Characterization of Planarization Capability of Polishing Pad

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Introduction

- Local Planarization
  - Planarization efficiency, step height reduction
- Global planarization
  - Planarization length
  - Proposing a new concept for consumable characterizations: Relaxation length
- Subject used for this study: oxide CMP
  - Relative simpler
  - Easier to collect data

Local Planarization

Approach I. Planarization efficiency (PE)

$PE = 1- R_T / R_L$

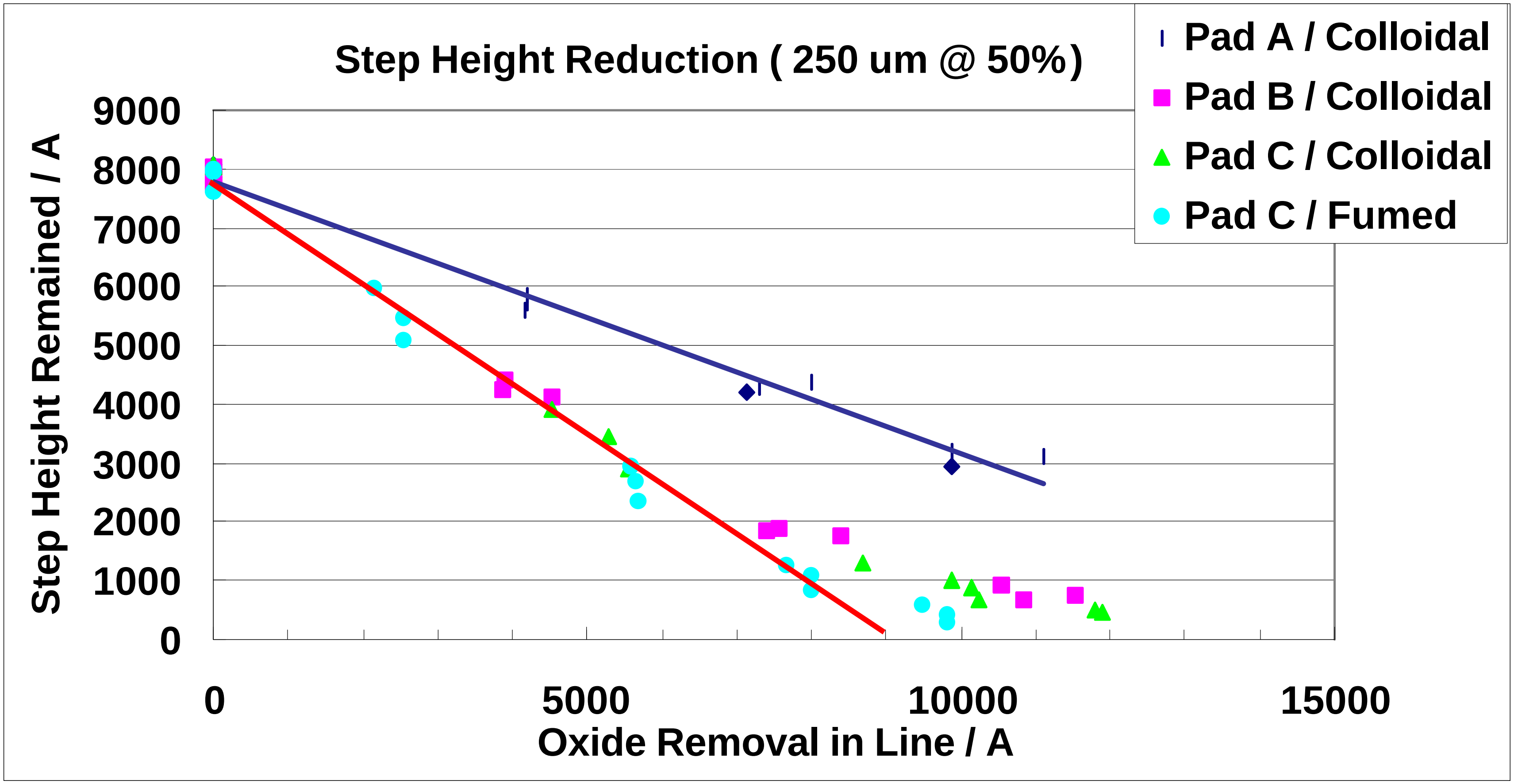
$SH(t) = SH(t=0) – (R_L – R_T)$

$SH(t) = SH(t=0) – PE \times R_L$

PE is the slope in the plot of step height as function of removal in line.

