Milling High Aspect Ratio (HAR) Holes in Dielectrics
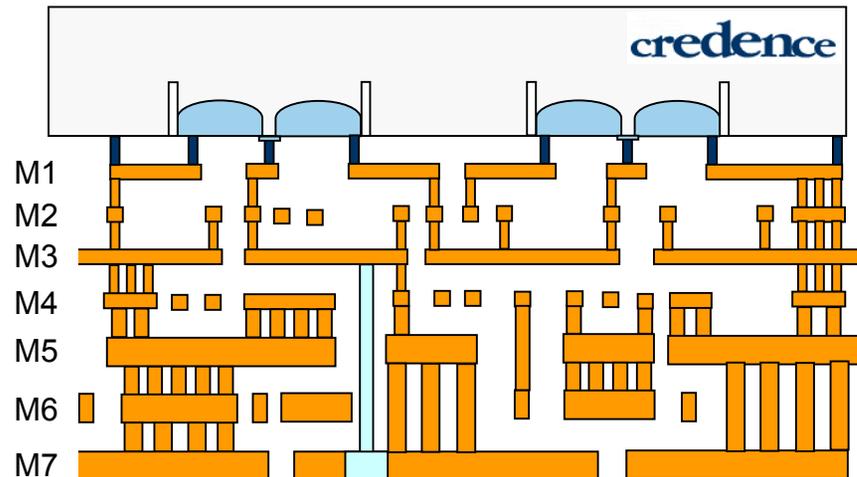
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Introduction

- HAR holes: critical in circuit edit to contact buried traces

- HAR hole milling & end-pointing difficult
    - Metallization levels increase with transistor density/ technology shrinks
    - Require aspect ratios >10 for box sizes <300nm

- Assisting chemistries are required to increase milling and reduce material redeposition

- In general, Front side edits requires higher aspect ratios than backside edits

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Front side getting more difficult

- From topside, access to lower metal ~impossible
  - Power planes become thicker
  - Number of metal levels increasing (>10)
    - Dummy fill metal makes each level more difficult
    - More power planes
    - Aspect ratios increase
    - Endpoint becomes harder
    - Hole filling becomes more difficult
    - Via fill resistance increases
    - Edit time increases
  - M1 lines require higher aspect ratios
    - 5um deep 350x350nm; aspect ratio = 14:1
- Aluminum capping layer requires 2 metal etch chemistries
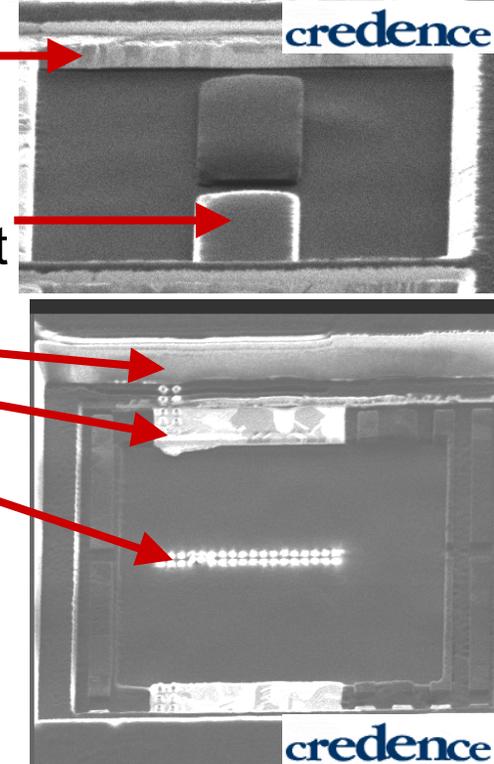
Challenge

- Optimal efficiency: floor surface sufficiently covered with assisting molecules
  - Arrival rate strongly depends on hole aspect ratio
    - Significantly limits hole depth reached for given geometry & local pressure

