Development of a Plasma Etch Insitu Chamber Clean (ICC) and Analysis of Etch Plasma Problems using a SEERS Plasma Sensor

Rupert Wagner[1], Heiko Richter[1], Ertzoument Chasanoglou[1], Michael Klick[2]

[1] Texas Instruments Deutschland GmbH
[2] Plasmetrex GmbH

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Motivation

- TEXAS INSTRUMENTS wafer FAB (Freising/Germany) has been using the *HERCULES* SEERS plasma sensor from PLASMETREX since 2011
- SEERS* sensor - used for process monitoring & controlling of Barc Poly Etch, STI and DT plasma etch tools

SEERS* sensor: extended usage in 2012

- ➢ development / adjustment of insitu chamber clean (ICC) recipe more efficiently at Applied Materials Centura DPS+ multi process etch chamber
- ➢ investigation of occurring process problems at DT etch

*) **SEERS:** 'Self Excited Electron Resonance Spectroscopy'
SEERS is a electrodynamic method for determination of absolute plasma parameters

Presentation content:
SEERS usage at etch process investigations

- Barc / Poly Etch @ AMAT DPS+ Poly Chamber
  - Insitu Chamber Clean (ICC) development and characterization
    - old status: process interaction without ICC
    - ICC development
    - new status: process interaction with ICC

- Very Deep Trench Etch @ AMAT DPS DT Chamber
  - Problem detection and verification
    - Chamber miss-conditioning
    - Bias generator problem

ICC Development and Characterization

Old status:

process interactions without Insitu Chamber Clean (ICC)

Process interaction on Gate Poly Etch

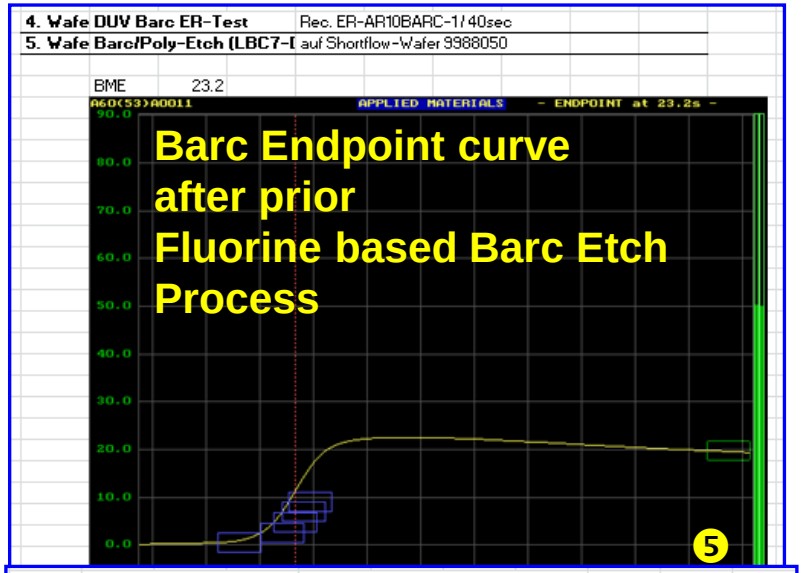
Problem: optical endpoint intensity varies in dependency to prior etch process and its etch chemistry

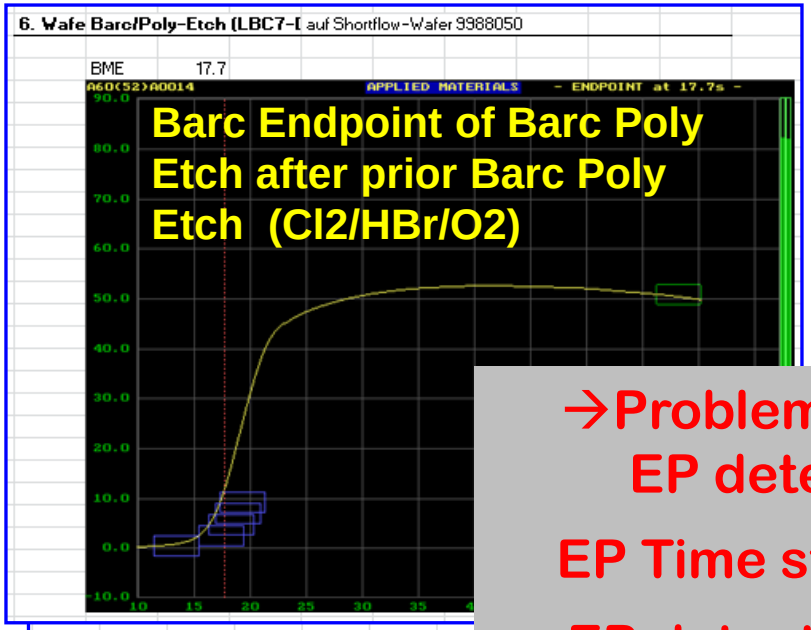
Example : Gate Poly Etch (Barc and Poly stack)

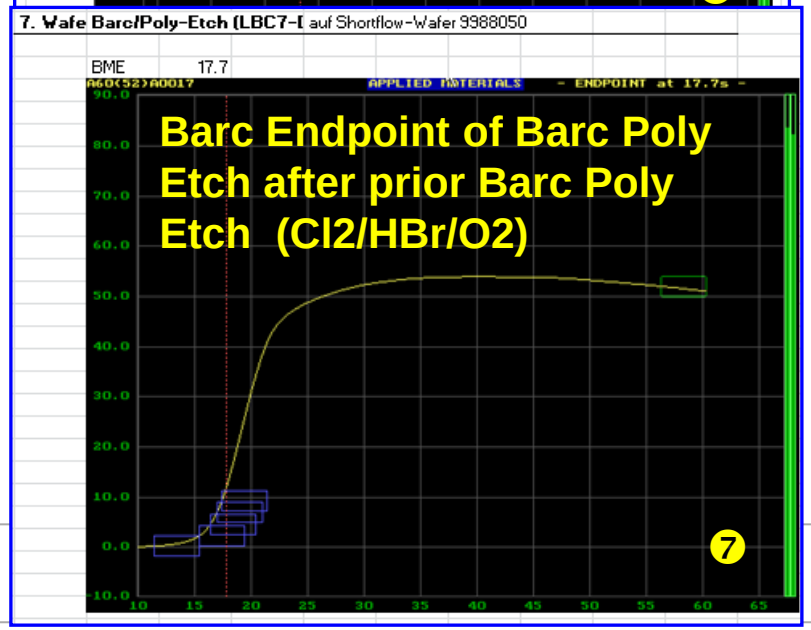
-> Barc endpoint issues (O2/HBr)
after preceding fluorine based processes

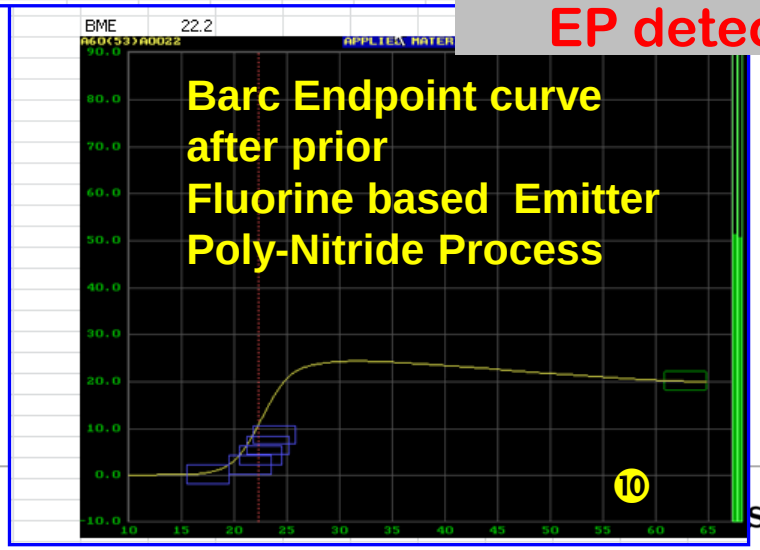
Slot	Prozess
4	DUV BARC Etchrate Test
5	Barc Poly Etch (LBC7-DUV)
6	Barc Poly Etch (LBC7-DUV)
7	Barc Poly Etch (LBC7-DUV)
8	NEMIT Poly Etch (copy CEN17C)
9	NEMIT Poly Etch (copy CEN17C)
10	Barc Poly Etch (LBC7-DUV)

Process interaction on Gate Poly Etch
[optical emmision: Barc Endpoint]







