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KLA-Tencor
Accelerating Yield

A Couple Of Considerations on the Dynamics of Defectivity Generation in CMP Technology

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- **Post- CMP Defectivity is one of the major factors affecting its performance (&FAB yield), and scratching is its most problematic constituent.**
- **Cu is a very soft material, thereby for Cu CMP scratching is especially painful**

Identification of scratching mechanism, origin and source of scratching objects is vitally critical both in R&D (process & consumables) and production environments (process control & troubleshooting).

Compensating pad conditioning action is a MUST in CMP

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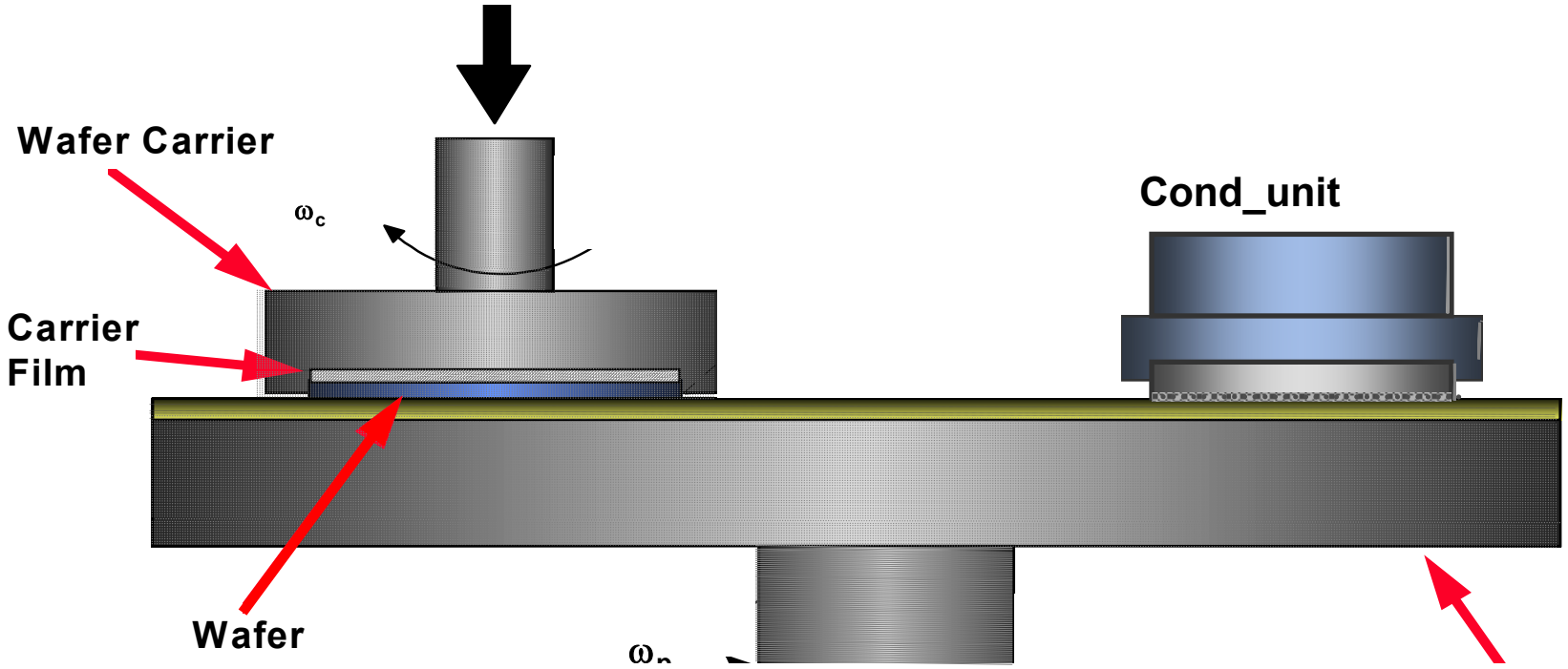
A two-object, wafer&pad, interactive system, with one of them, the wafer, purposely changing its state, in principle, is unstable.

A third object, pad conditioning unit, compensating for drifts in wafer/pad contact interface, is introduced to manage stability.



Pad Conditioning (PC)

- It is a combo of abrasive and chemical action applied to the pad surface.
- Its purpose - clean the existing pores and open new ones, remove by-products and upper glazed material.

Only balanced PC, exactly compensating for the wafer/pad interaction effects, provides both quality and stability.

- Too mild PC action does not compensate well, over-conditioning causes numerous quality issues.

The most frequently used CMP model is oversimplified and, thereby, misleading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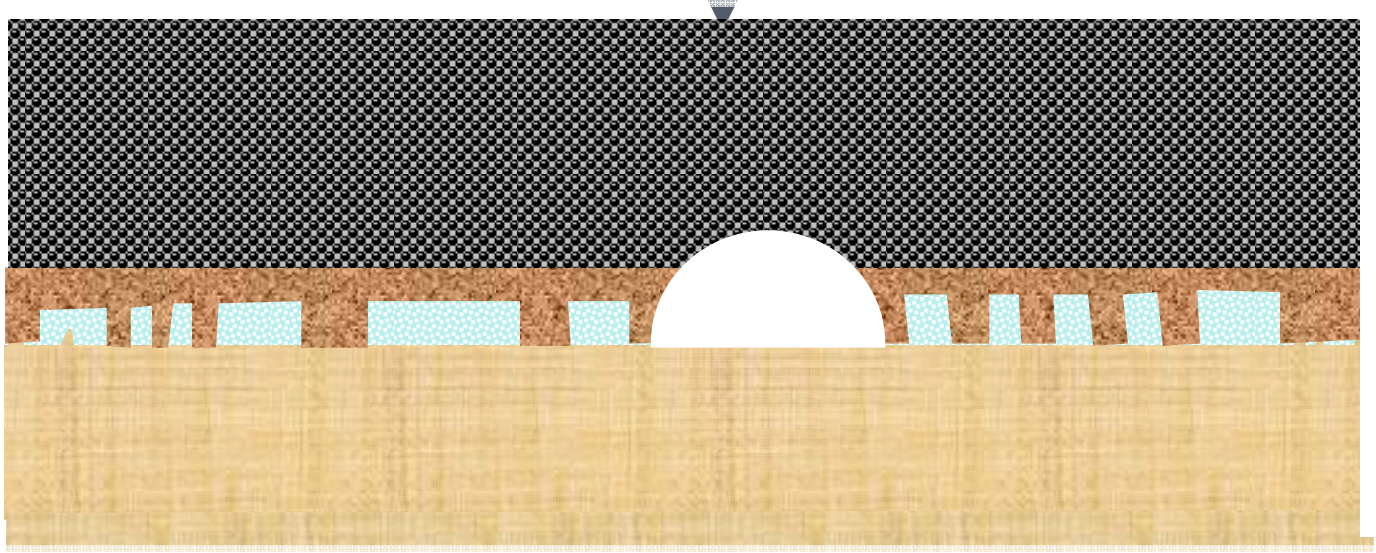
Wafer and pad interact via protrusion/intrusion engagement of fine features, asperities, and this is the key coupling phenomenon, which has always to be kept in mind, while discussing any CMP problem
(SHR, PL, D&E, defectivity, selectivity etc.)



