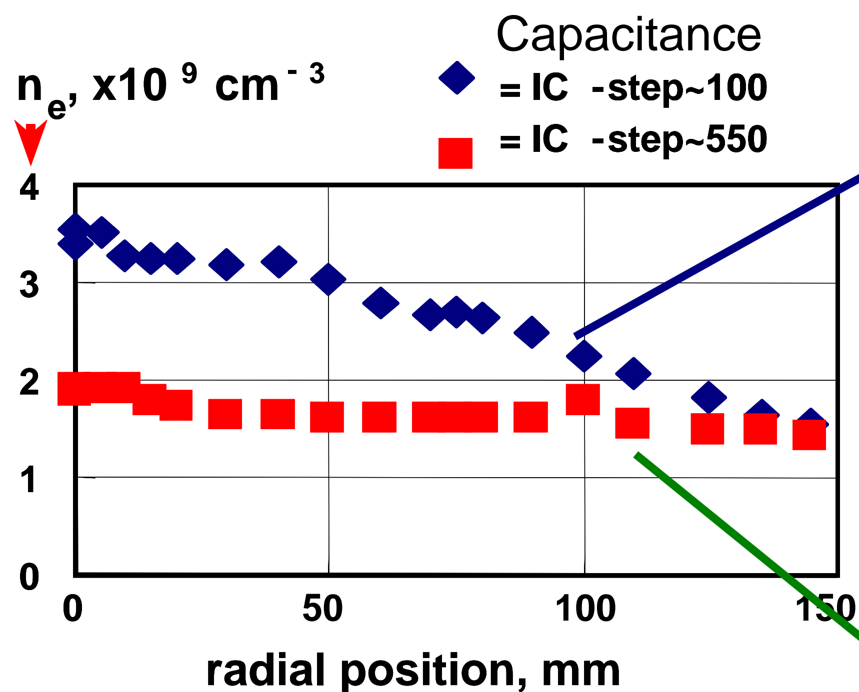


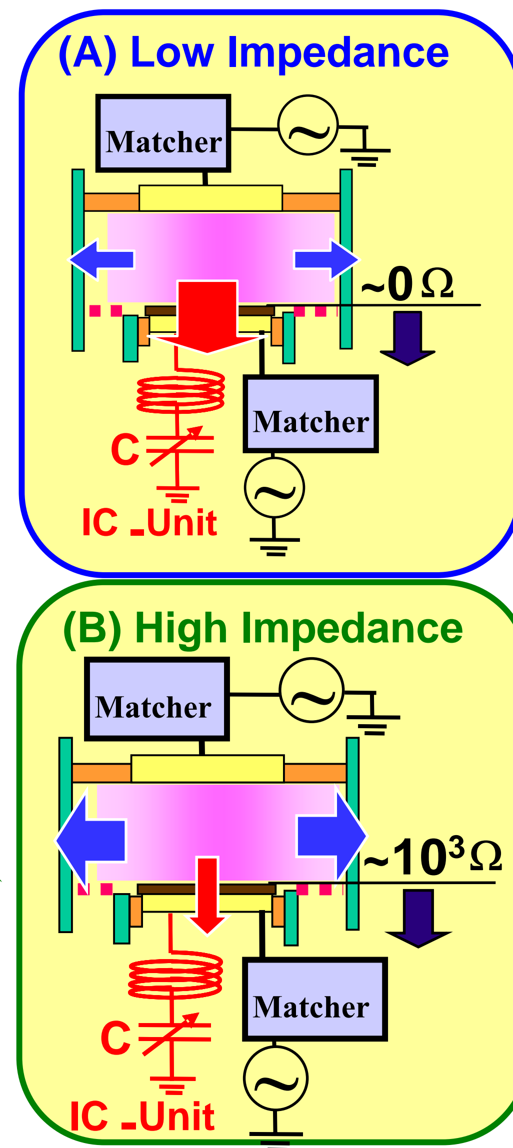


IC-Unit effect on electron density

(low-pressure HBr-based chemistry – ME Case)

A significant change of the n_e distribution was observed.