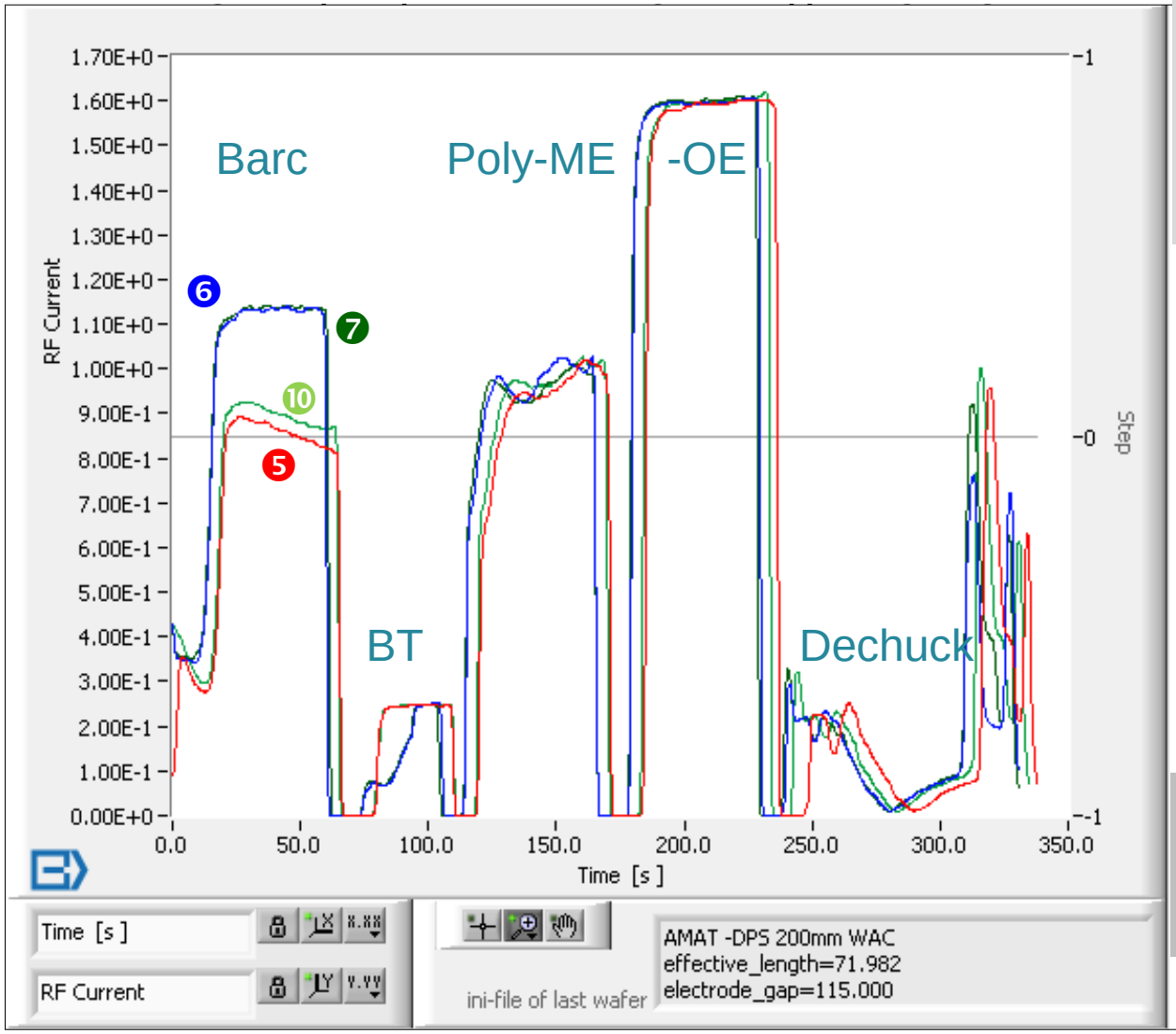


→Problems with EP detection

EP Time stability

EP detectability

Process interaction on Gate Poly Etch
[SEERS: plasma parameter RF current]



changes in Barc etch plasma,

induced by prior process

--> visible in RF-Current measured by Hercules Sensor

4 Barc/Poly Etch-Wafer:

- **5: post fluorine Barc Etch**
- **6: post same B/P Etch**
- **7: post same B/P Etch**
- **10: nach NEMIT Poly Etch**

HBr/O2 based Barc Etch
--> big impact from fluorine based preceding Etches

Process interaction on Emitter Poly Etch

Problem: optical endpoint curve inclination
varies in dependency to prior
etch process and its etch chemistry

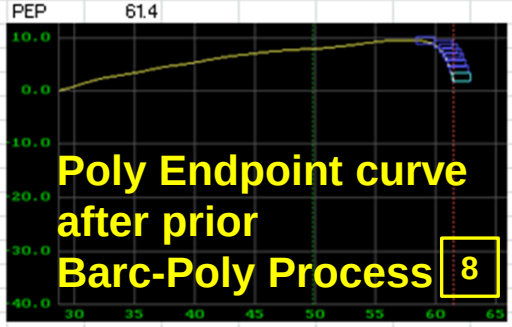
Example 2 : Emitter Poly Etch (Poly, no Barc)

-> Poly main etch endpoint issues
after preceding Barc-Poly etch processes

Slot	Prozess
7	Barc Poly Etch (LBC7-DUV)
8	NEMIT Poly Etch (copy CEN17C)
9	NEMIT Poly Etch (copy CEN17C)
10	Barc Poly Etch (LBC7-DUV)
11	NEMIT Poly Etch (copy CEN17C)
12	NEMIT Poly Etch (copy CEN17C)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	DUV BARC Etchrate Test
16	DUV BARC Etchrate Test
17	DUV BARC Etchrate Test
18	NEMIT Poly Etch (copy CEN17C)
19	NEMIT Poly Etch (copy CEN17C)

Process interaction on Emitter Etch
[optical emmision: Poly Endpoint]

7. Wafe Barc/Poly-Etch (LBC7-[auf Shortflow-Wafer 9988050
8. Wafe NEMIT-Poly-Etch auf Shortflow-Wafer 9988019



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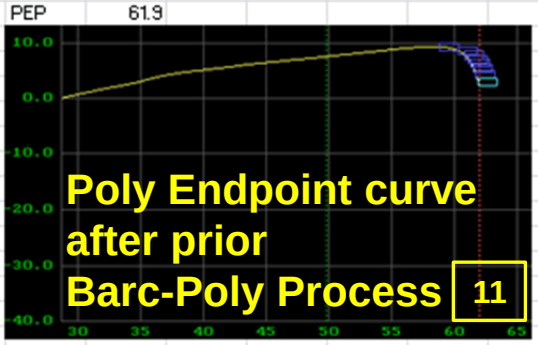
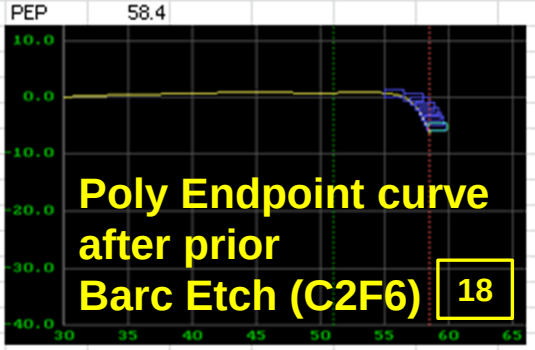
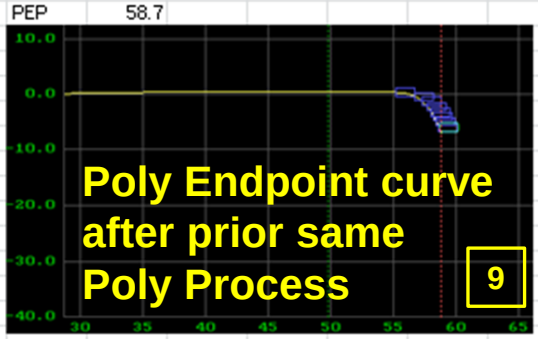


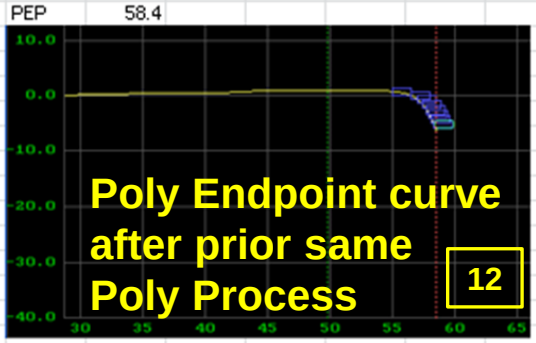
17. Wafe DUV Barc ER-Test Rec. ER-AR10BARC-1/ 40sec
18. Wafe NEMIT-Poly-Etch auf Shortflow-Wafer 9988019



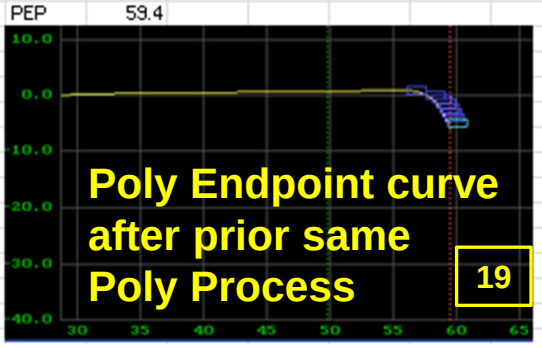
9. Wafe NEMIT-Poly-Etch auf Shortflow-Wafer 9988019



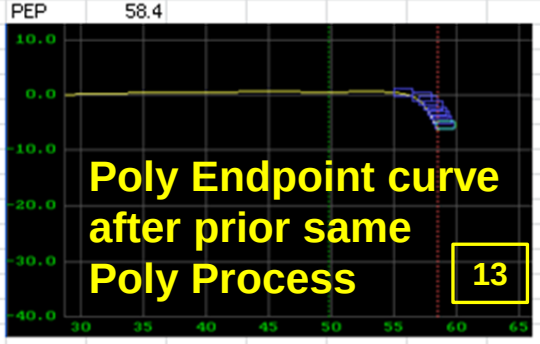
12. Wafe NEMIT-Poly-Etch auf Shortflow-Wafer 9988019



19. Wafe NEMIT-Poly-Etch auf Shortflow-Wafer 9988019



13. Wafe NEMIT-Poly-Etch auf Shortflow-Wafer 9988019



Slot	Prozess
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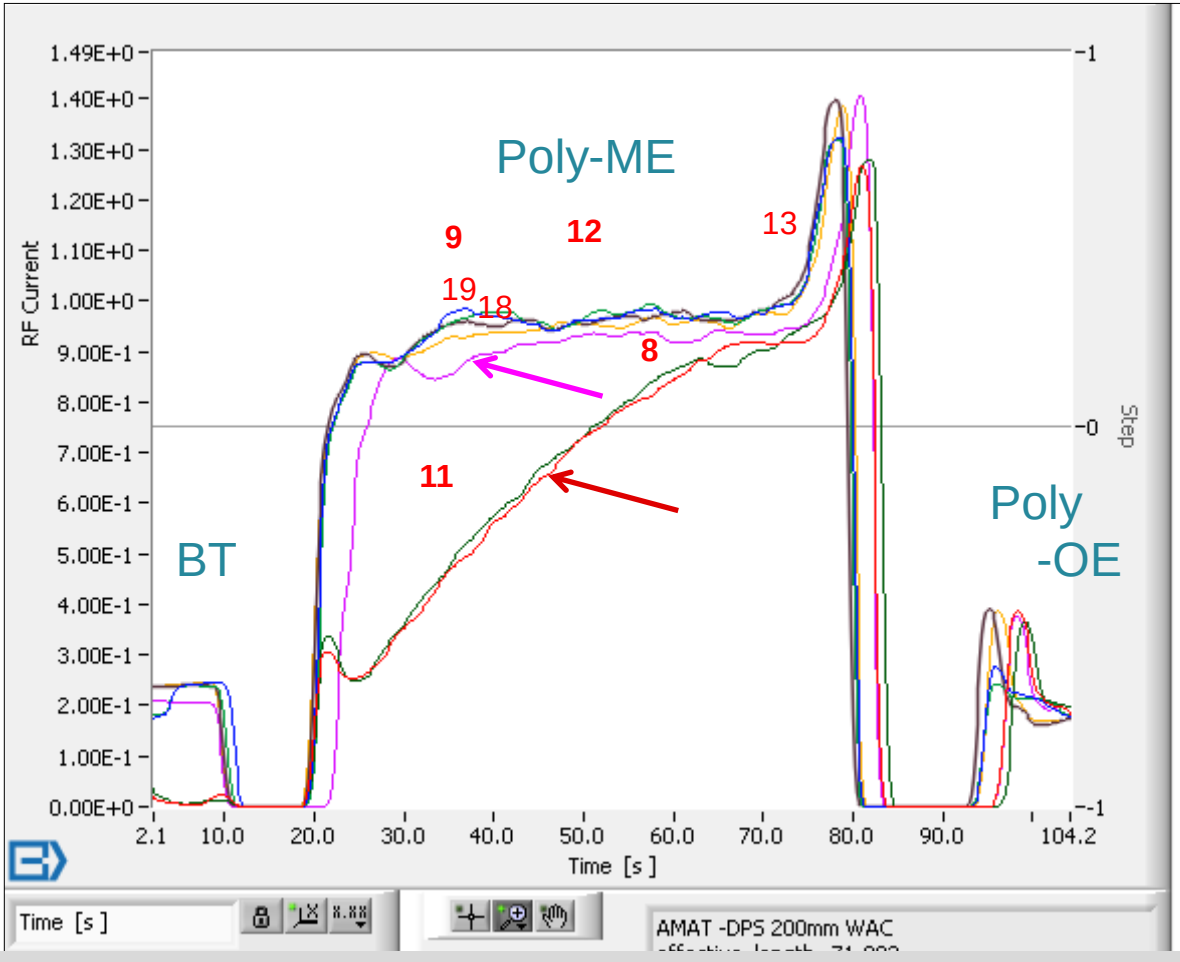
8	NEMIT Poly Etch (copy CEN17C)
9	NEMIT Poly Etch (copy CEN17C)
10	Barc Poly Etch (LBC7-DUV)
11	NEMIT Poly Etch (copy CEN17C)
12	NEMIT Poly Etch (copy CEN17C)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	DUV BARC Etchrate Test
16	DUV BARC Etchrate Test
17	DUV BARC Etchrate Test
18	NEMIT Poly Etch (copy CEN17C)
19	NEMIT Poly Etch (copy CEN17C)