HAR
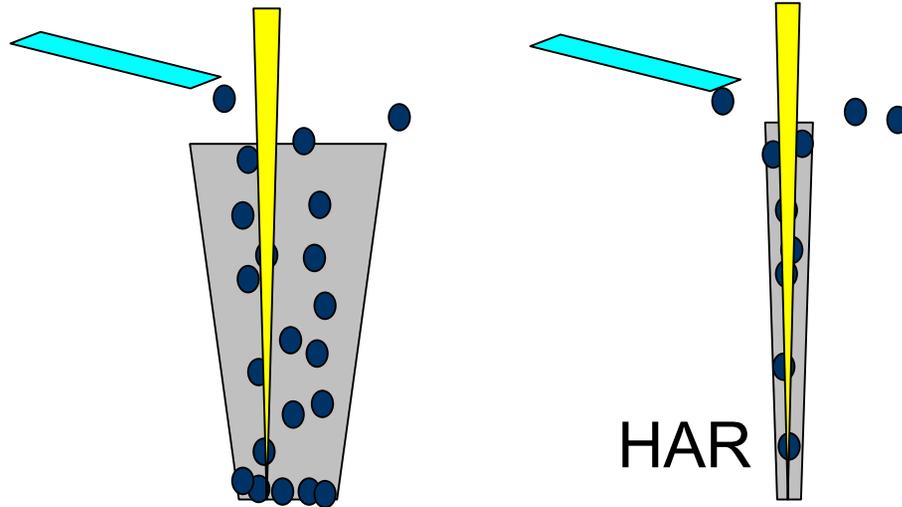
- Assisting molecules stick to side walls and few reach hole floor
- Hole depth reached depends on geometry & local pressure

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Experiment

- HAR hole Chemistries are the same
  - XeF_2 works great
- Endpoint detection is critical
- Low beam currents are important
- Limit depth concept
- Dynamics of milling HAR holes in SiO2 using XeF_2 studied, using limit depth concept for various dwell & frame times.
- Reachable hole depth for a given aspect ratio increases with frame times

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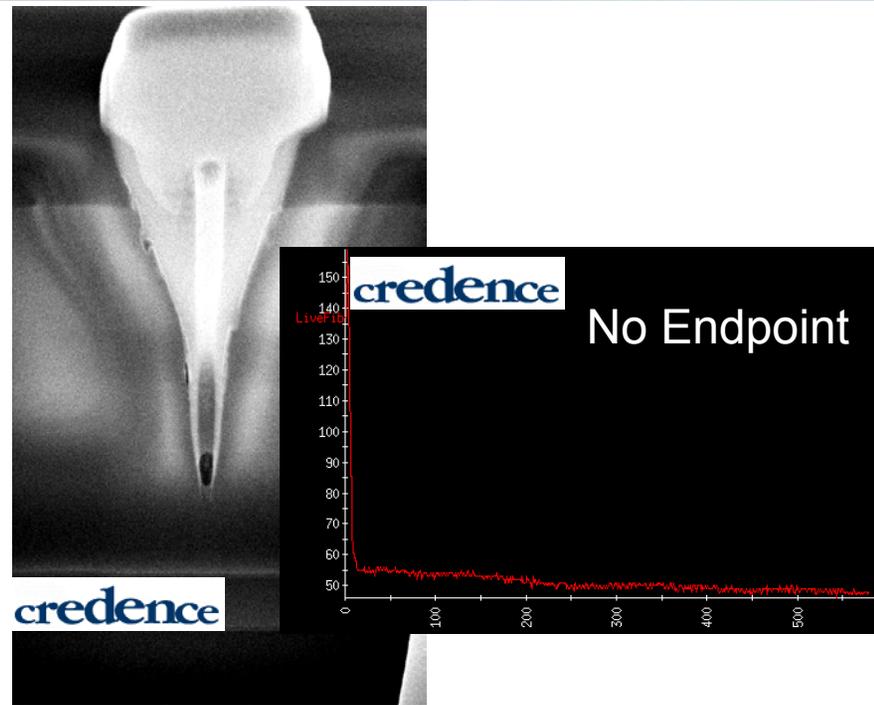# Depth Limit Concept