The more intrusive and aggressive the asperities the stronger their impact on CMP performance

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Wafer Acually Engages With The Interfacial Skin Layer, Asperities And Debris…

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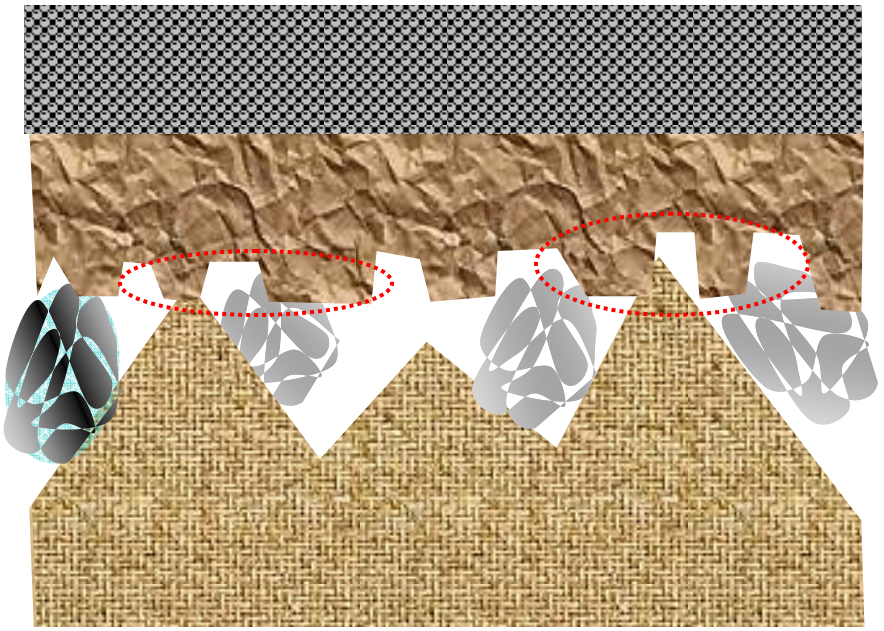
…and not with bulk polymer!



Three types of interactions in a system of two_surfaces & a_ball

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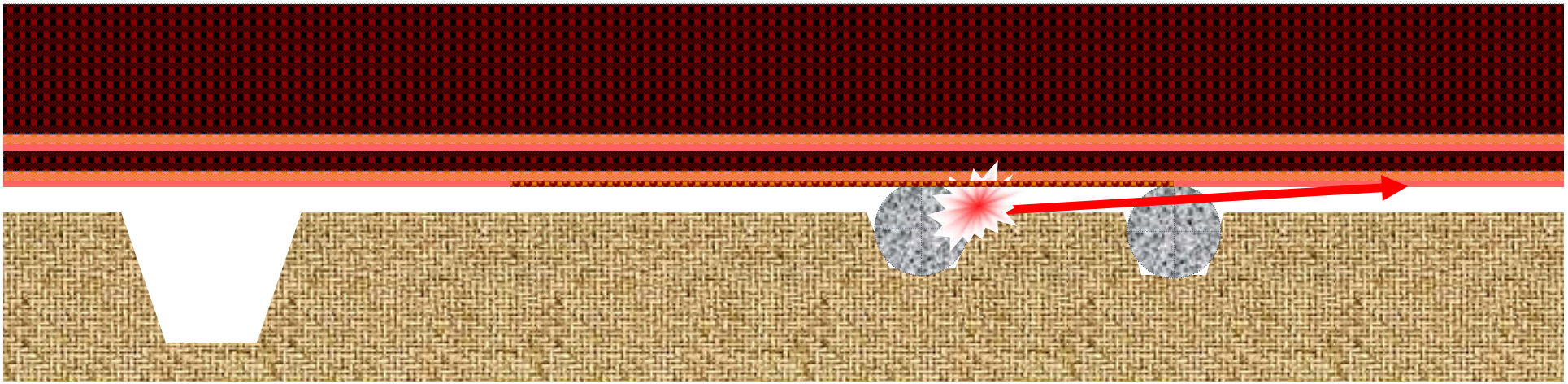
1. Hard object (HO) trapped in a deep surface defect ($d > r_{HO}$) – One translational degree of freedom (ODOF) → **scratching**
2. HO trapped in a shallow ($d < r_{HO}$) surface defect (capable to roll out) - Two degrees of freedom, namely, **translation and rolling** (TDOF) → HO pattern printing. "Rolling stones"
3. HO trapped by defects in both surfaces – Zero degrees of freedom (ZDOF)→ **damage** due to stress accumulation until one of the defects or the HO is destroyed or strongly deformed.