→Risk of wrong detected Endpoints

Process interaction on Emitter Etch
[SEERS: plasma parameter RF current]



7 Emitter Poly Etch Wafer:

red(#8) and green (#11): Both wafer post prior Barc Poly Etch

#18 (pink) post Barc Etch (C2F6) only

all other Wafer post Same NEMIT Poly Etch

Slot	Prozess
7	Barc Poly Etch (LBC7-DUV)
8	NEMIT Poly Etch (copy CEN17C)
9	NEMIT Poly Etch (copy CEN17C)
10	Barc Poly Etch (LBC7-DUV)
11	NEMIT Poly Etch (copy CEN17C)
12	NEMIT Poly Etch (copy CEN17C)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	DUV BARC Etchrate Test
16	DUV BARC Etchrate Test
17	DUV BARC Etchrate Test
18	NEMIT Poly Etch (copy CEN17C)
19	NEMIT Poly Etch (copy CEN17C)

changes in BT- and Poly etch plasma --> visible in RF-Current

Cl2/ HBr/ O2 based etch process
--> big impact on succeeding etch process
with nearly same etch chemistry

Process interaction on DT Barc Etch

Problem: optical endpoint curve incliniation and intensity drop varies in dependency to prior etch process and its etch chemistry

Example 3 : DT Barc Etch (Barc only, C2F6)

-> slight Barc endpoint variances after preceding Barc etch processes (N2/O2)

Slot	Prozess
1	DUV BARC Etchrate Test
2	XHRI BARC Etchrate Test
3	DUV BARC Etchrate Test
4	DUV BARC Etchrate Test
5	Barc Poly Etch (LBC7-DUV)
6	Barc Poly Etch (LBC7-DUV)
7	Barc Poly Etch (LBC7-DUV)
8	NEMIT Poly Etch (copy CEN17C)
9	NEMIT Poly Etch (copy CEN17C)
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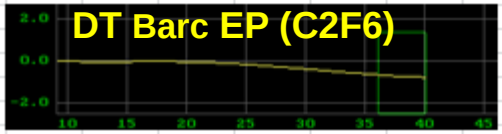
12	NEMIT Poly Etch (copy CEN17C)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	DUV BARC Etchrate Test
16	DUV BARC Etchrate Test
17	DUV BARC Etchrate Test

Process interaction on DT Barc Etch
[optical emmision: Barc Endpoint]

1. Wafe DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec

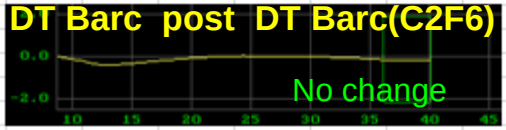


Etchrate [A/sec]: **24.3**

2. Wafe XHRI Barc ER-Test — Rec. ER-XHRIBARC-1 / 60sec
3. Wafe DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec

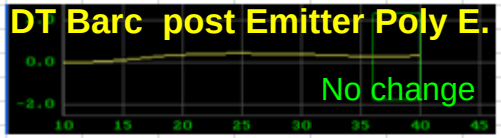
Etchrate [A/sec]: **24.4**

4. Wafe DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec



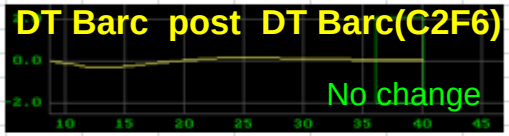
Etchrate [A/sec]: **23.8**

12. Waf NEMIT-Poly-Etch — auf Shortflow-Wafer 9988019
13. Waf NEMIT-Poly-Etch — auf Shortflow-Wafer 9988019
14. Waf DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec



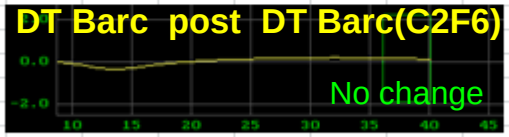
Etchrate [A/sec]: **24.2**

15. Waf DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec



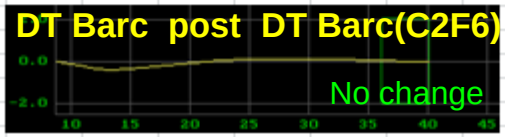
Etchrate [A/sec]: **23.8**

16. Waf DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec



Etchrate [A/sec]: **23.8**

17. Waf DUV Barc ER-Test — Rec. ER-AR10BARC-1 / 40sec



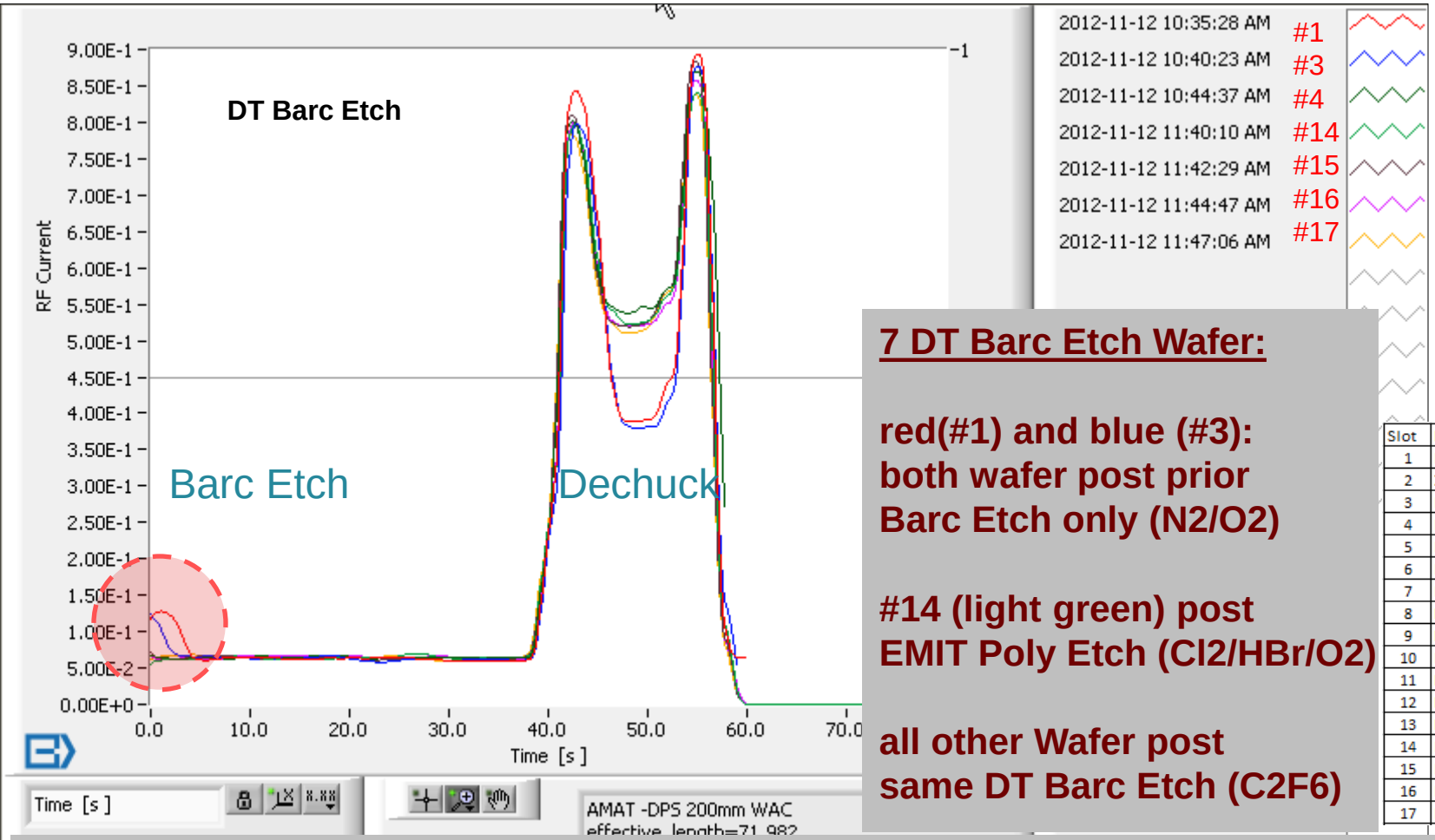
Etchrate [A/sec]: **23.7**

Slot	Prozess
1	DUV BARC Etchrate Test
2	XHRI BARC Etchrate Test
3	DUV BARC Etchrate Test
4	DUV BARC Etchrate Test
5	Barc Poly Etch (LBC7-DUV)
6	Barc Poly Etch (LBC7-DUV)
7	Barc Poly Etch (LBC7-DUV)
8	NEMIT Poly Etch (copy CEN17C)
9	NEMIT Poly Etch (copy CEN17C)
10	Barc Poly Etch (LBC7-DUV)
11	NEMIT Poly Etch (copy CEN17C)
12	NEMIT Poly Etch (copy CEN17C)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	DUV BARC Etchrate Test
16	DUV BARC Etchrate Test
17	DUV BARC Etchrate Test