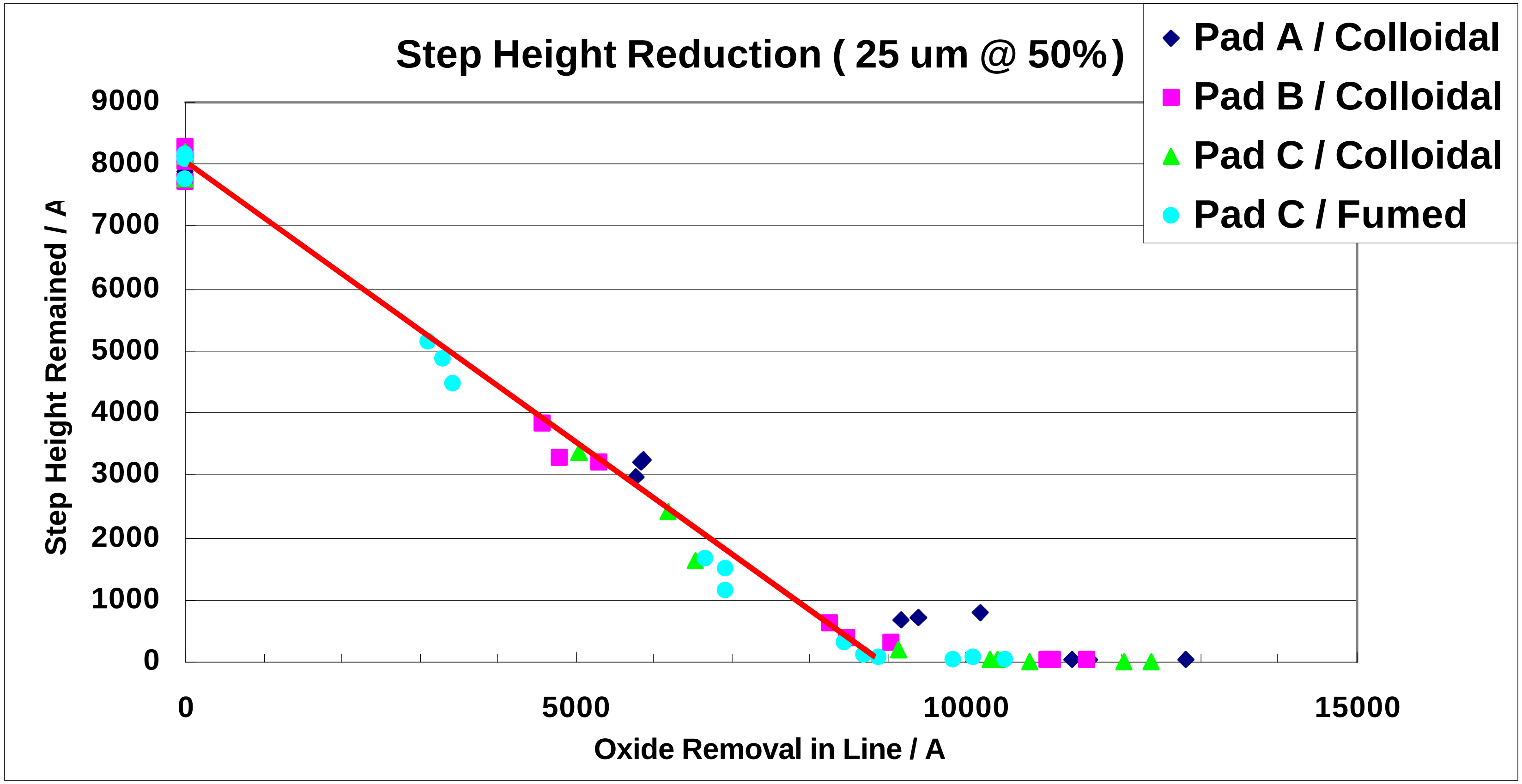
Approach II. Step height reduction as function of polishing time(removal in field)

Step Height Reduction of 250 /250 μm Structure



Pad A, B, and C are three different versions of Hard Porous Pads.

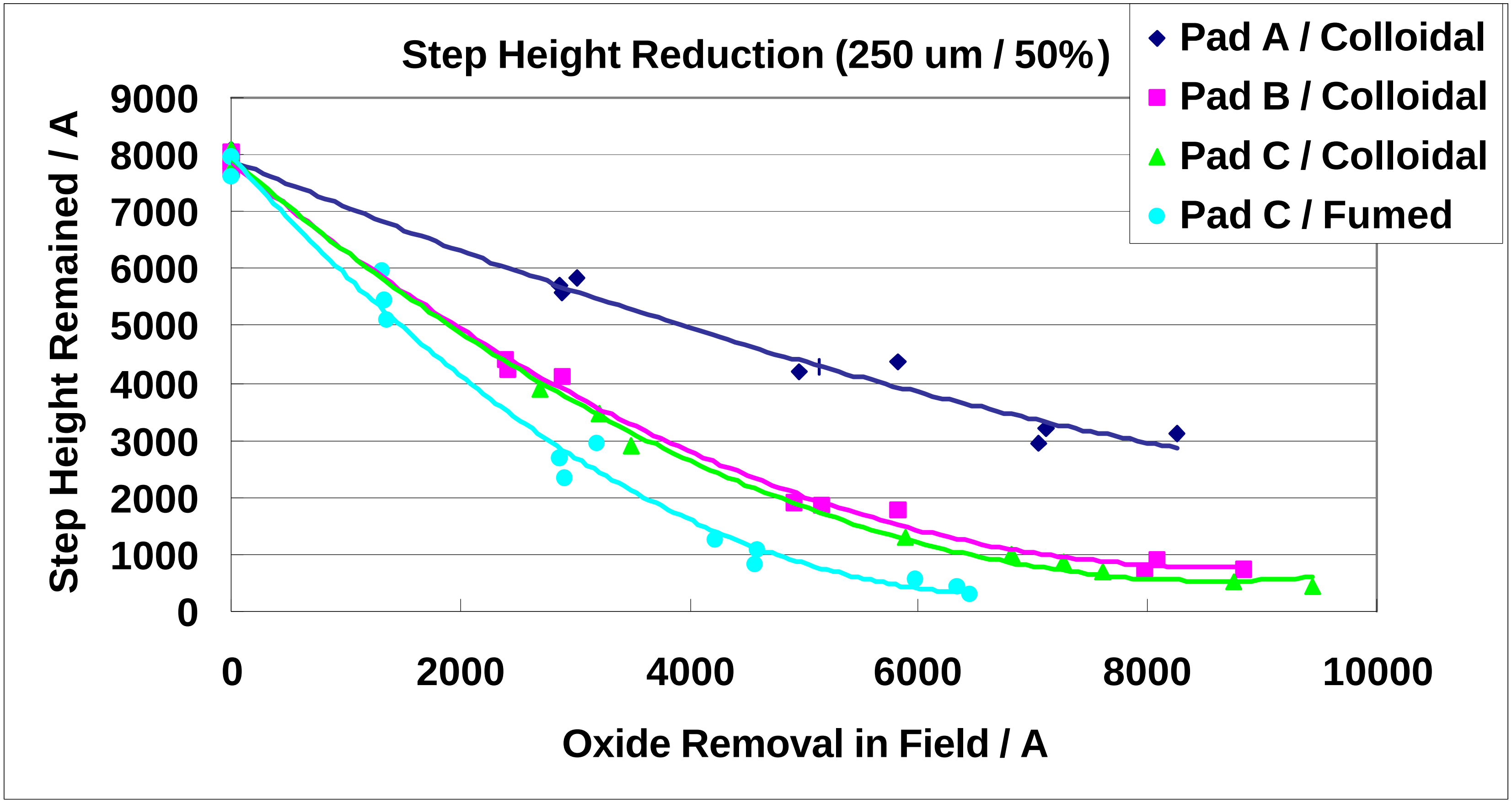
Step Height Reduction of 25 /25 µm Structure