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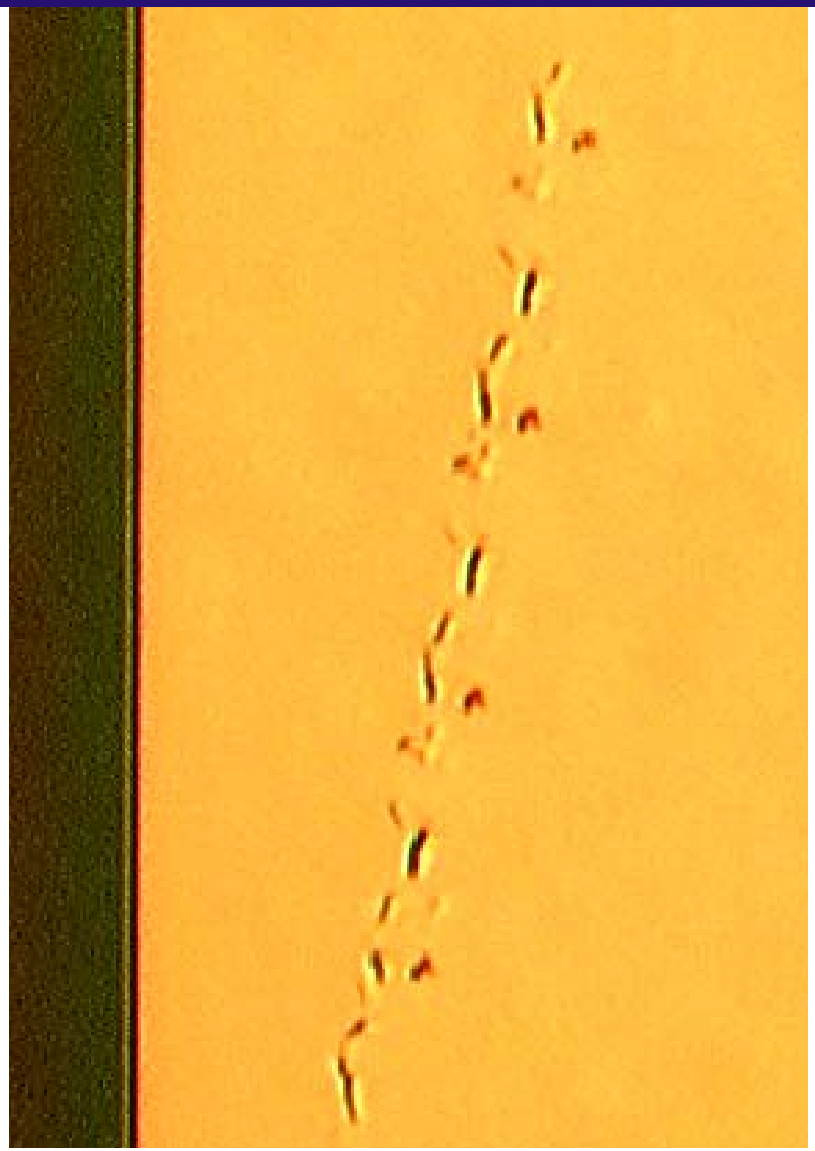
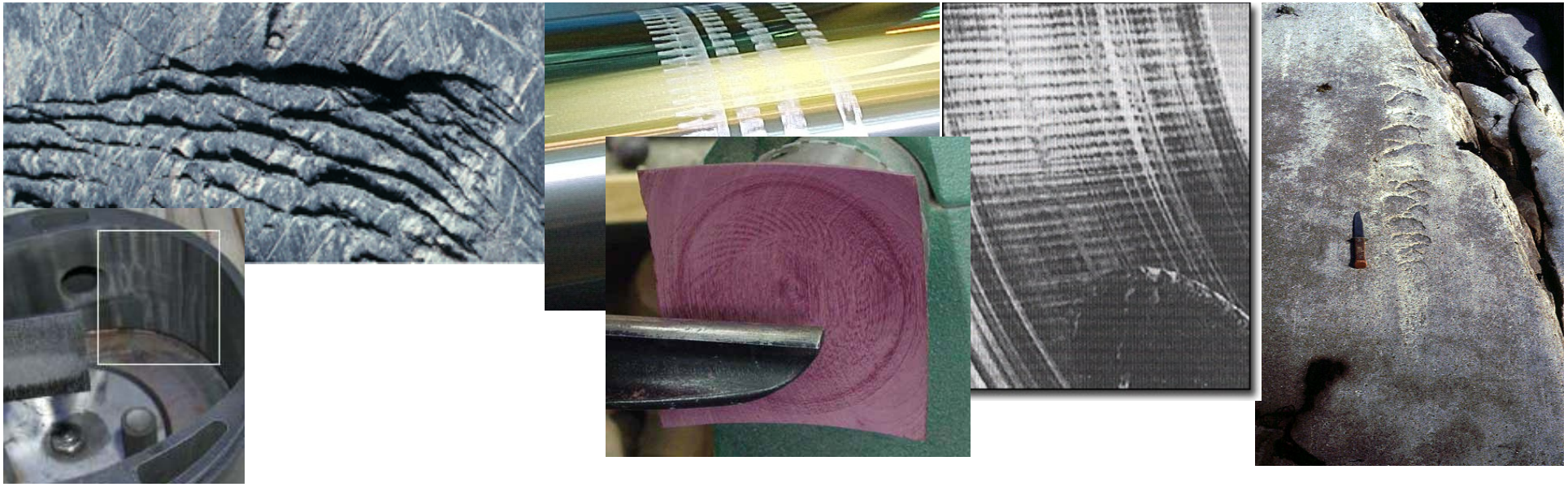
Analyze the details of the particle trajectories in the bubble-chamber analysis fashion





“Chatter”marks

It looks like the “chatter” marks indeed are periodic prints originating to a rolling motion of a large rough particle, a “Rolling Stone”.

Chatter mark- a mark left on something that has been machined, caused by vibration during the machining process.

Chatter mark- (YG) periodic deformation marks produced as a result of “Stick-and-Slip” translation