Fluorine based DT Barc Etch -> slight impact from N2/O2 Barc Etch

→ slight variances in Endpoint traces and Etch Rate

Process interaction on Emitter Etch
[SEERS: plasma parameter RF current]



7 DT Barc Etch Wafer:

red(#1) and blue (#3): both wafer post prior Barc Etch only (N2/O2)

#14 (light green) post EMIT Poly Etch (Cl2/HBr/O2)

all other Wafer post same DT Barc Etch (C2F6)

Slot	Prozess
1	DUV BARC Etchrate Test
2	XHRI BARC Etchrate Test
3	DUV BARC Etchrate Test
4	DUV BARC Etchrate Test
5	Barc Poly Etch (LBC7-DUV)
6	Barc Poly Etch (LBC7-DUV)
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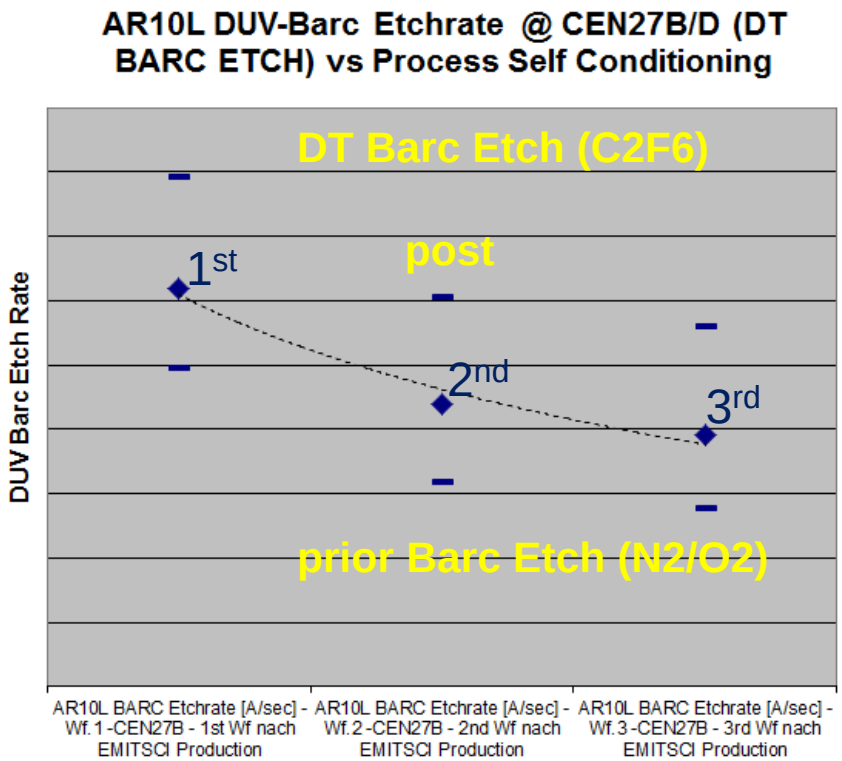
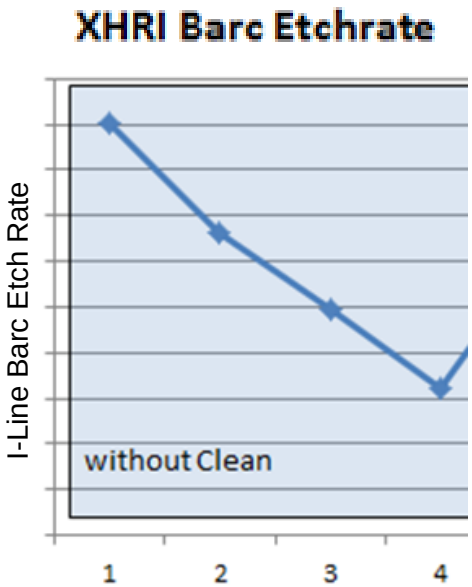
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	DUV BARC Etchrate Test
16	DUV BARC Etchrate Test
17	DUV BARC Etchrate Test

Fluorine based DT Barc Etch
--> light impact from N2/O2 Barc Etch at beginning of etch step

Process interaction on DT Barc Etch
[process parameter: Barc Etch Rate]





- BARC-only Etch process (DUV/I-line) show self conditioning effect for its own etch rate
- ER decreases from wafer to wafer and gets stable after a few runs

→ 1st Wafer effect, respectively a first-five-Wafer effect

generates problems **especially on Fixed Time Etch** processes

ICC Development and Characterization

Development of an suitable Insitu Chamber Clean (ICC)

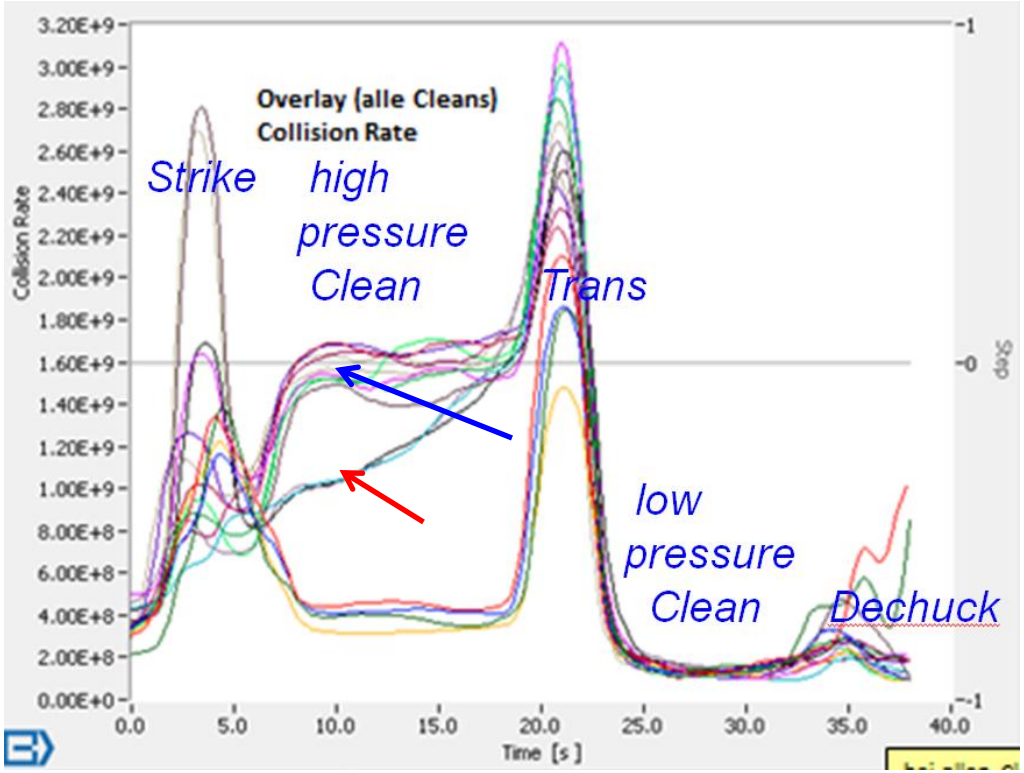
Development of Clean Etch Process (ICC)

ICC Setup → 4 Step process :

- Plasma Strike
- High Pressure Clean
  (remove Poly-,Oxide-,Nitride-Etch byproducts)
- Transition step
- Low Pressure Clean
  (remove organic resist etch-byproducts)

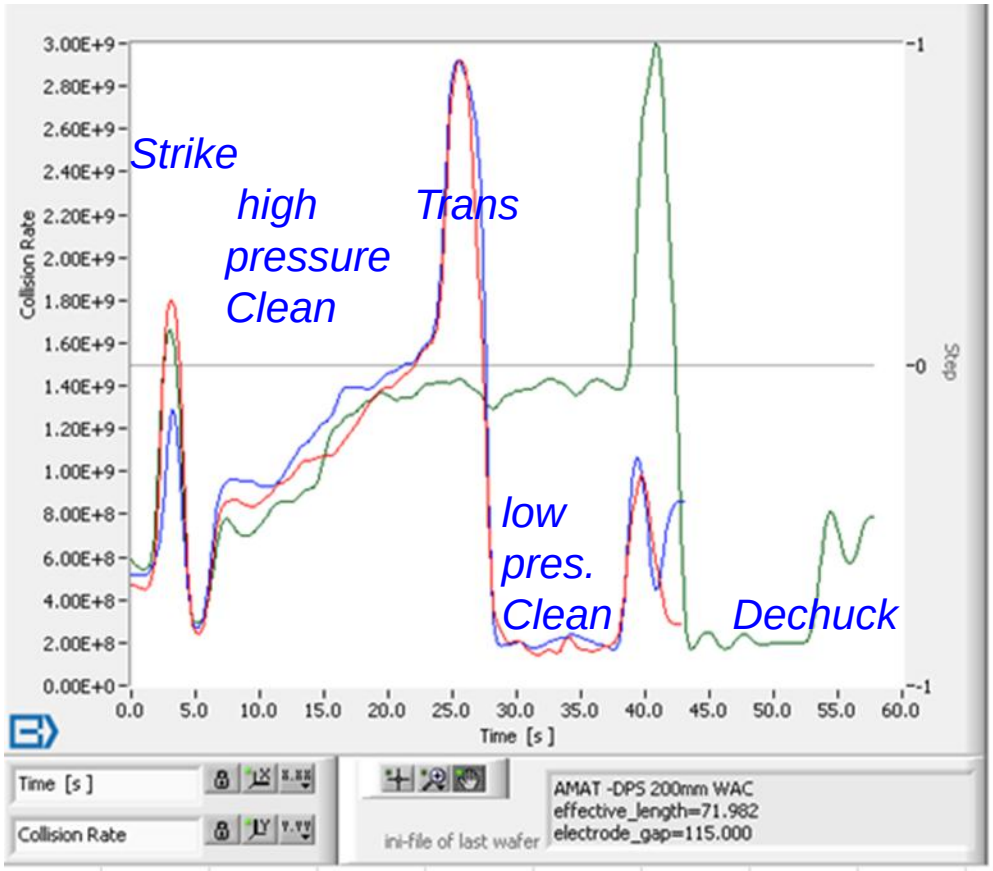
Development of Clean Etch Process (ICC)
[SEERS: plasma parameter collision rate]

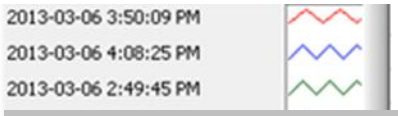
Overlay Collision Rate traces of ICC process post all used Etch processes :



- **Collision Rate shows plasma changes during ICC Clean process clearly**
- **Plasma Collision rate during etch depends on preceding process**
- **Saturation of collision rate trace during high pressure clean show finished clean process!**
- **ICC post most of the etch processes show Clean-End after ~10sec in high pressure step**
- **Exeption: ICC Clean post Barc Poly Etch process needs significantly more time to clean the chamber!**

Development of Clean Etch Process (ICC)
[SEERS: plasma parameter collision rate]





ICC optimization for Barc Poly Etch processes → prolong the 'high pressure clean' step

- **Red and blue curve:**
  hp-clean 25sec
  → no curve saturation
  ➔ chamber clean not finished
- **Green curve:**
  hp-clean 40sec
  → curve saturation reached
  ➔ chamber clean finished

Use of SEERS plasma information very useful for correct ICC setup!