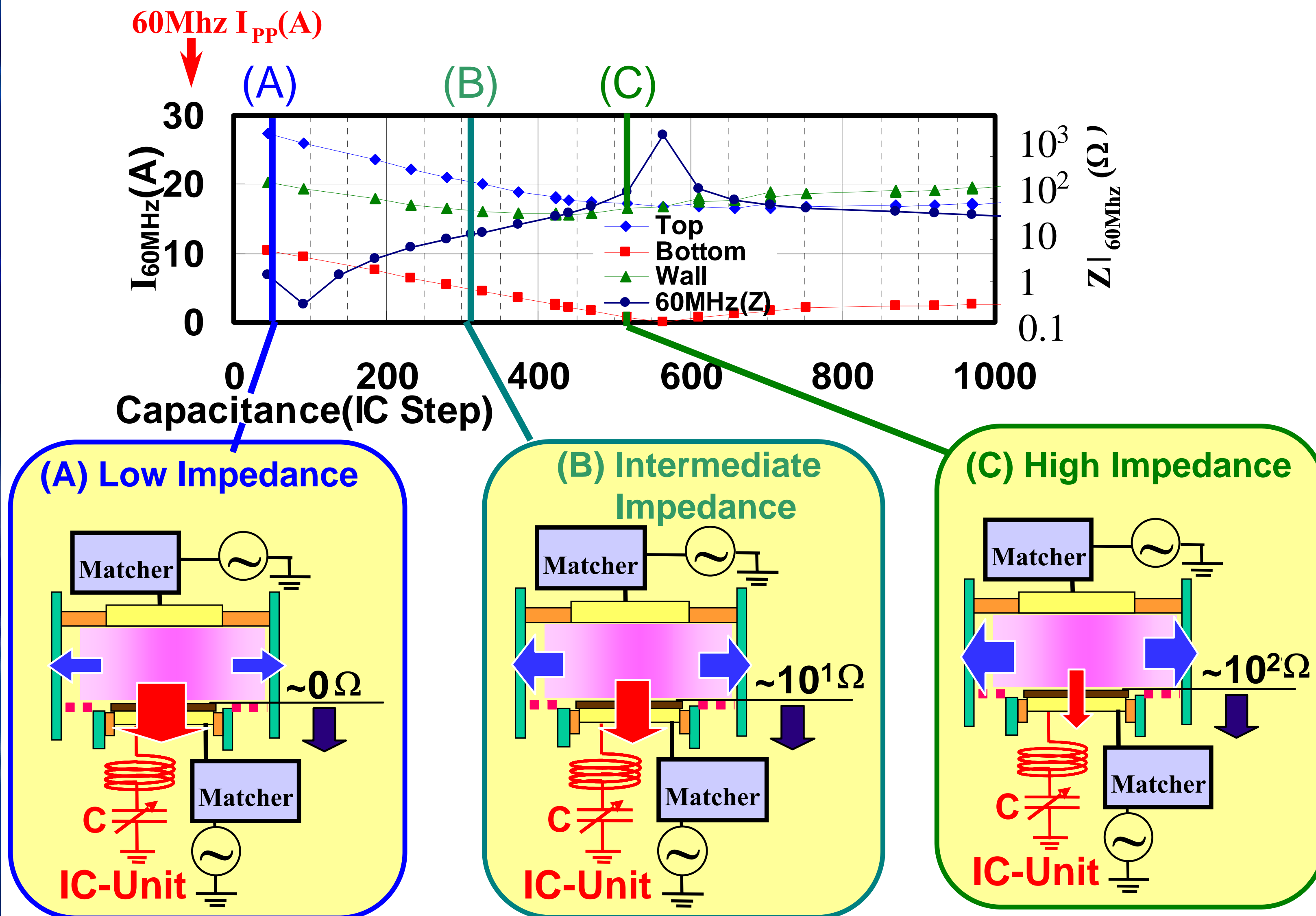


(A) IC-step~100: bottom I_{60Mhz} = maximum
(B) IC-step~550: bottom I_{60Mhz} = minimum