The “Rolling Stone” size is a good indication of its origin

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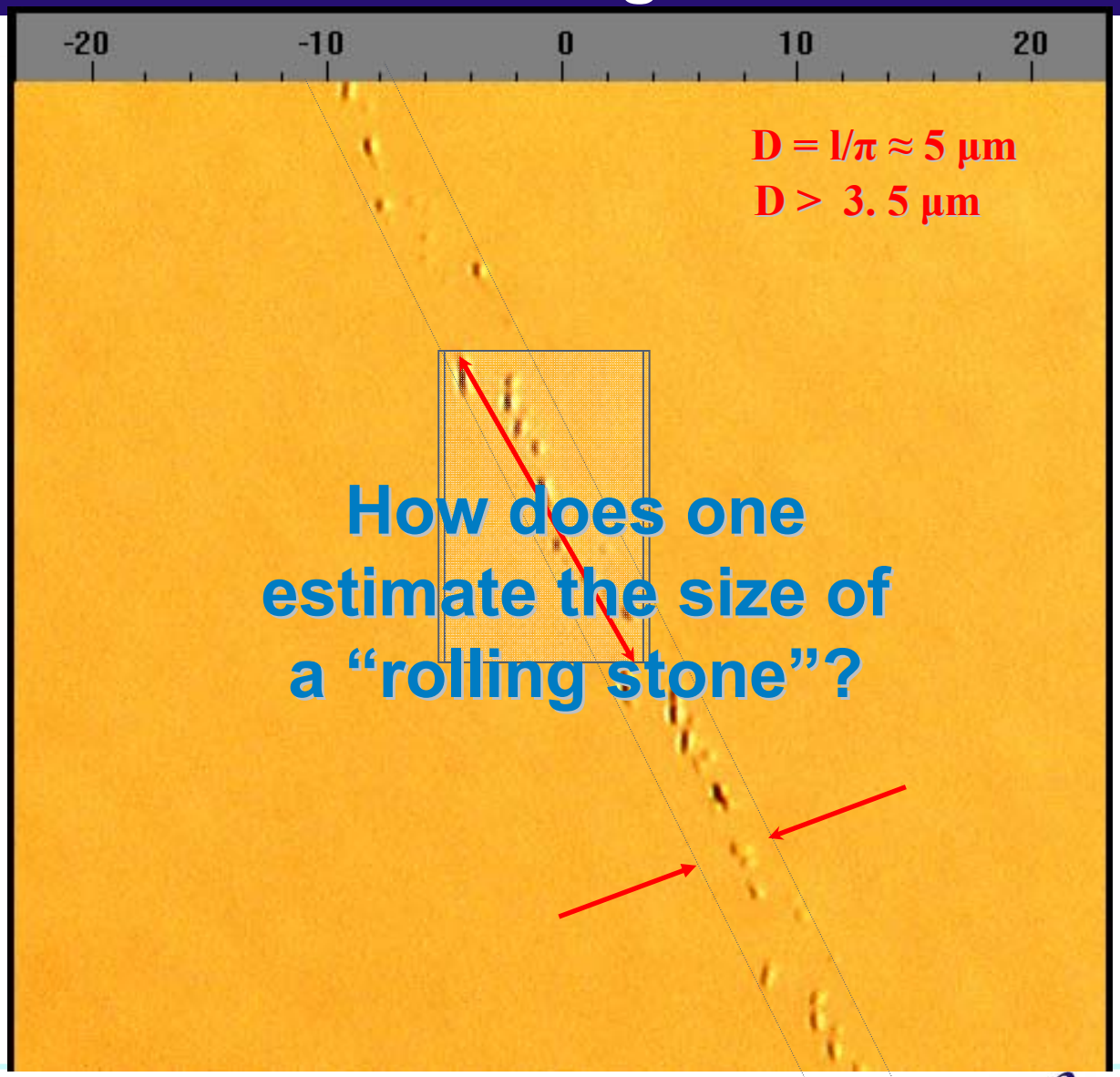
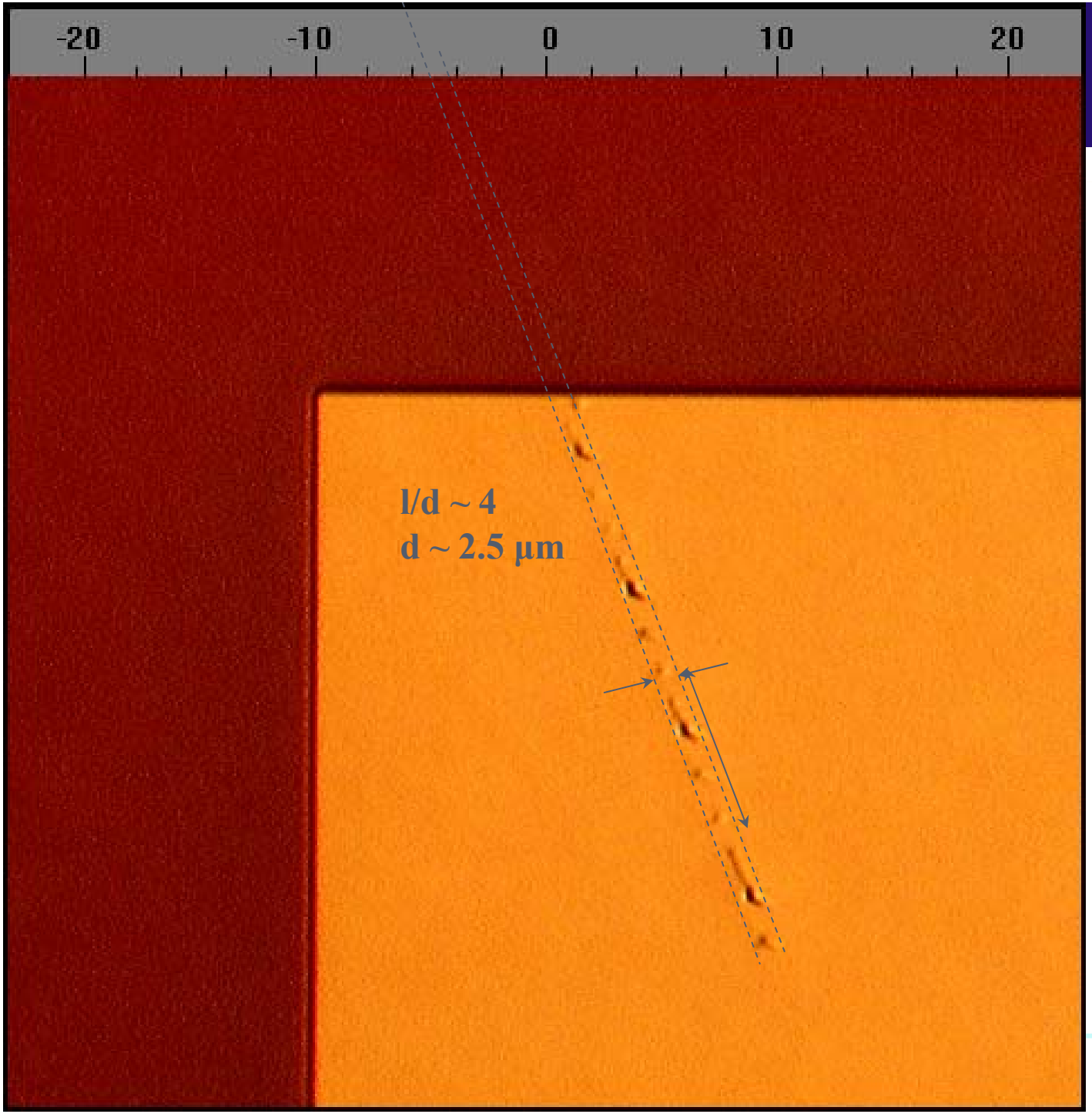