- **Gate Poly Etch needs longer 'high pressure clean' step**
- **Finished cleaning is visible in saturated curve**

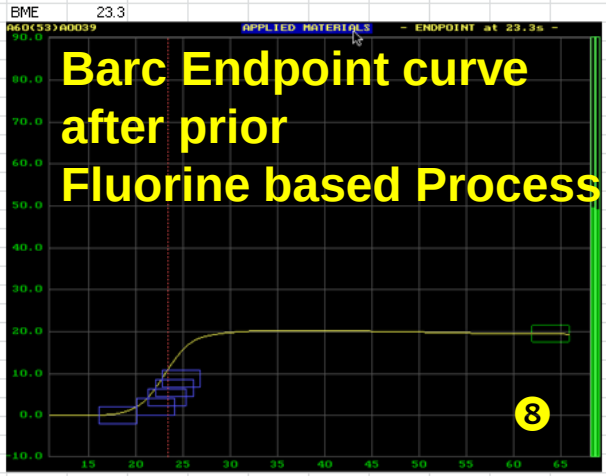
ICC Development and Characterization

New status:

Process interactions with Insitu Chamber Clean (ICC)

Process interaction on Gate Poly Etch
[optical emmision: Barc Endpoint]

7. Wafe DUV Barc ER-Test	Rec. ER-AR10BARC-1/40sec	danach Clean 20/10
8. Wafe Barc/Poly-Etch (LBC7-[	auf Shortflow-Wafer 9988050	danach Clean 20/10



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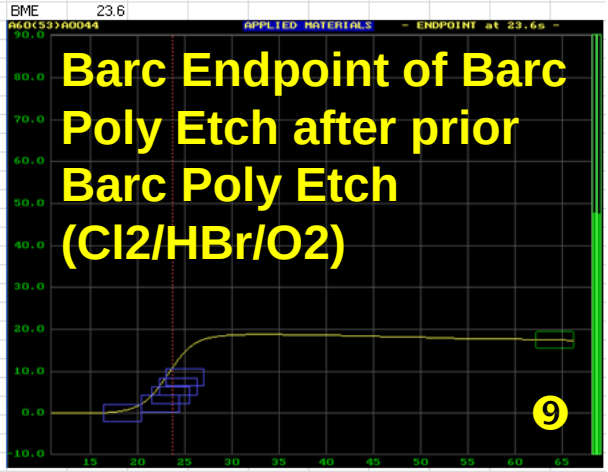
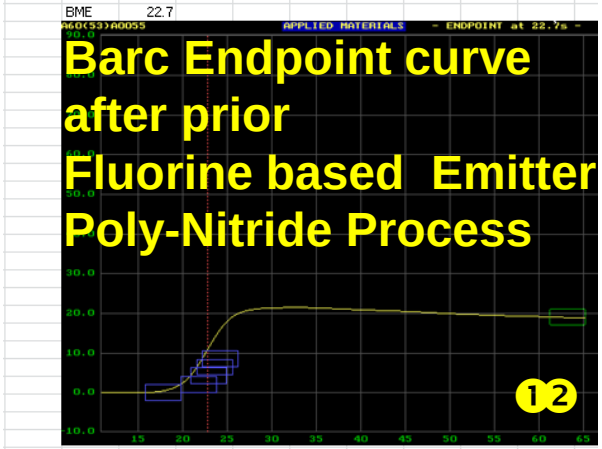
11	NEMIT Poly Etch (copy CEN17C)
12	Barc Poly Etch (LBC7-DUV)

With ICC after every wafer

9. Wafe Barc/Poly-Etch (LBC7-[	auf Shortflow-Wafer 9988050	danach Clean 20/10

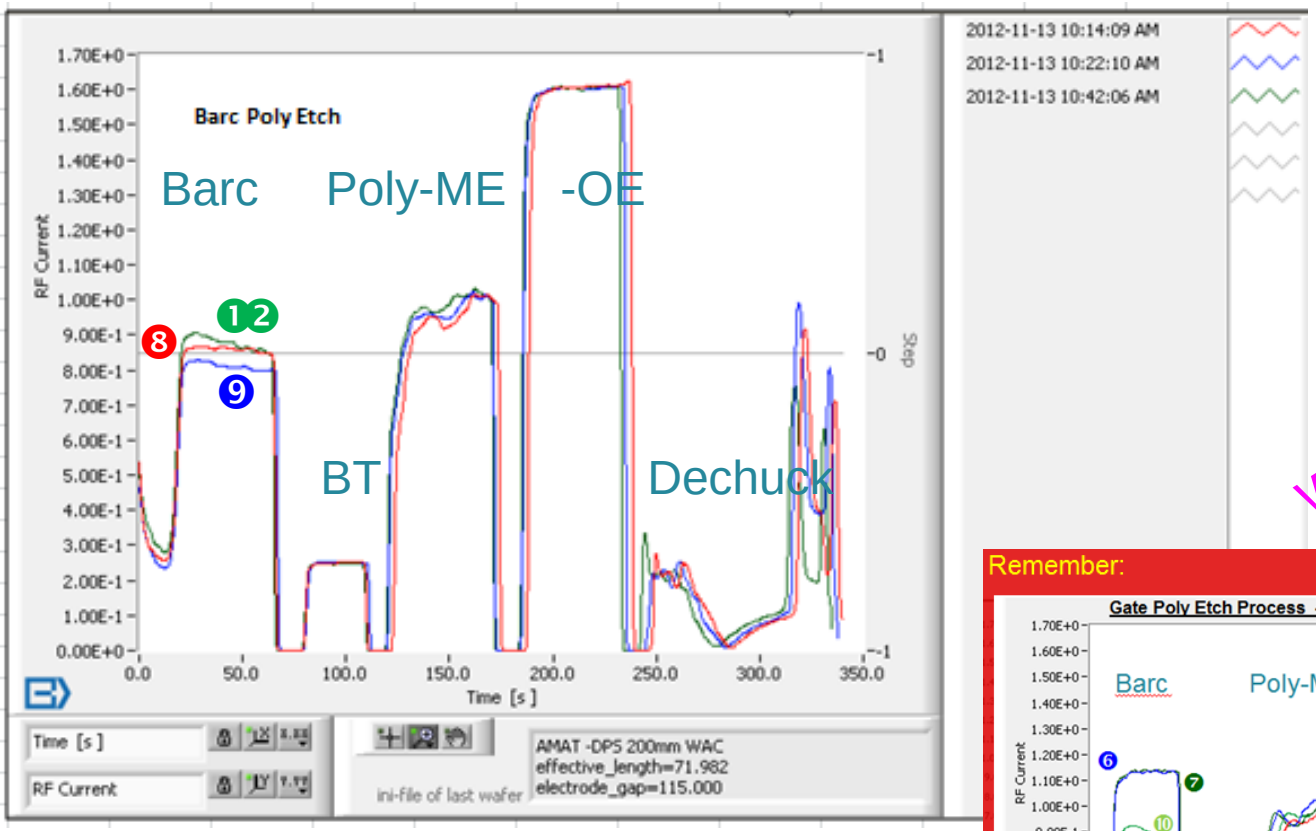


10. Wafe NEMIT-Poly-Etch	auf Shortflow-Wafer 9988019	danach Clean 20/10
11. Wafe NEMIT-Poly-Etch	auf Shortflow-Wafer 9988019	danach Clean 20/10
12. Wafe Barc/Poly-Etch (LBC7-[	auf Shortflow-Wafer 9988050	danach Clean 20/10



Endpoint intensity and EP time are now very stable and indipendent to preceding etch process and its etch chemistry

Process interaction on Gate Poly Etch
[SEERS: plasma parameter RF current]



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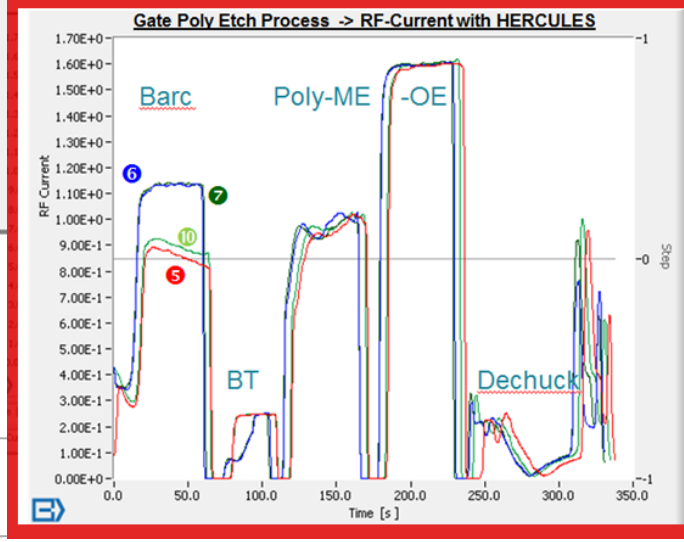
12	Barc Poly Etch (LBC7-DUV)

With ICC after every wafer

Remember:

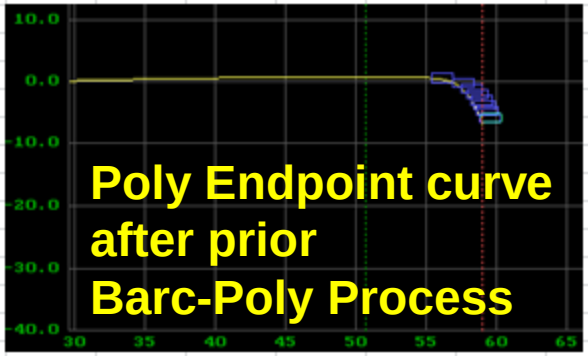


Gate Poly Etch without ICC

Process interaction on Emitter Etch
[optical emmision: Poly Endpoint]