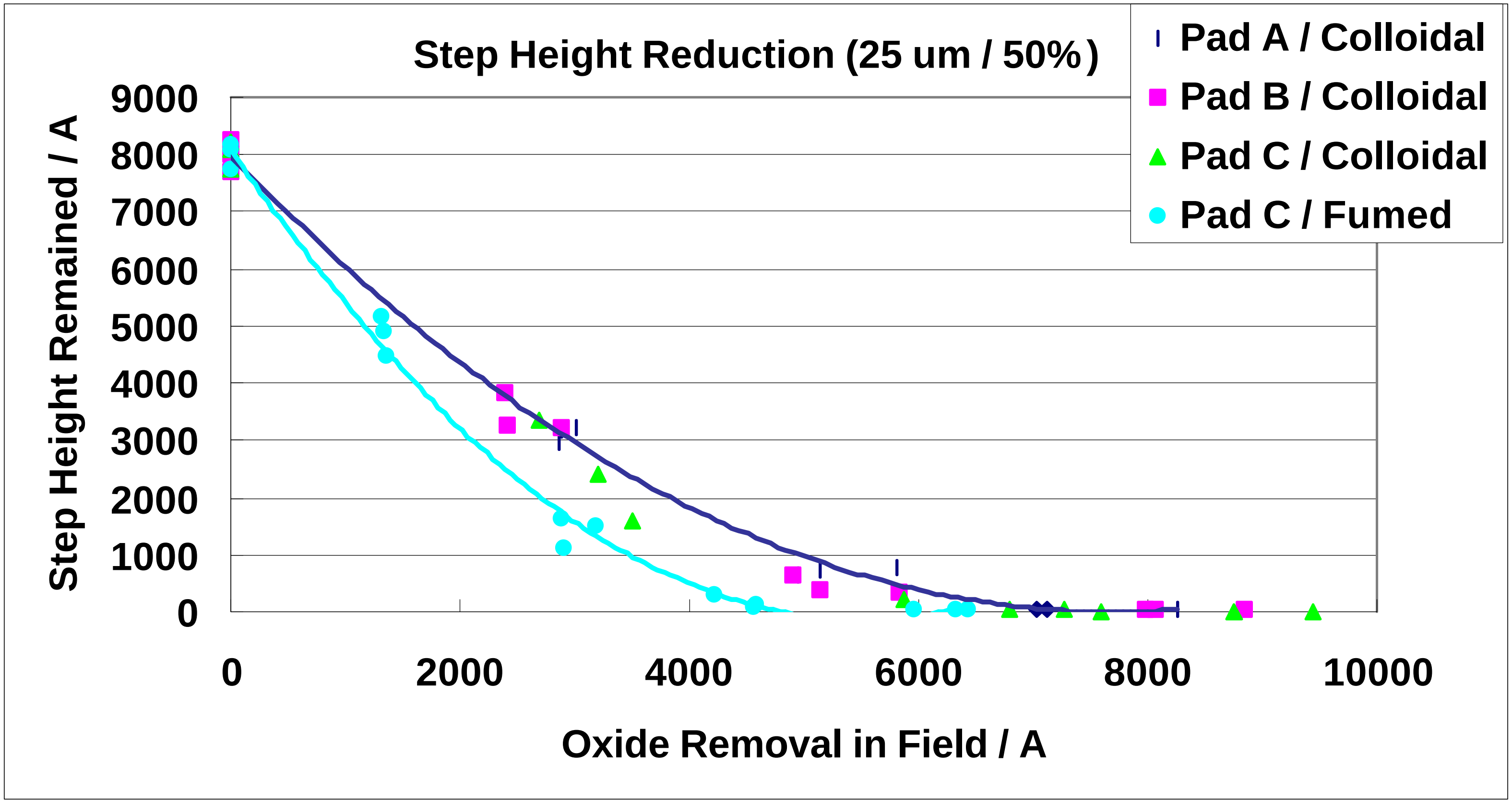
PE is feature size dependent

PE may not be a constant, could decrease with decreasing step height

Step Height Reduction of 250 /250 μm Structure



Step Height Reduction of 25 /25 μm Structure



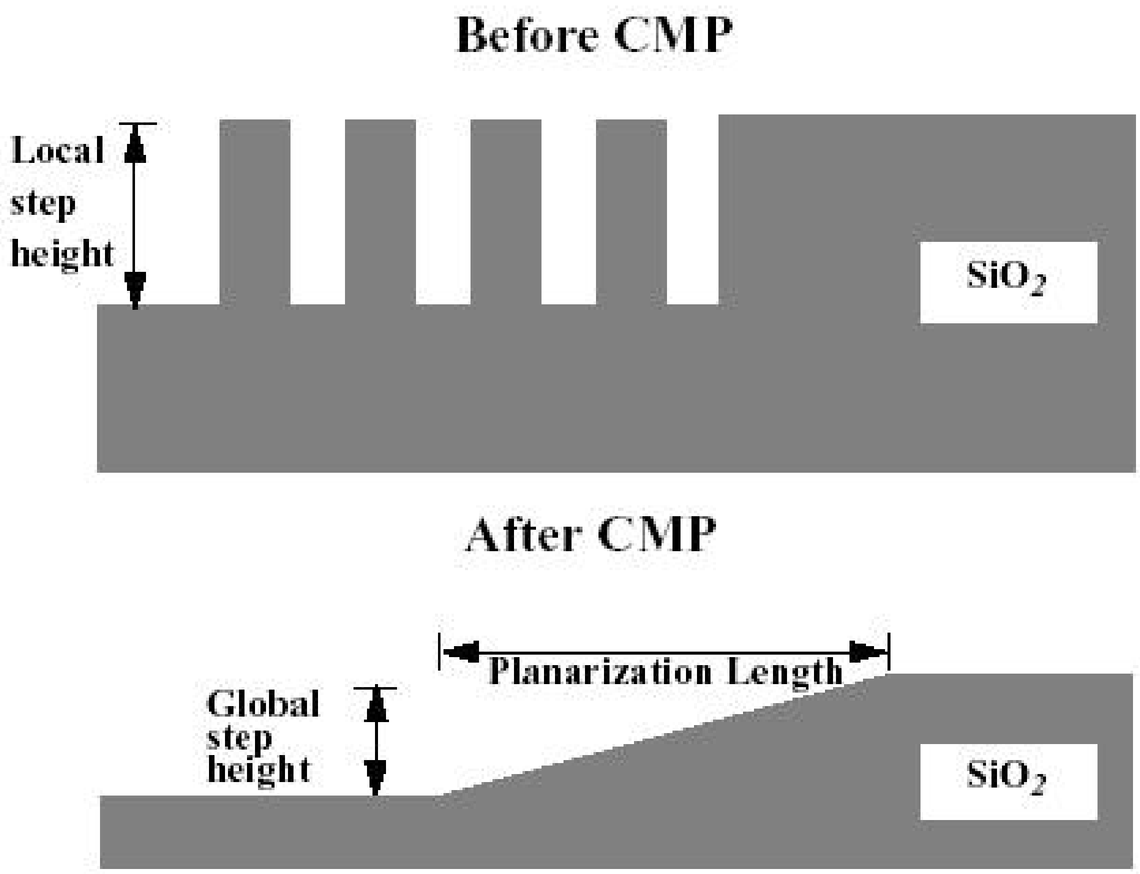
Comparison Between Approaches

Approach I (PE)	Approach II (SH reduction)