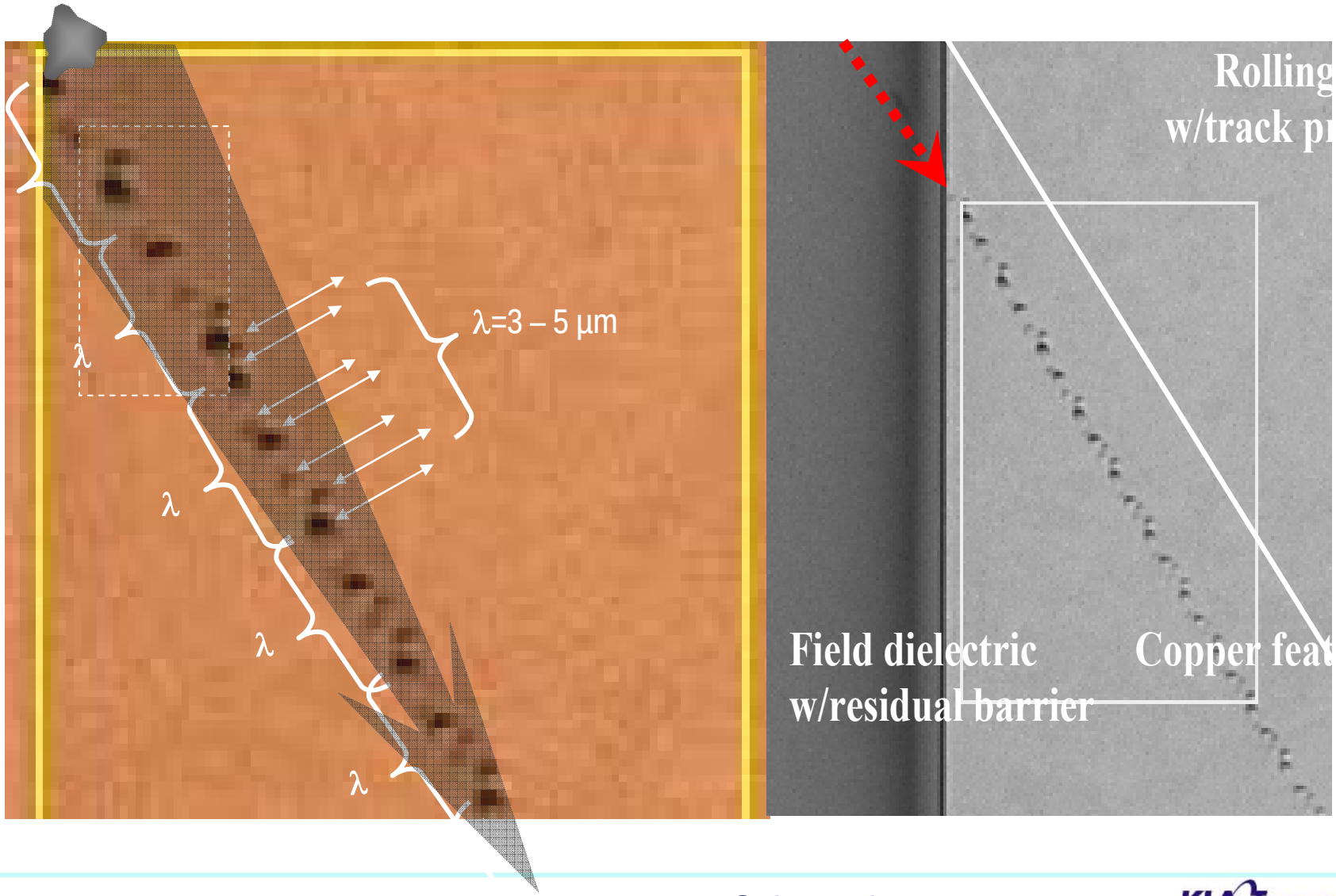


In the most cases

$\lambda \approx (1.5 - 3)d$

meaning that RS is shaped as a rough base ball

An early published case of “rolling stones”



Particle erosion/distortion during rolling

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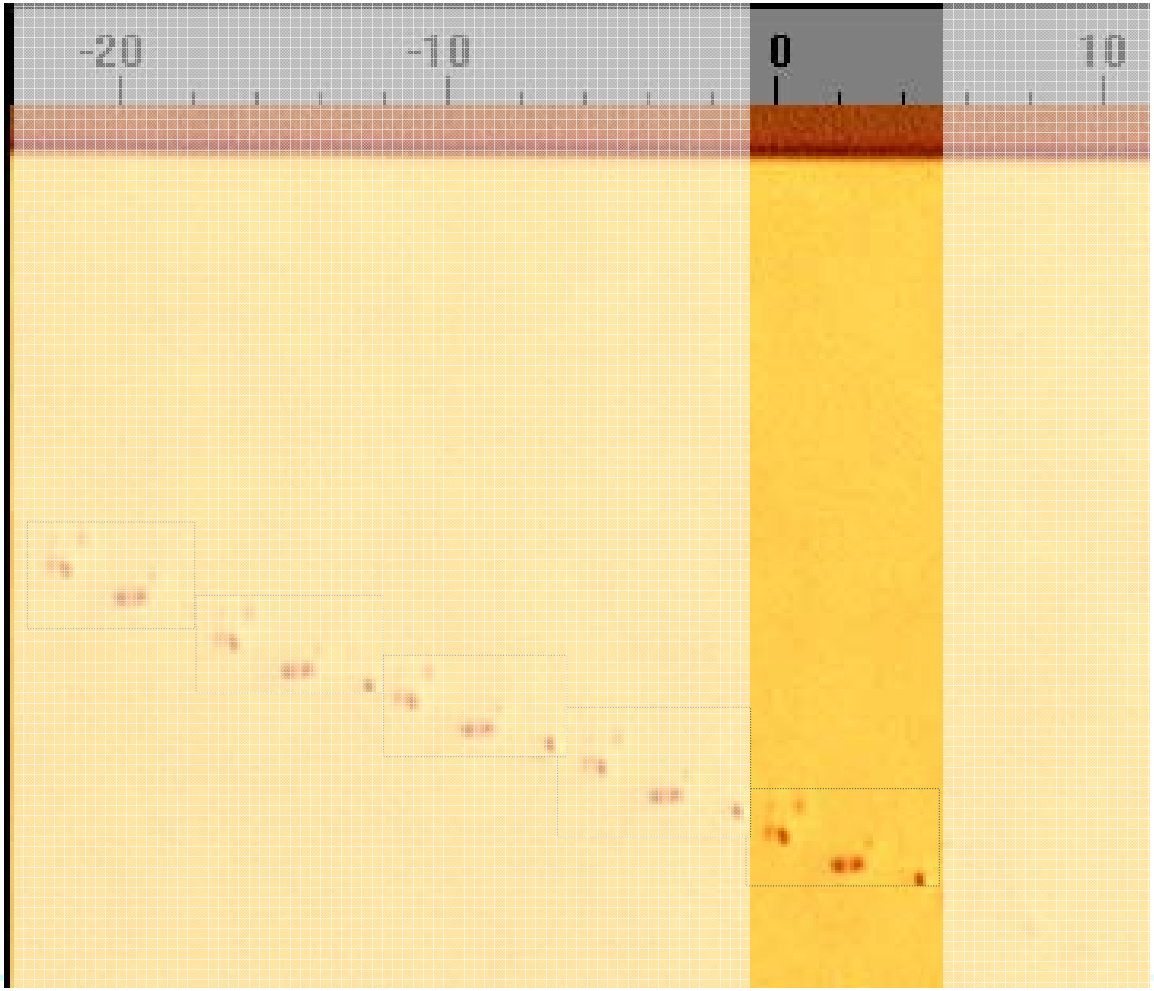