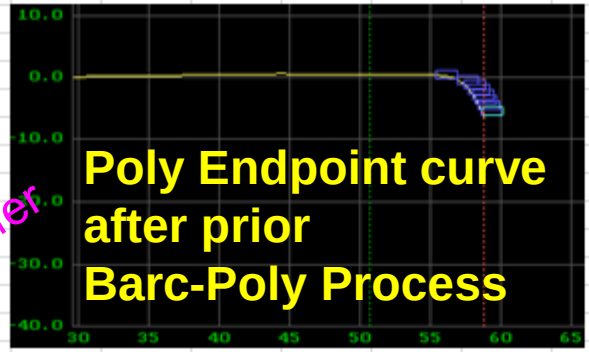
9. Wafe	Barc/Poly-Etch (LBC7-I	auf Shortflow-Wafer 9988050	danach Clean 20/10
10. Waf	NEMIT-Poly-Etch	auf Shortflow-Wafer 9988019	danach Clean 20/10

PEP 58.9



12. Waf	Barc/Poly-Etch (LBC7-I	auf Shortflow-Wafer 9988050	danach Clean 20/10
13. Waf	NEMIT-Poly-Etch	auf Shortflow-Wafer 9988019	danach Clean 20/10

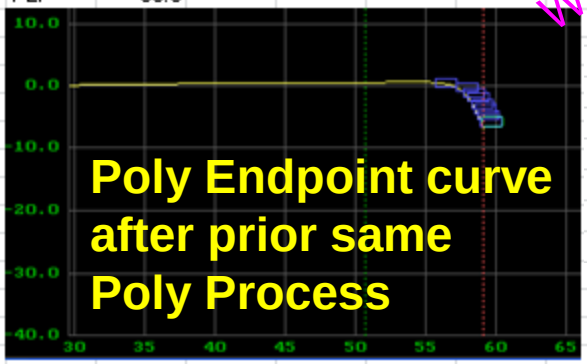
PEP 58.7



With ICC after every wafer

11. Wafe	NEMIT-Poly-Etch	auf Shortflow-Wafer 9988019	danach Clean 20/10

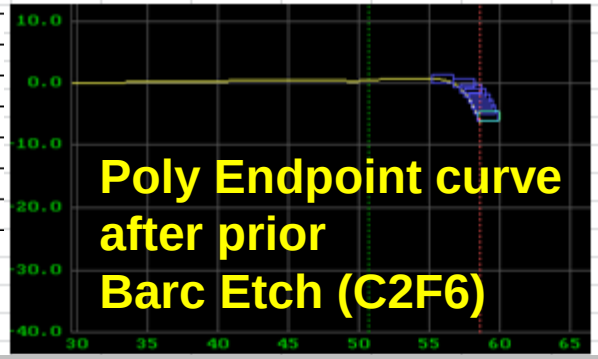
PEP 59.0



9	Barc Poly Etch (LBC7-DUV)
10	NEMIT Poly Etch (copy CEN17C)
11	NEMIT Poly Etch (copy CEN17C)
12	Barc Poly Etch (LBC7-DUV)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	NEMIT Poly Etch (copy CEN17C)

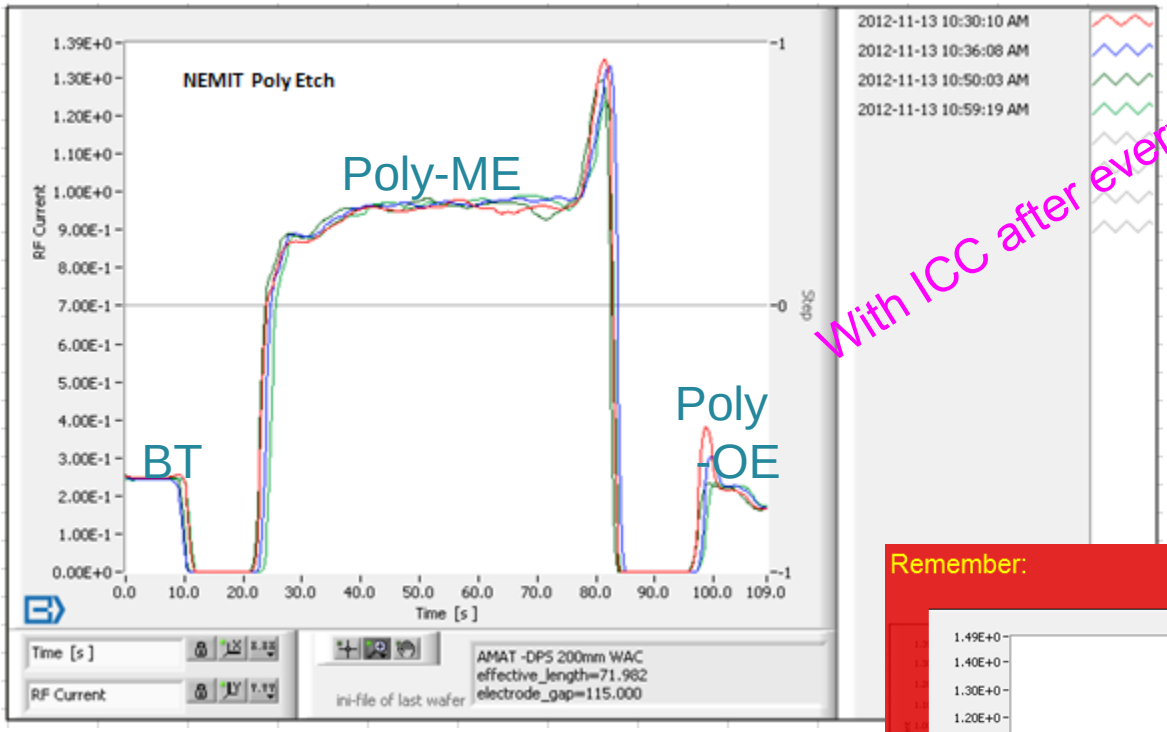
14. Waf	DUV Barc ER-Test	Rec. ER-AR10BARC-1/40sec	danach Clean 20/10
15. Waf	NEMIT-Poly-Etch	auf Shortflow-Wafer 9988019	danach Clean 20/10

PEP 58.5



- Endpoint curve intensity are now very stable
- Endpoints can detected safely

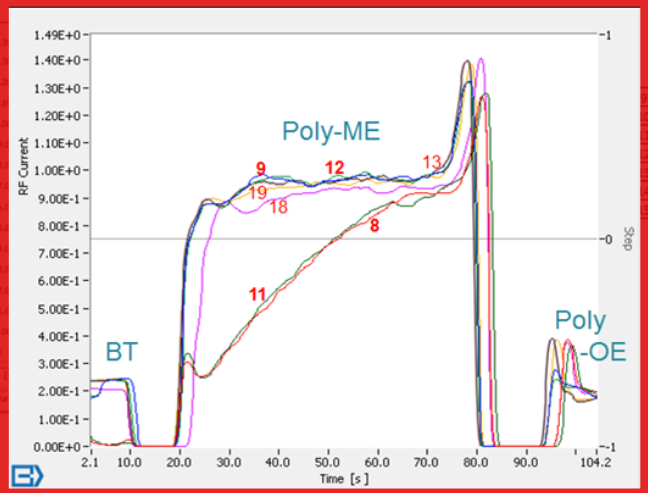
Process interaction on Emitter Etch
[SEERS: plasma parameter RF current]



With ICC after every wafer

9	Barc Poly Etch (LBC7-DUV)
10	NEMIT Poly Etch (copy CEN17C)
11	NEMIT Poly Etch (copy CEN17C)
12	Barc Poly Etch (LBC7-DUV)
13	NEMIT Poly Etch (copy CEN17C)
14	DUV BARC Etchrate Test
15	NEMIT Poly Etch (copy CEN17C)

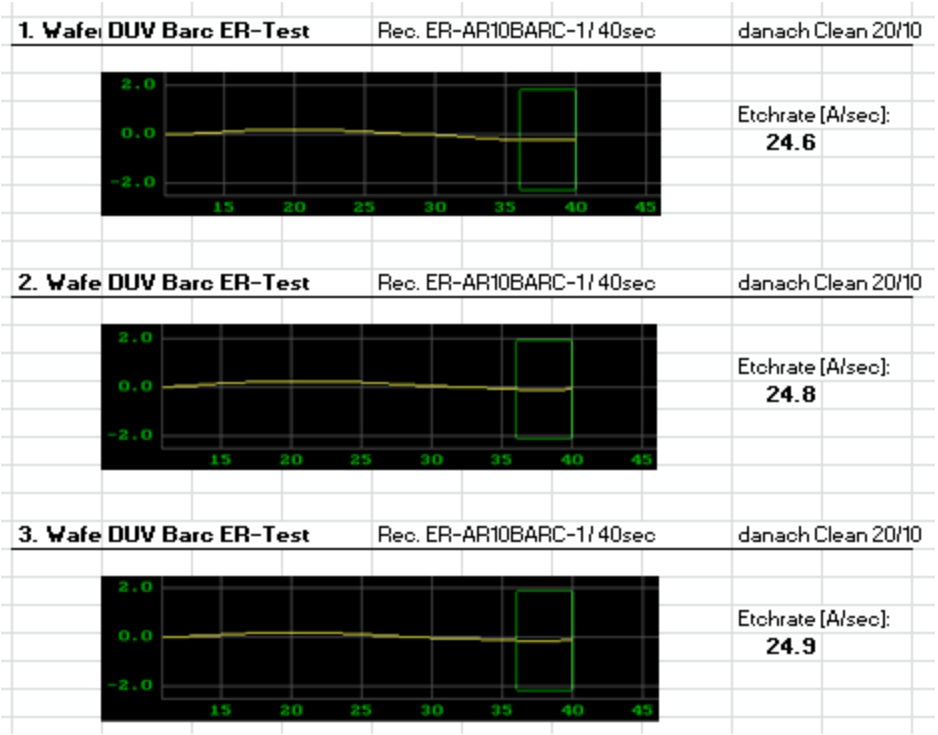
Remember:



Emitter Poly Etch without ICC

With ICC after every w

Process interaction on DT Barc Etch
[optical emmision: Barc Endpoint]