Endpoint
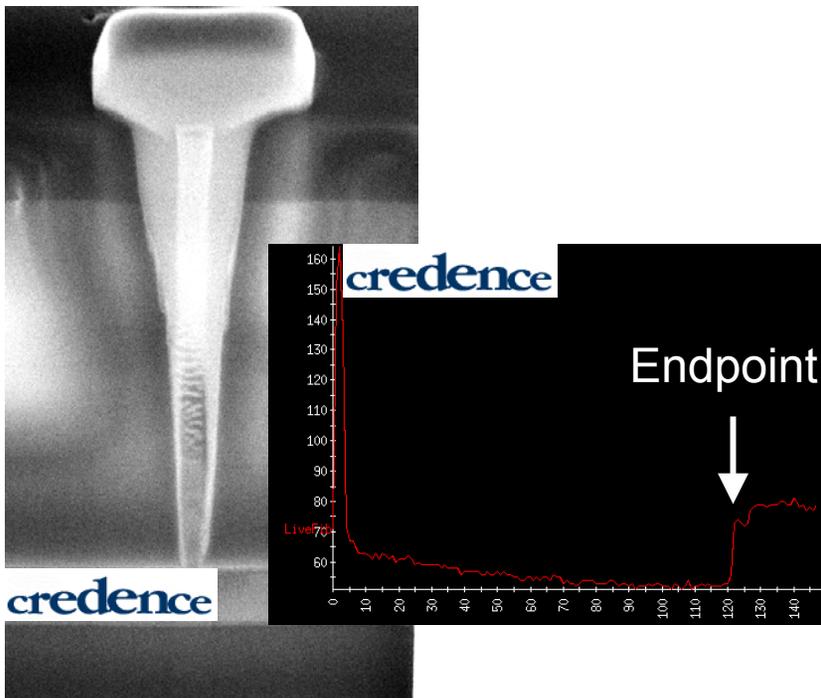
No Endpoint

Successful End Pointing

Box size 0.32umx0.32um

Depth 4.2um

Etch time 2.1min–Good End Point

Limit Depth Concept
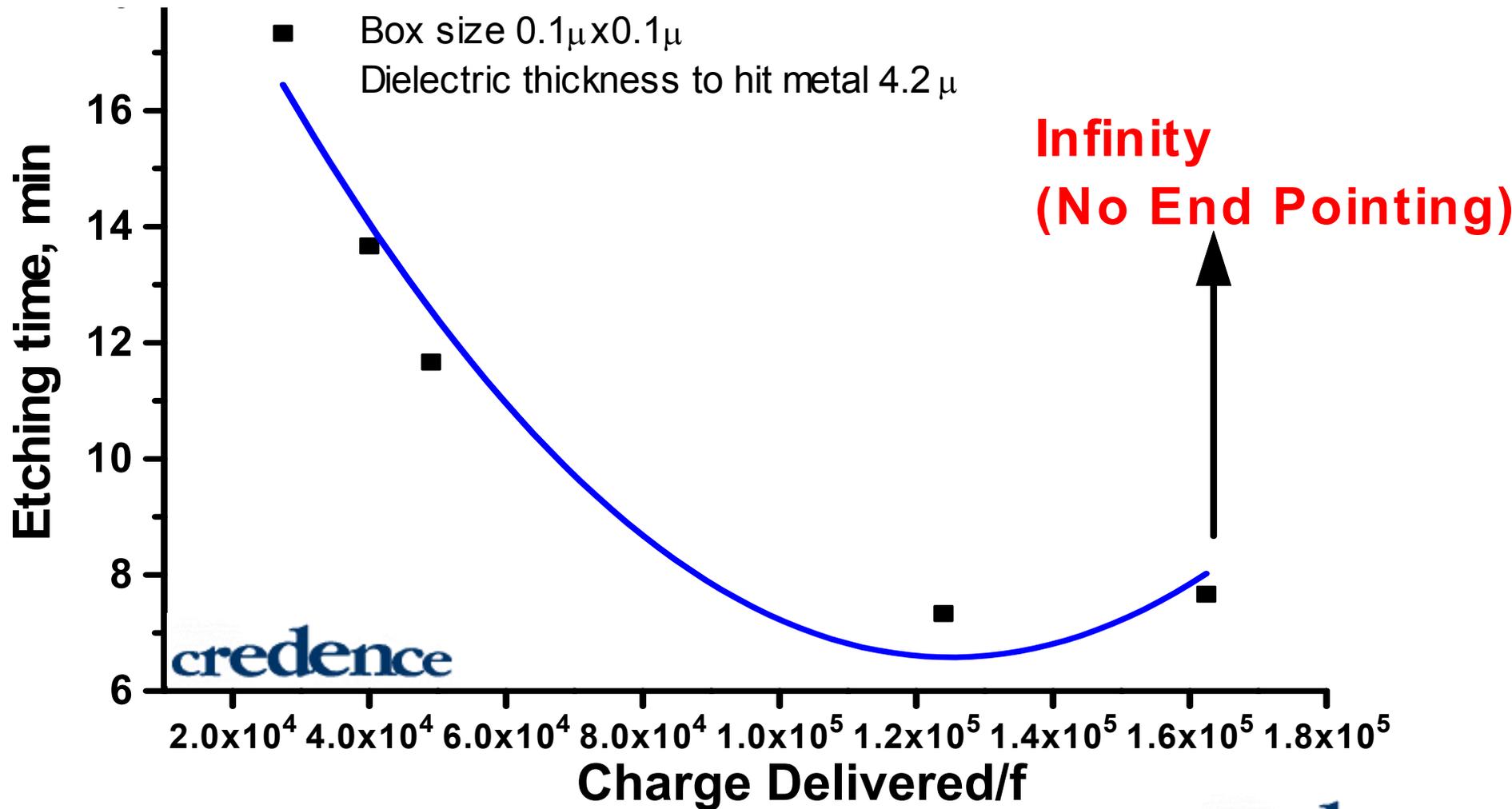
Box size 0.2umx0.2um