RS profile

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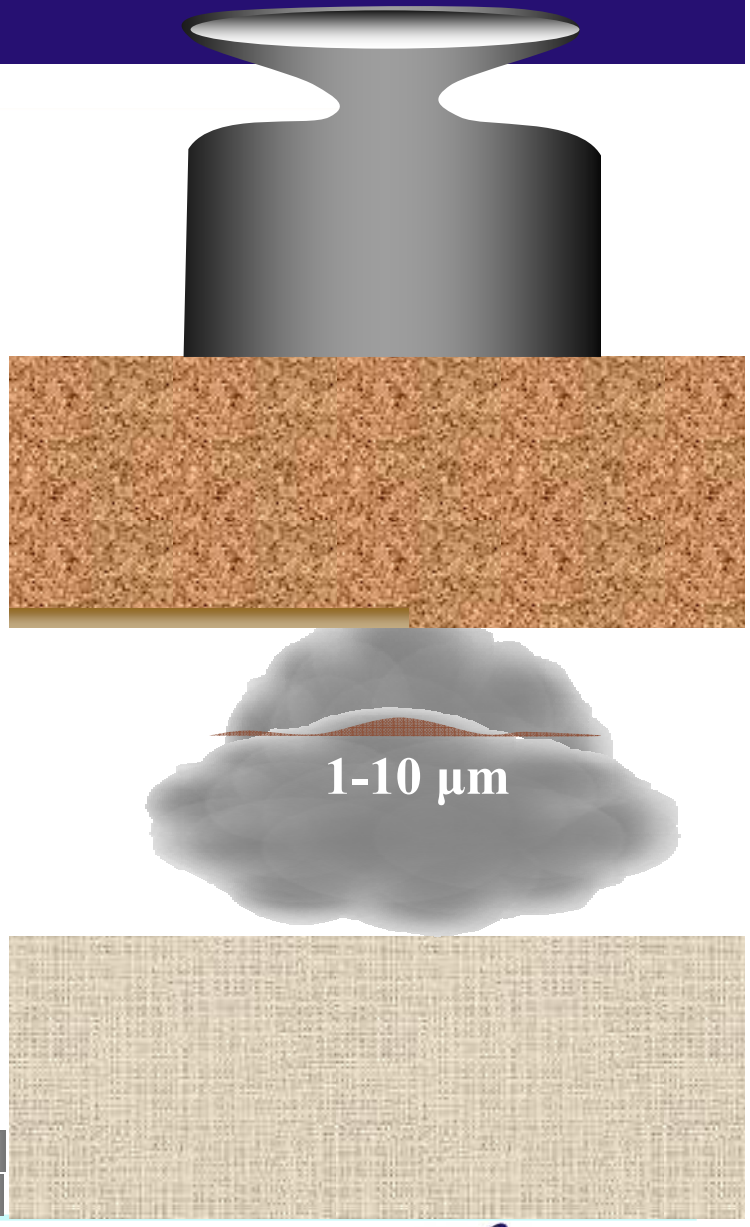
- Shaped like a rough base ball (λ/w ≈1.5 - 3)
- Sized 1-10 microns
- Hard enough to leave prints on copper, but relatively soft not to damage significantly hard dielectrics (silica).
- Compressed/eroded/deformed, but preserves its integrity while being rolled between the pad and the wafer
- Pops up suddenly, and suddenly disappears
- Causes "shallow" (width>>depth), and frequently bundle scratching in ODOF cases



Now, when we've profiled the bad guys let's consider where they can arrive from

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RS candidates:
1. Slurry aggregates

- It requires ~10^6 slurry abrasive particles to build a 5 μm aggregate, which is not likely to happen in short period of time between filtering point and point of use.
- Aggregates have loose structure and it is hard to believe they can withstand high polishing pressure and friction and preserve their structural integrity, as RS do.

Slurry aggregates are not the likely candidates for the RS role

RS candidates:
2. Cu grains

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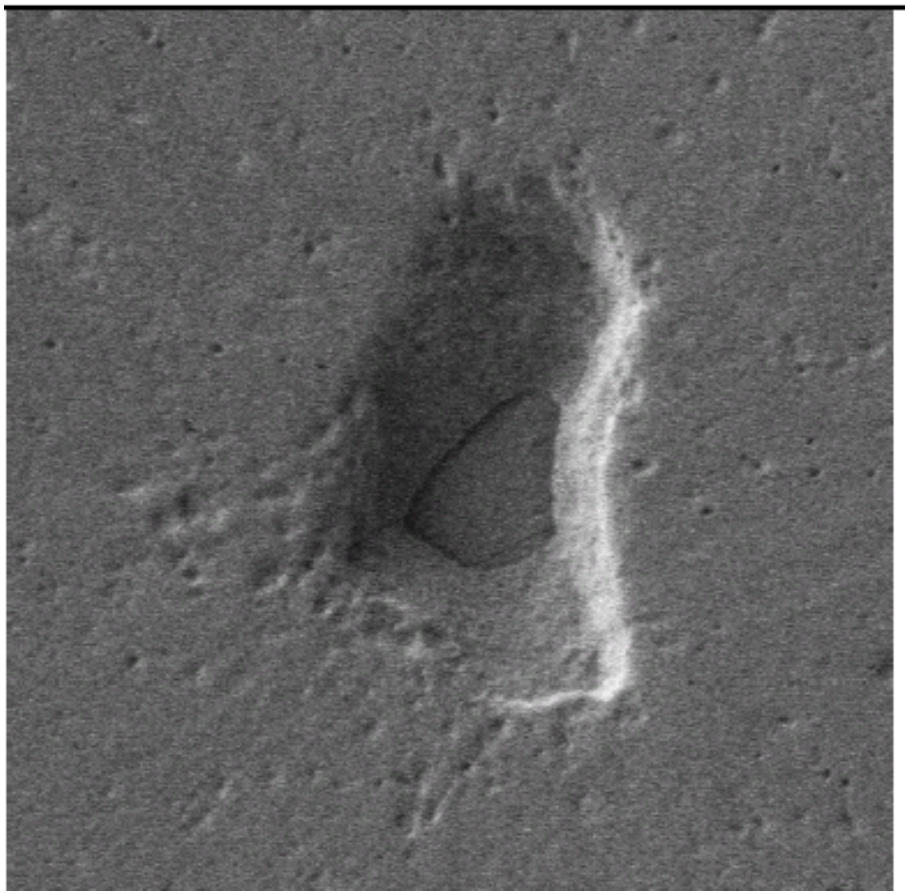
- Cu grains are known to be pulled sometimes out.
- However, the CuDD grains hardly get bigger than 1-2 μm

Cu grains also do not fit the RS profile



RS candidates:
3. PC debris (PCD)