• Large feature: Pad B & C perform better than Pad A	• Large feature: Pad B & C perform better than Pad A
• Small feature: All three pads perform about the same	• Small feature: All three pads perform about the same
• Slurry: no effect on performance	• Slurry: fumed silica performs better than colloidal silica

Conclusions from the two approaches may not be the same

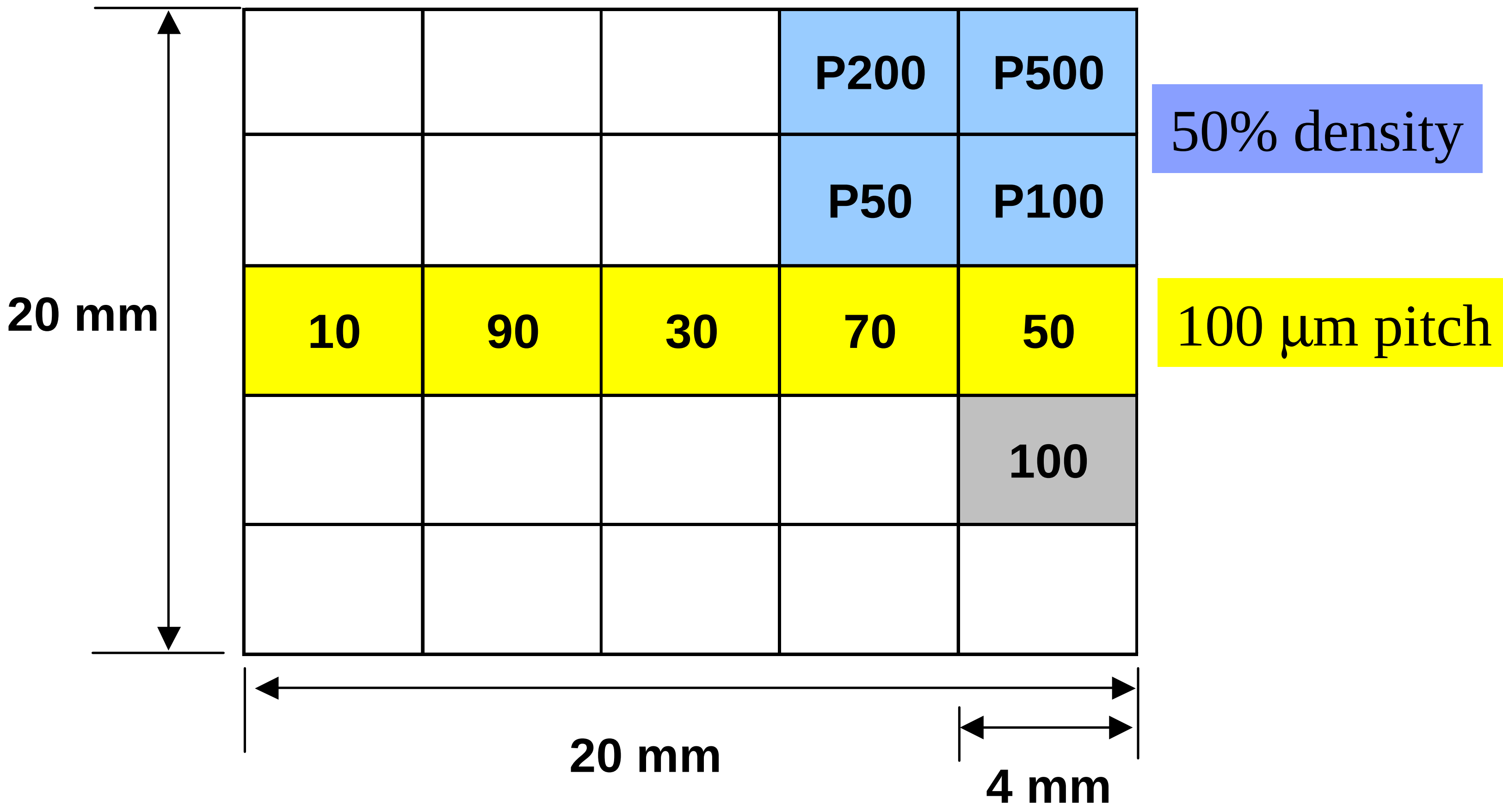
Approach II is a hybrid of local and global