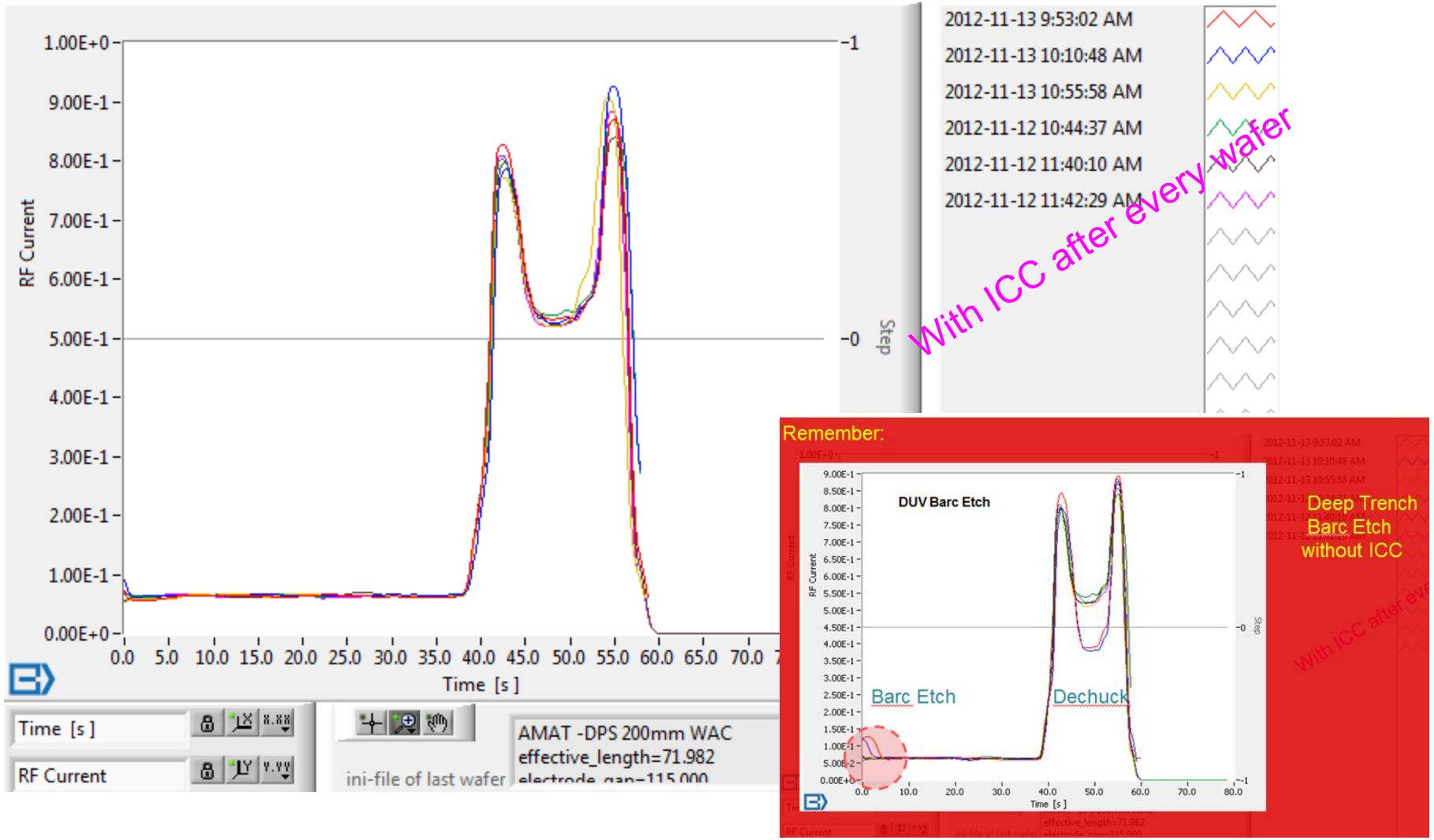


With ICC after every wafer

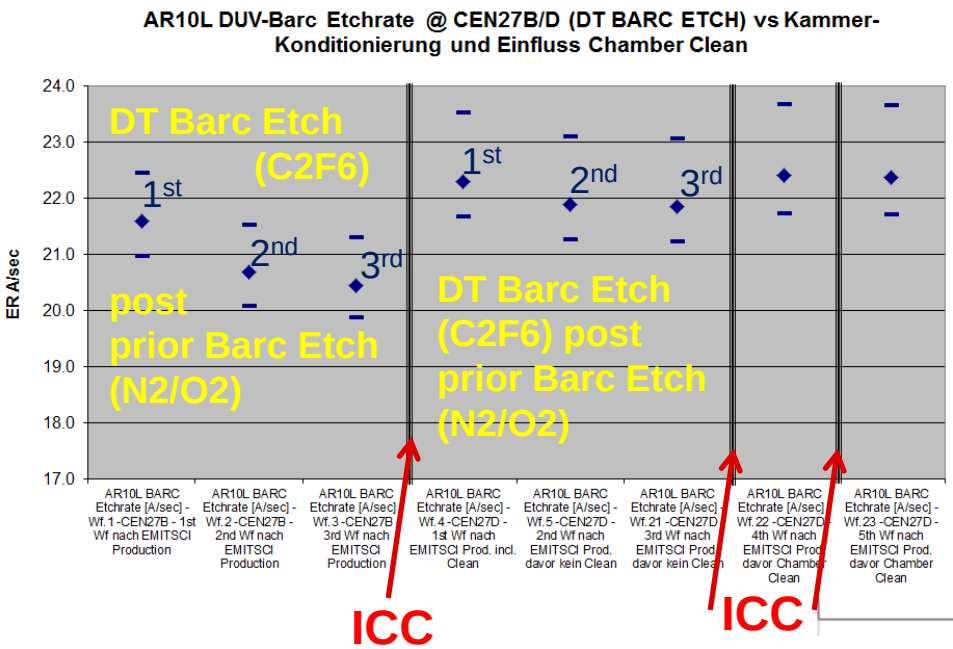
Fluorine based DT Barc Etch:

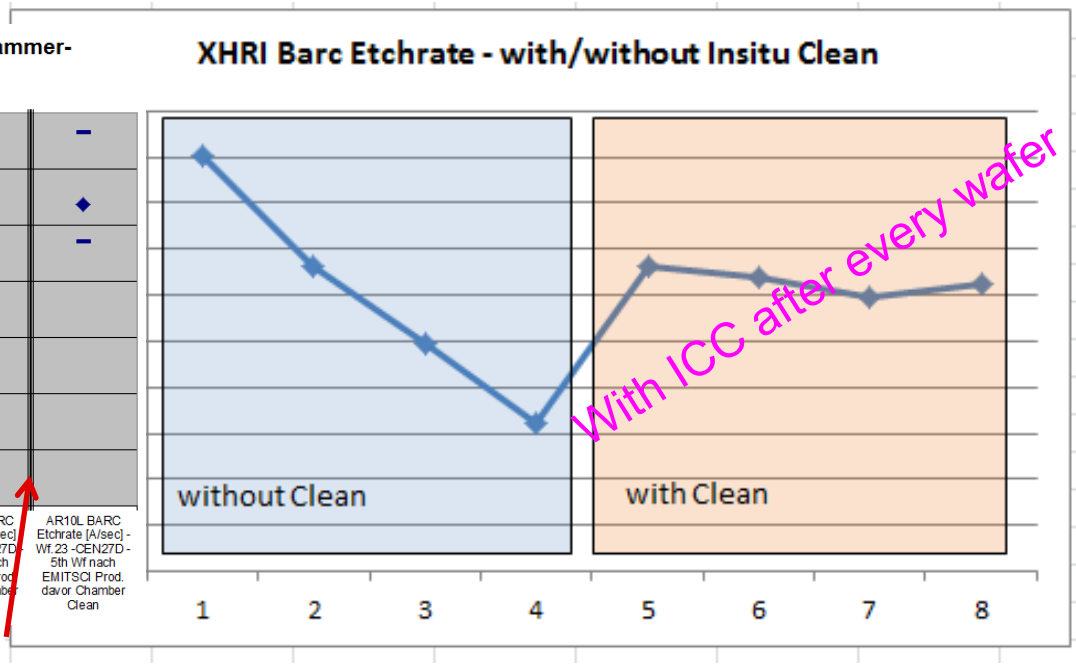
- **Very stable Endpoint traces**
- **Stable Etch Rate**

Process interaction on Emitter Etch
[SEERS: plasma parameter RF current]



Process interaction on DT Barc Etch
[process parameter: Barc Etch Rate]





<u>With ICC</u> – clean post every wafer:

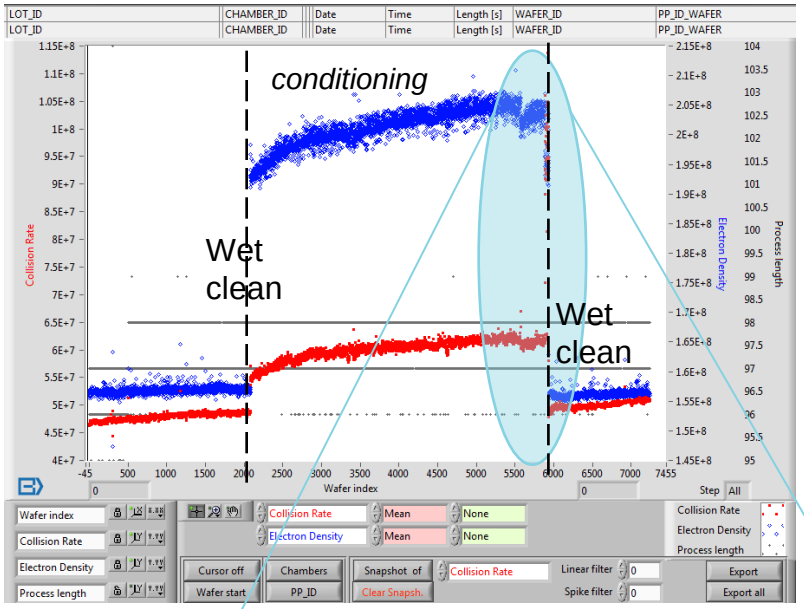
- **BARC Etch Rates (both kind of Barc) increase**
- **Barc Etch Rate keep stable**
- **No more 1st Wafer effect**