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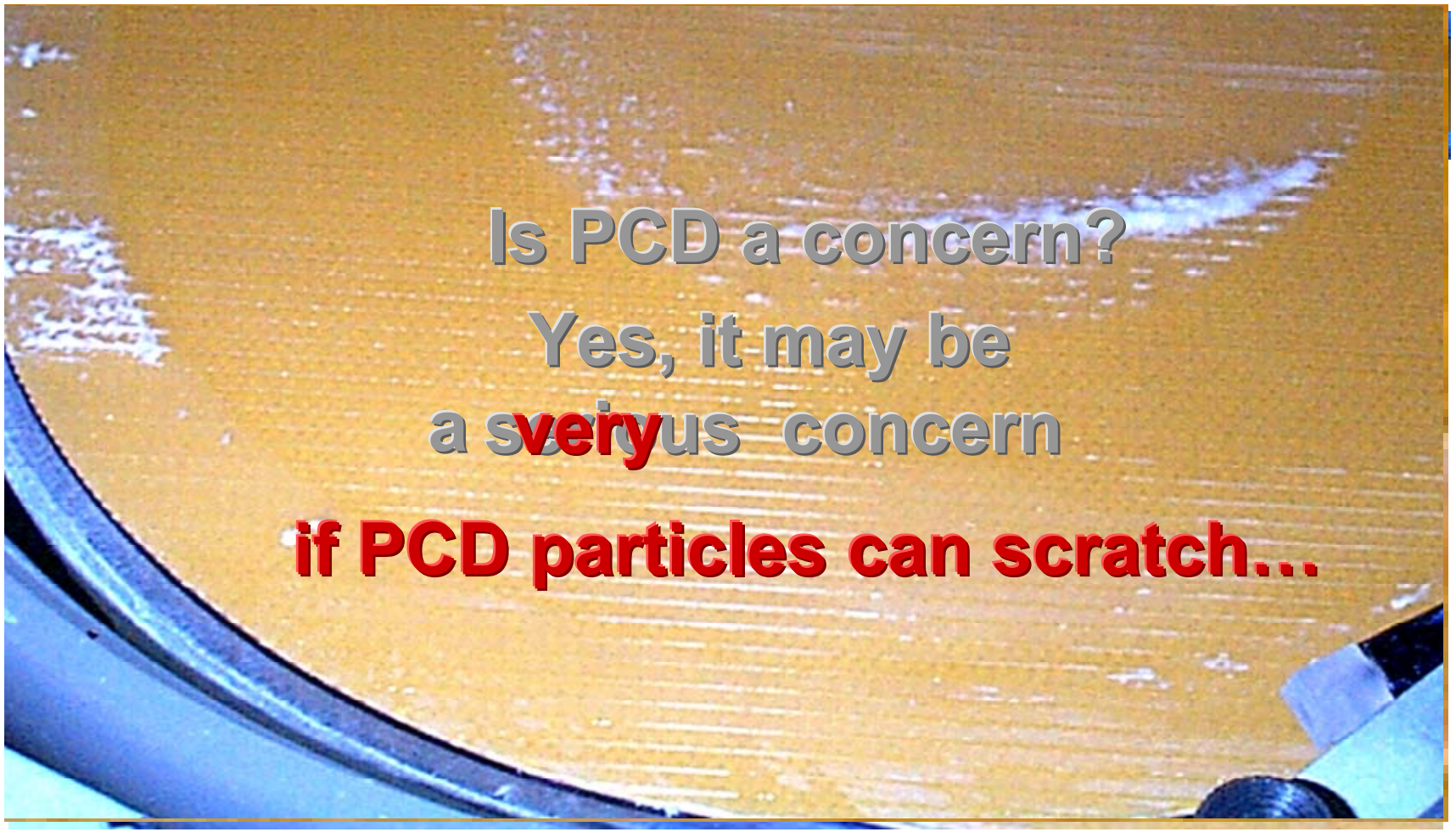

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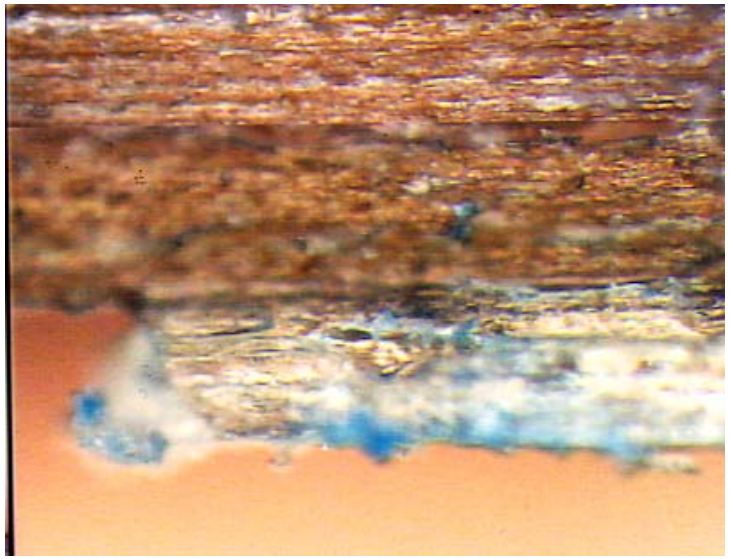
…and they do get this capability while being impregnated with process components

- Fractured and cracked PCD species are easily impregnated with precipitated slurry agglomerates and process by-products, which converts them into reasonably hard and rough species capable to abrade and imprint.
- In the same time PCD particles still preserve significant portion of the polymer framework helping to keep their structural integrity while being rolled between the wafer and the pad.

PCD particles are excellent candidates for the RS role



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RS candidates:
4. PC_unit precipitation deposits

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- PC_unit accumulates slurry precipitate over its surface and edge.
- Getting thick precipitate cracks and delaminates, releasing large particles capable to scratch.

PC_unit deposits are also very realistic potential sources of scratching particles

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Scratches
(ODOF and ZDOF cases)

ZDOF case- scratchier trapped by both upper and lower surface defects

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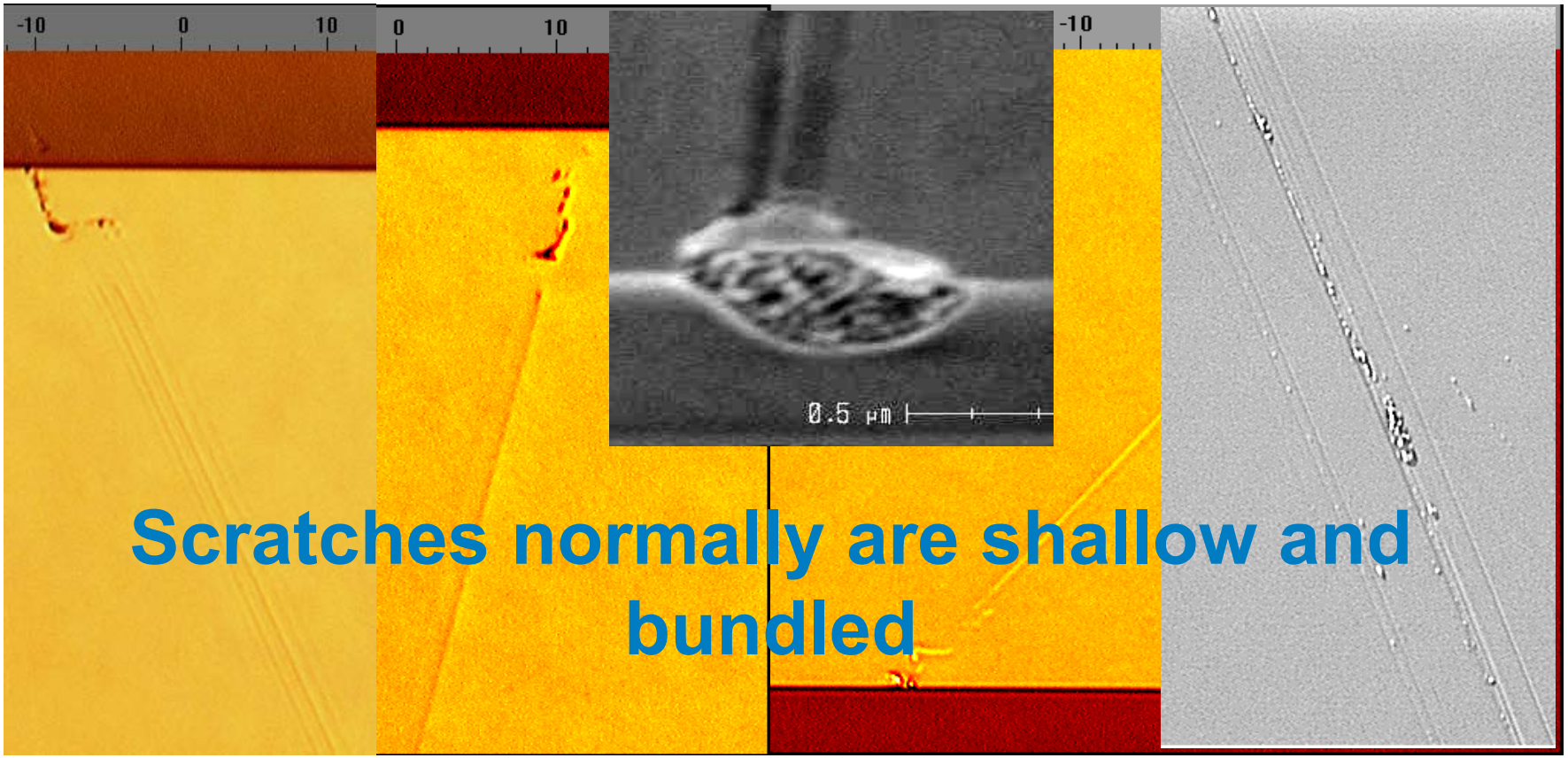