Global Planarization –Planarization Length

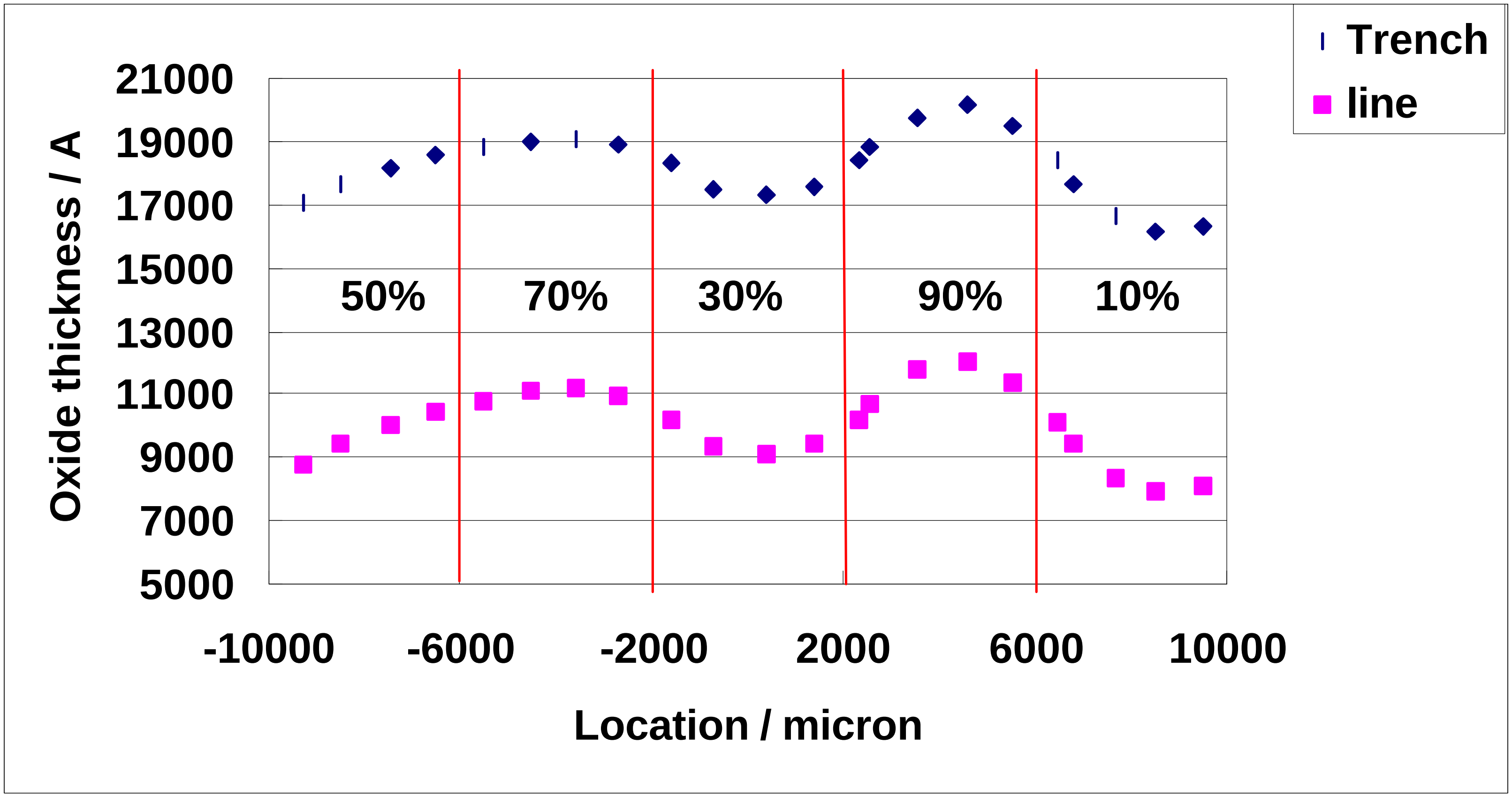


B. Stine, et al: CMP-MIC 1997

Pattern Wafer Layout

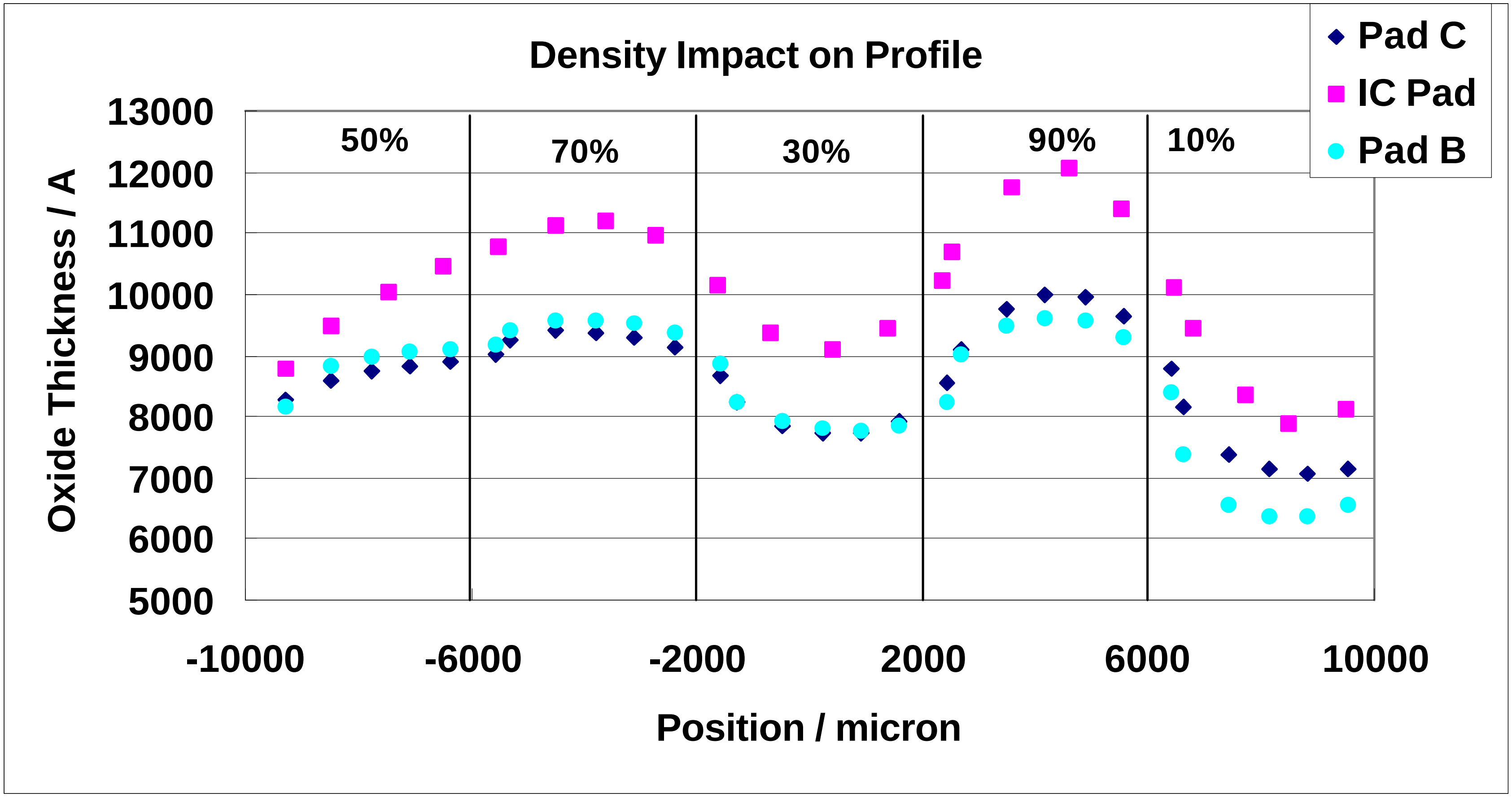