IC-Unit electrical characterization

(high-pressure HBr-based chemistry – OE case)

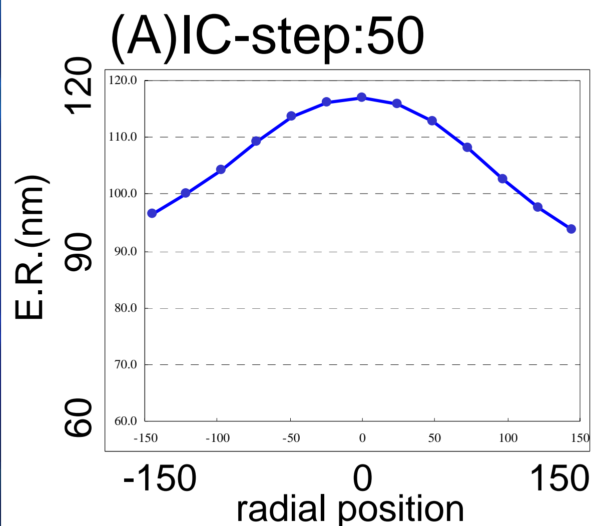
- **Similar effect is observed in high pressure.**



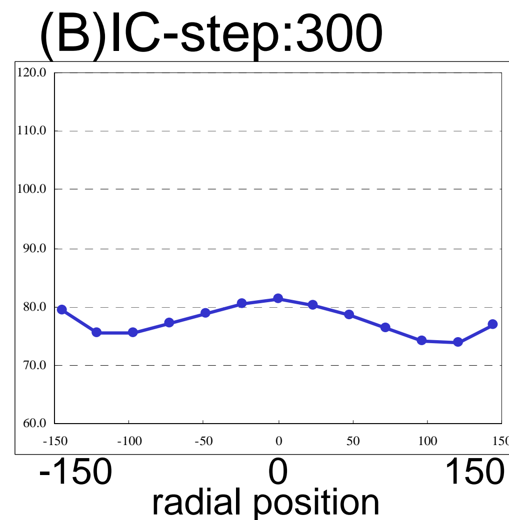
E.R. distribution controllability of IC-unit