Scratches normally are shallow and bundled

An important question at the end


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Out of three major process steps, namely, BULK, SL and BARRIER&BUFF, which one is the most "scratch productive"?

Considerations

I. Bulk

- RR ~ 100 A/sec (6000 Å/min)
- scratch depth ~ 1000 Å

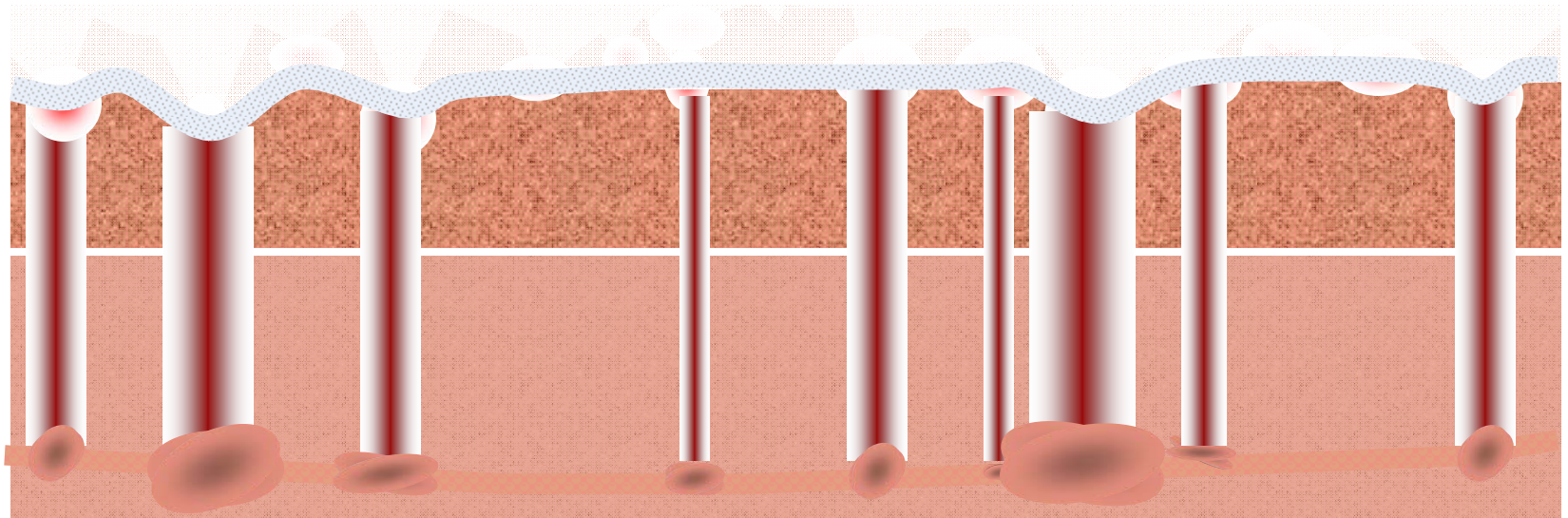
- It requires 10 sec to polish the scratch out.
- Scratch generation is not cumulative. Only the scratches generated at the last 10 seconds of the BULK step are transferred to the SL step, at which, however, they will be anywhere removed.

Scratching generated during the BULK step would not be a very endangering matter,

If…

… if early BULK scratches were entirely harmless

And they are not!



An early scratch could be completely polished out except a few deepest spots, but these spots readily undergo **stress-induced corrosion** and, due to this, look like regular corrosion spots.

Their lined up arrangement along the polishing tracks indicates that indeed it is just decoration of a former scratch deepest points.

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Considerations

II. SL

- The heterogeneous surface appears first, and the secondary topography (recess SH) starts to develop at SL.
- Also, scratches induced at this phase, will have little chance to be removed at the next step, especially if high selectivity BARRIER process is used.
- However, everything is mild at SL (DF, amount of material to be removed, RR, pad load etc.), so scratch generation efficiency (frequency, depth, length) is significantly lower and the scratches are much shallower than the BULK ones.

Soft Landing --- Mild (if any) Scratching

Considerations

III. Barrier&Buff (No Copper removal HS case)

B&B step appears to have most quality endangering one layer of:

- Cumulative scratch formation
- Poor (CuO) lubricity, possibility of stick-and-slip
- High sensitivity
- Exposed material (Cu, Barrier, DE) surface hydrophilicity, resulting in sharp COF and other local surface property undulations.

B&B are the most endangering steps as far as the scratching is concerned!

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Summary

- **By analyzing details of scratch structure, one can learn a lot about the scratching mechanism, root cause and possible problem solution.**
- **Pad conditioning debris and conditioning unit deposits should be seriously considered** while dealing with scratching issues
- **PC action** is critical at each process step and **has to be finely tuned to the lowest possible aggressiveness.**
- **Although BULK scratches are** normally wiped out**, they may leave behind lined up sequences of stress induced corrosion spots.**
- **Barrier&Buff** potentially are **the most scratch-productive** steps, thereby **PC action at this phase has to be as delicate as possible (and also preferentially *ex situ*).**

Thank you for your attention!

EE 298-12 State Technology and Devices Seminar

http://microlab.berkeley.edu/text/298-12.seminar

Friday, 23 March 2007 1-2 pm in the Hogan Room (521 Cory)

Dynamics Of Defect Generation

In CMP Technology

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Abstract and slides available at

http://microlab.berkeley.edu/text/298-12.seminar

http://microlab.berkeley.edu/text/seminars/2007slides.html

Sliding on the heterogeneous CuDD surface…


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…could be accompanied with somersaulting on the soft Cu sections

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