Comparison of Profiles of Trench & Line



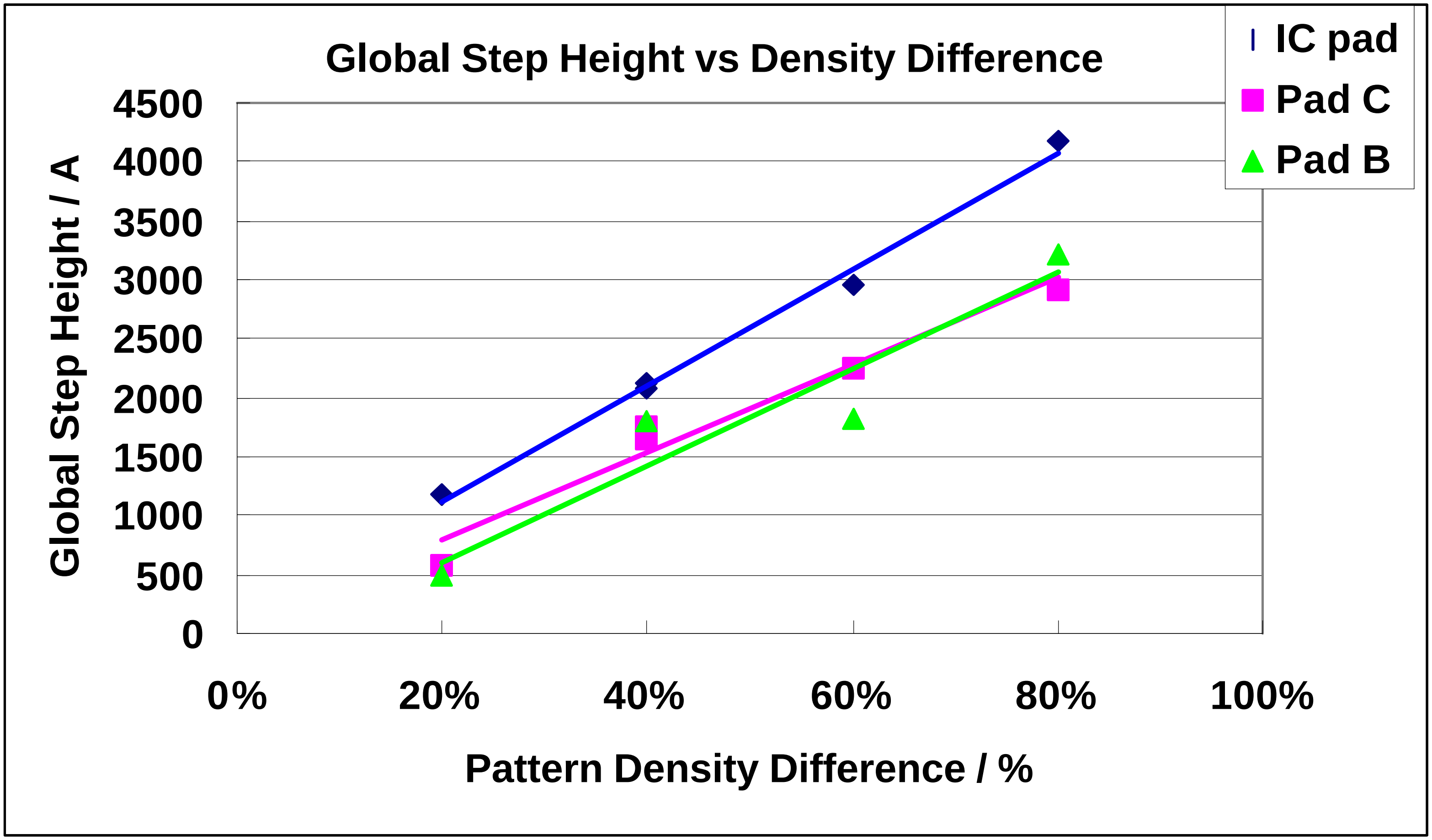
Initial film thickness ~ 20.4 KA; step height ~ 8000 A
Trench and line have similar profiles