Observed Etch Rate

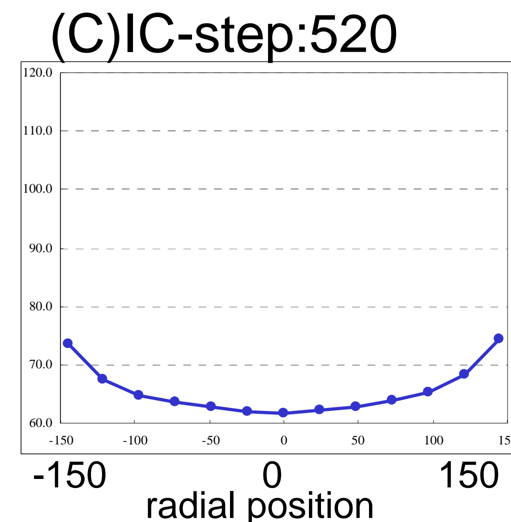
(A)IC-step:50

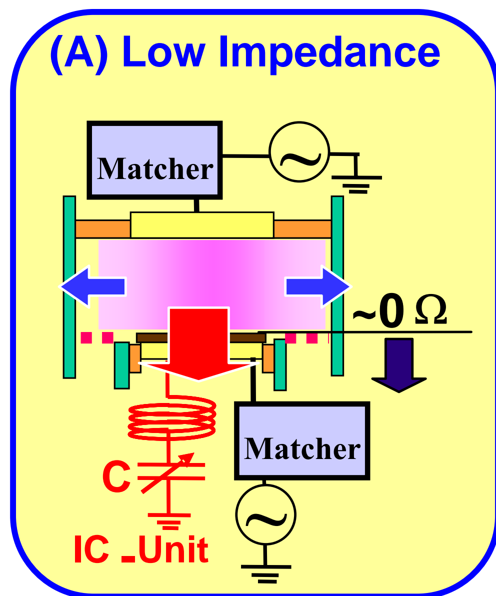


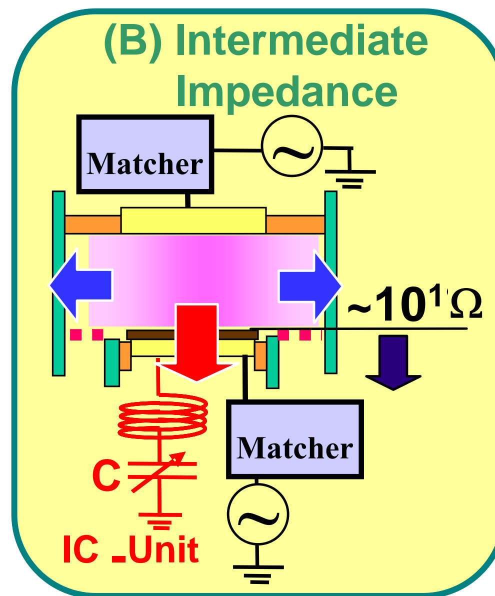
(B)IC-step:300

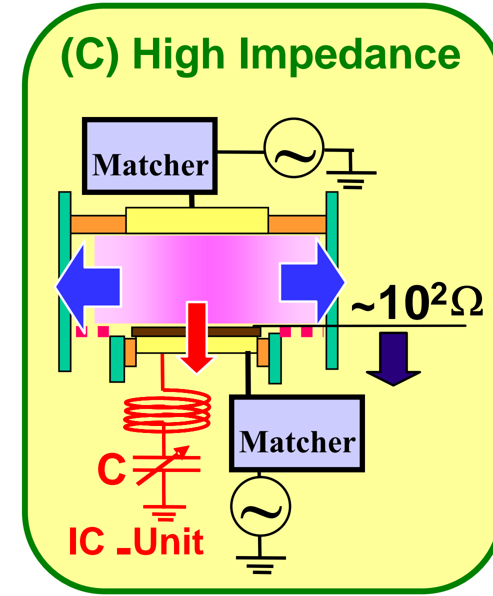


(C)IC-step:520





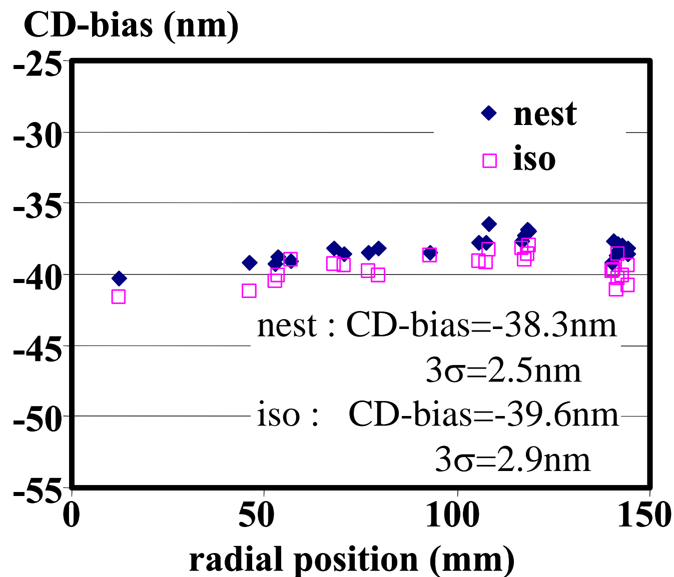




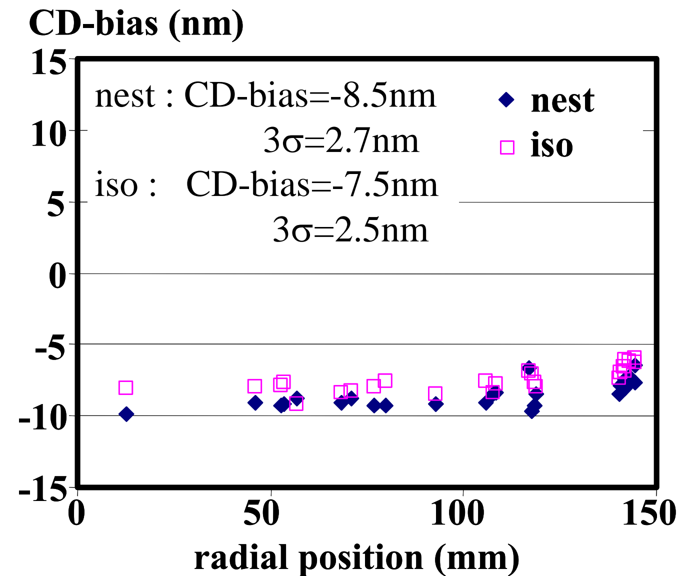
Full gate-stack etch CD results

Step I process:
Obtained by using 3 additional knobs, 3σ=2.5nm achieved

Step II process:
(Conventional undope poly etch)
Original etcher (w/o 3knobs) has enough ability to achieve good CD uniformity.



Step#1: BARC+TEOS+n+-poly+strip/clean with optimized settings of the 3 control knobs



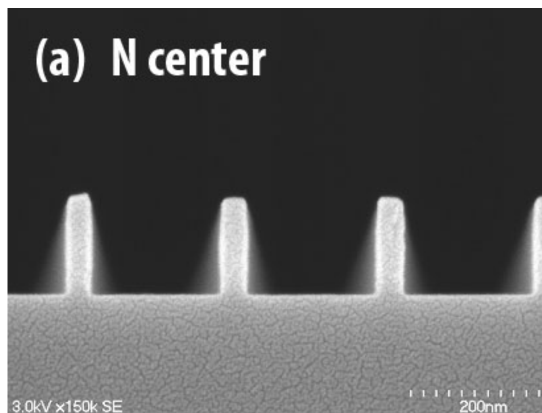