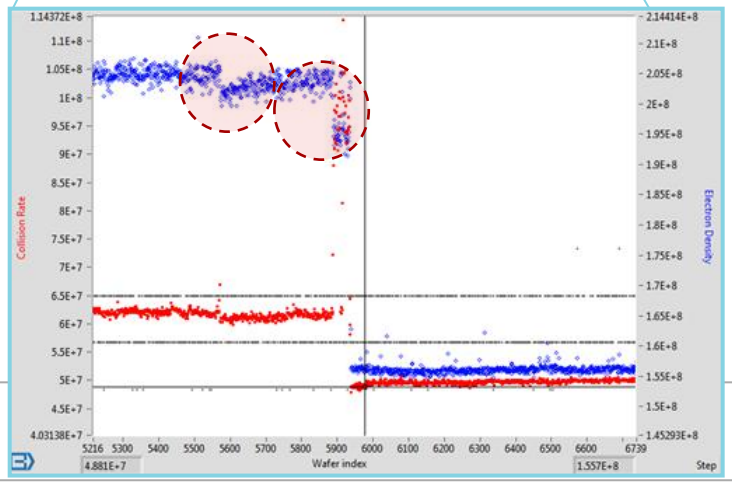
Very Deep Trench Etch @ AMAT DPS DT chamber

Plasma Instabilities during DT Etch (BICOM3X)

Very Deep Trench Etch @ AMAT DPS DT chamber: problem verification

[SEERS: plasma parameter Collision rate]



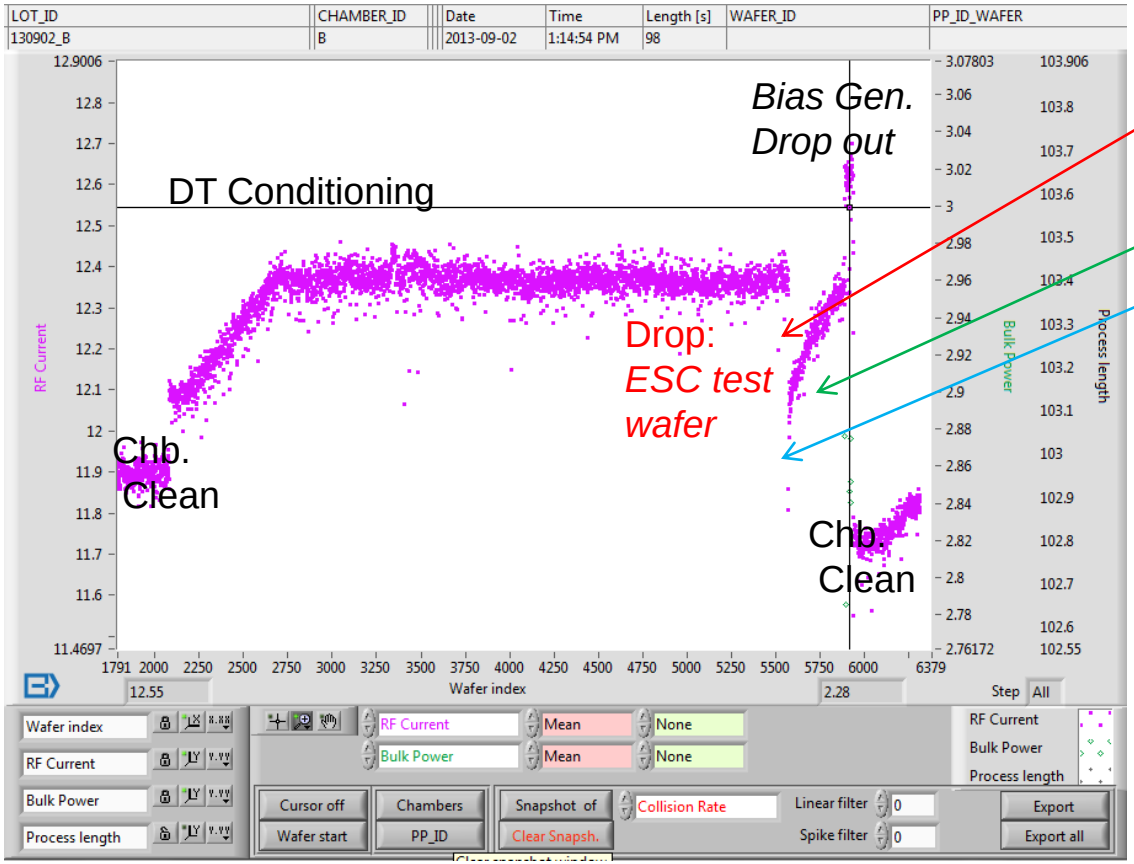


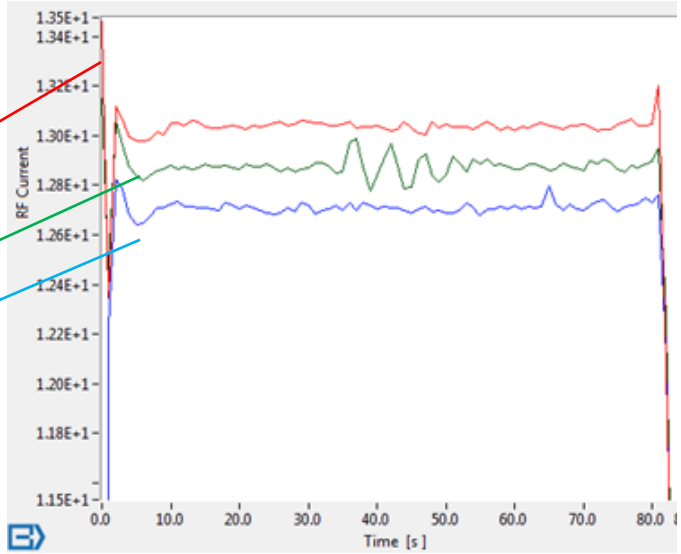
Collision Rate and Electron Density during DT procuction cycle (between wet cleans)

- **Wet cleans visible**
- **Conditioning**
- **Problems / issues visible**

Very Deep Trench Etch @ AMAT DPS DT chamber: problem verification

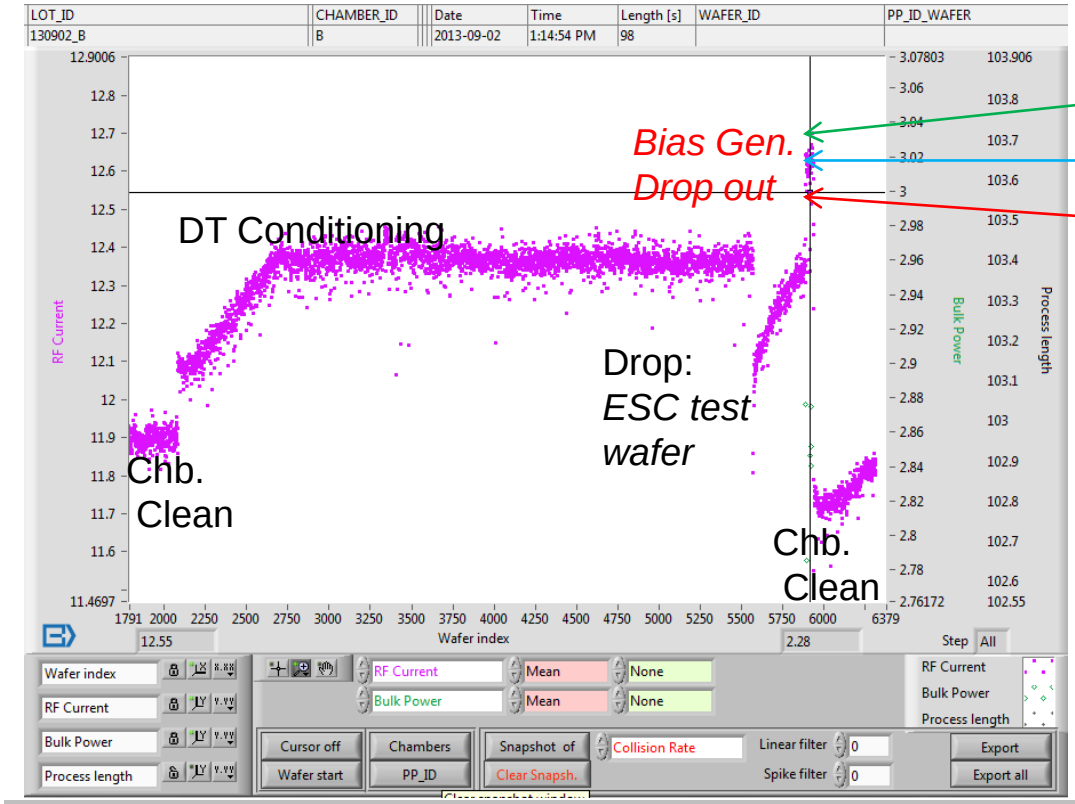
[SEERS: plasma parameter RF current]

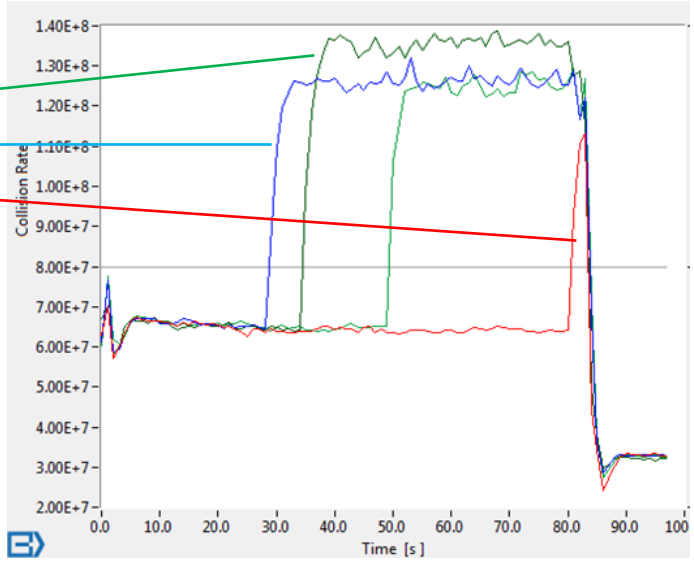




- **Drop of plasma RF current due to wrong testwafer which were run between production material**

Very Deep Trench Etch @ AMAT DPS DT chamber: problem verification *[SEERS: plasma parameter RF current]*





- **Reason for Drop: Bias generator becomes too hot and shuts down**
- **Root cause: defect cooling fan**
- **The process has not stopped, because Bias-Power Settings are lower (12W) than Alarm limits**
- **The process continous with only Source Power**

Conclusion

The SEERS sensor ‘Hercules’ from Plasmetrex

- **provides absolute physical plasma parameter in addition to the Endpoint data, which shows a small part of the optical plasma frequence spectrum**

- **afford comprehensive process investigations using detailed primary plasma information**
- **enables a more efficiently ICC setup**
- **provide information of correct ICC functionality quickly, easily and cost effective**

- **Allow detailed plasma monitoring and controlling**

Thank You

14th European Advanced Process Control and Manufacturing Conference (APCM)

- Rome, Italy - April 7-9, 2014