Etch time 9min – no End Pointing

Note: Long etching time to hit metal leads to funnel shape
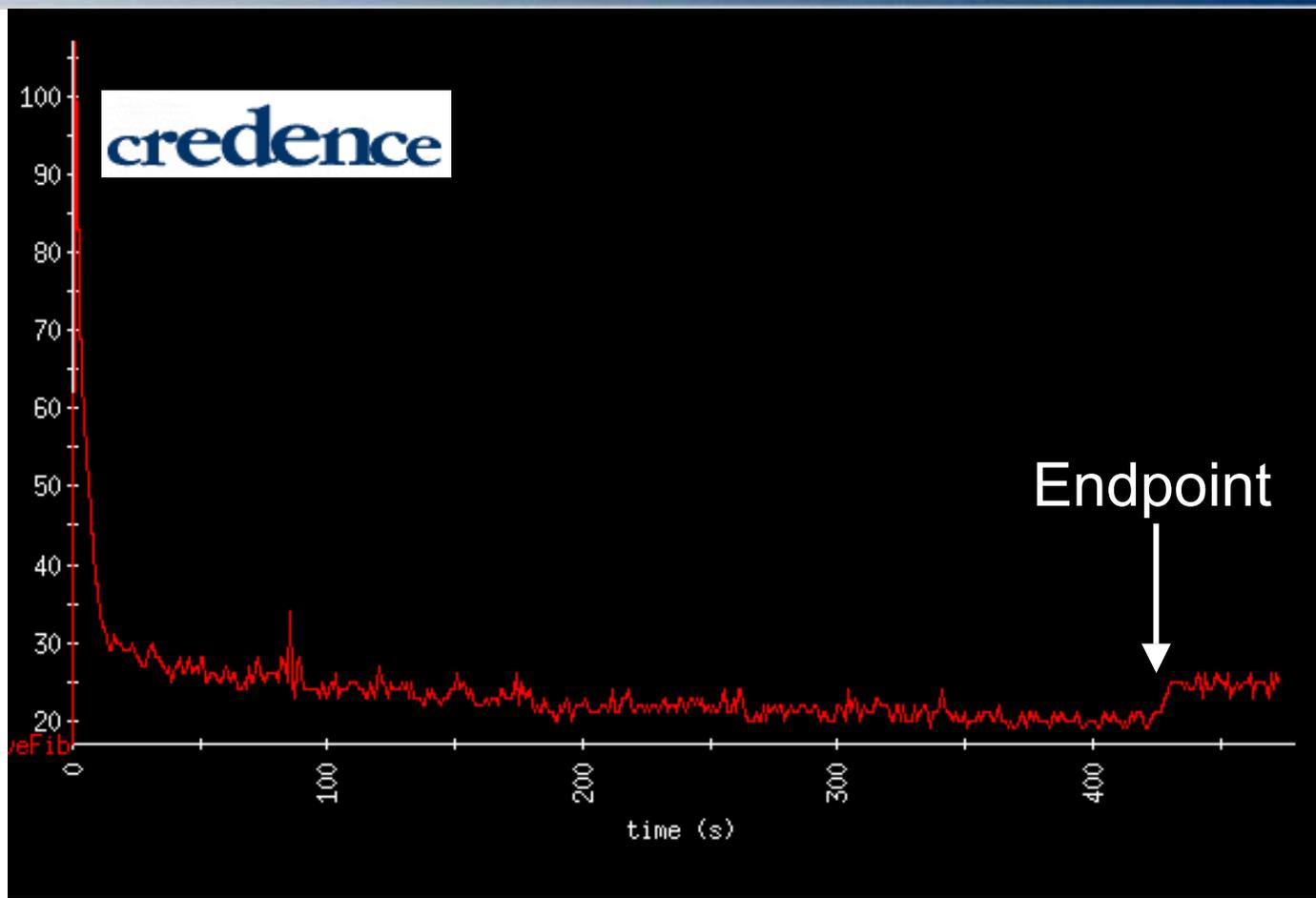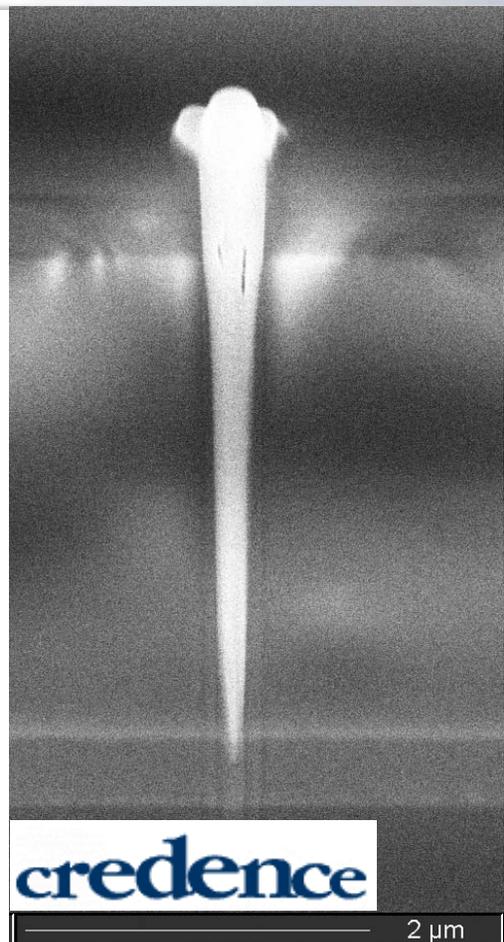
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Why Depth Limit Exists?

- When holes become so deep that ions delivered to hole bottom in one frame exceeds amount of XeF_2 reaching hole bottom within that frame, etching stops.

- Model
  - Greatest number of pixels, for which etching to given depth is feasible, is **proportional** to amount of XeF_2 reaching the bottom
  - Use greatest number of pixels as measure of XeF_2 coverage

Depth Limit Concept Investigated—Vary Number of Pixels

Box size $0.1\mu \times 0.1\mu$

Dielectric thickness to hit metal $4.2\,\mu$

Infinity (No End Pointing)

Etching time, min

Charge Delivered/f

Results: Successful End Pointing on deep metal

3pA, 100x100nm, 125x125pixels, Metal 4.2um deep.

Etch time 7.8min

Conclusions

- HAR hole milling's dependence on frame time explained by model which addresses rate of accumulation of assisting molecules at hole bottom

- Successful milling of HAR holes with aspect ratios >30 and reliable end point is demonstrated.

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