Step#2: BT+ME+OE1+OE2+clean without any of the 3 control knobs

Current Best (2003)

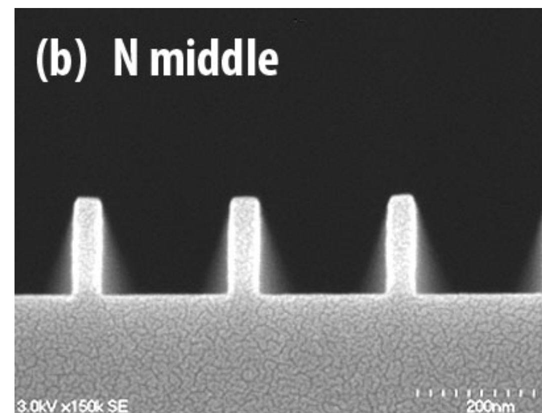
- **Step I + Step II : 36nm CD 3σ=2.5nm**

X-section SEM after Poly Conductor etch

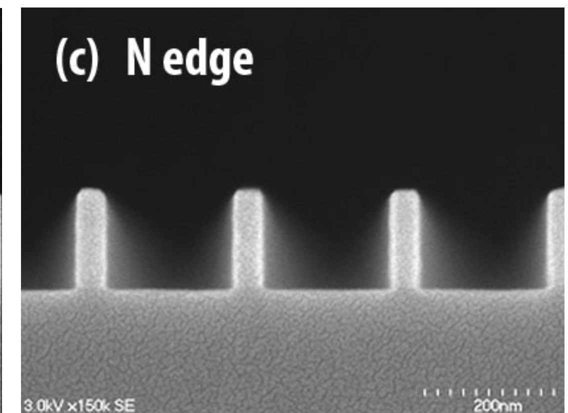
Center



Middle



Edge



Conclusion

- **Barc etch, HMO and n+etch are critical in determining the final CD-bias uniformity.**
- **Additional knobs are implemented onto the etcher.**
  - 2 zone temperature wafer-electrode has strong effect on the isotropic reactivity and hence the final CD.
  - IC-Unit (Impedance Control of the wafer-electrode) has Strong effect on n_e , E.R. and their uniformities.
- **Final CD 36nm, 3σ=2.5mm achieved.**