Density Effect on Topographic Profile of Line



Initial film thickness: Pad C & B ~ 19.1 KA; IC pad ~20.4 KA

Density Effect on Topographic Profile of Line



Global step height is a function of density variation

Relaxation Model

- **Pad deformation controls the topographic profile**
- **Pad deformation profile can be described by exponential function**

$Thickness = A + B_1 exp(-C*X) + B_2 exp(-C*(4000-X))$

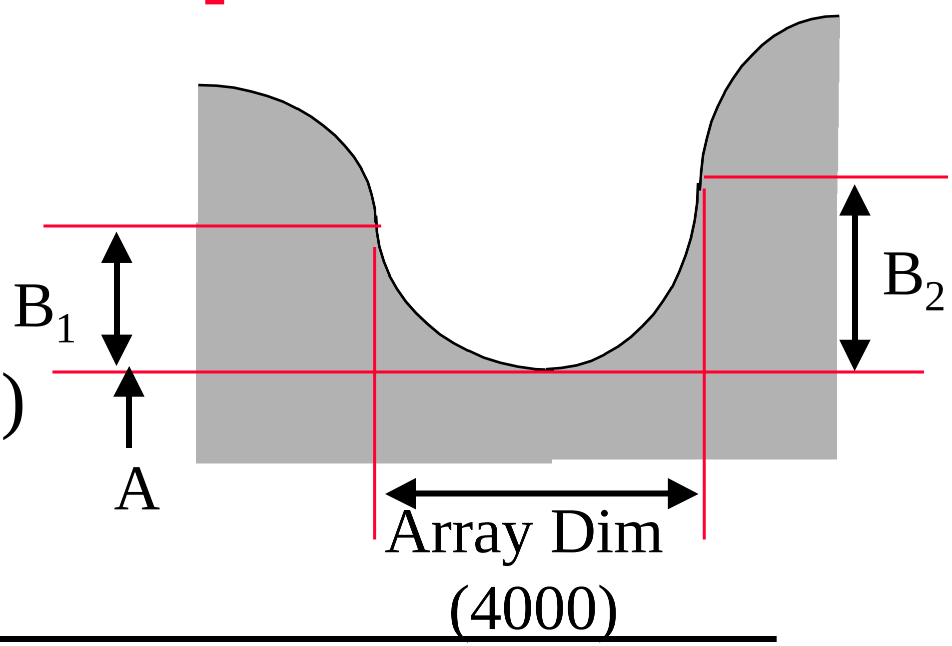
A: thickness offset

B: step height

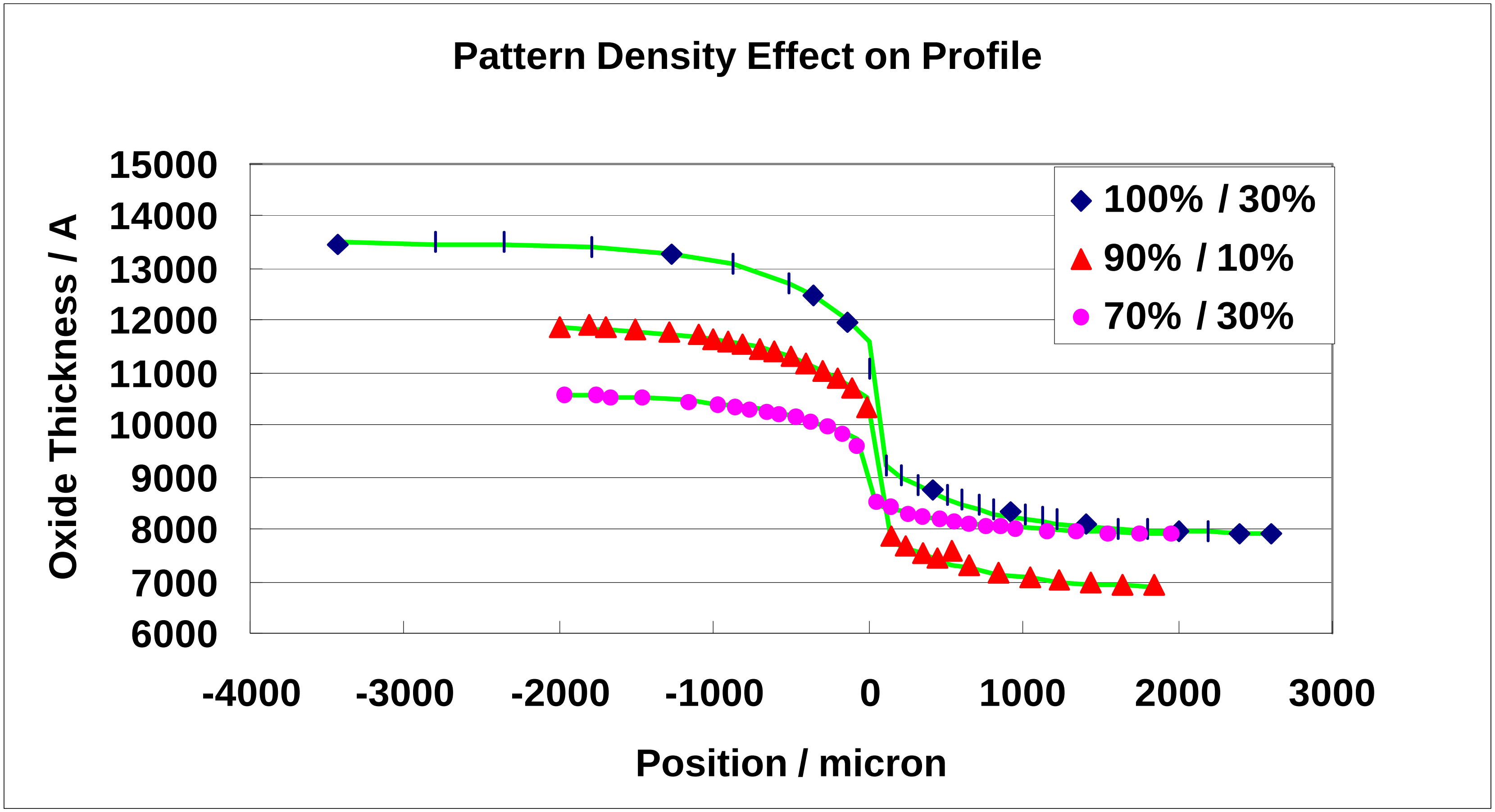
C: relaxation constant

1/C : relaxation length(RL)

4000: array dimension

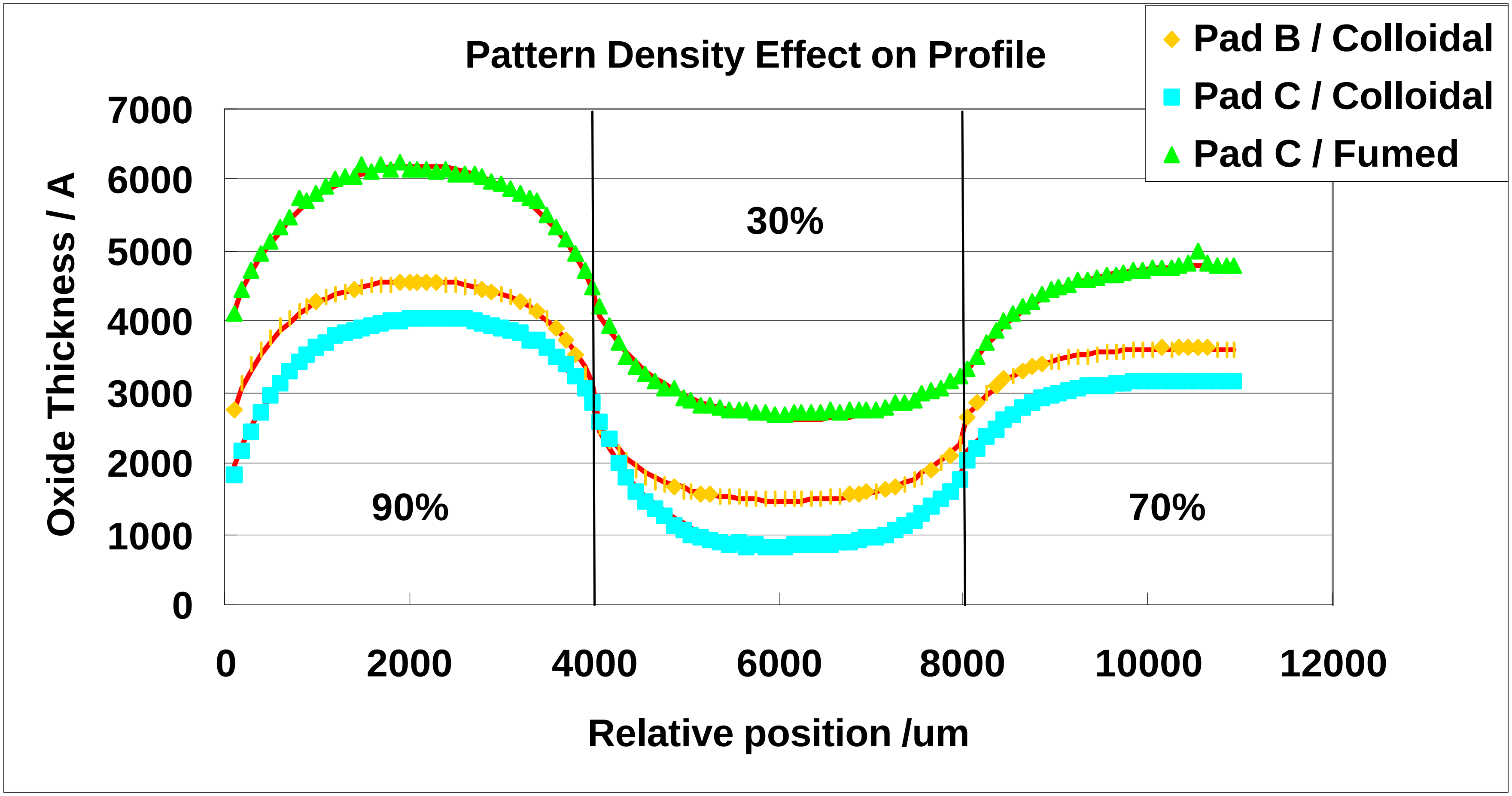


Profile Transition --Pad A



All fittings use the same relaxation constant (0.0017 um^{-1})

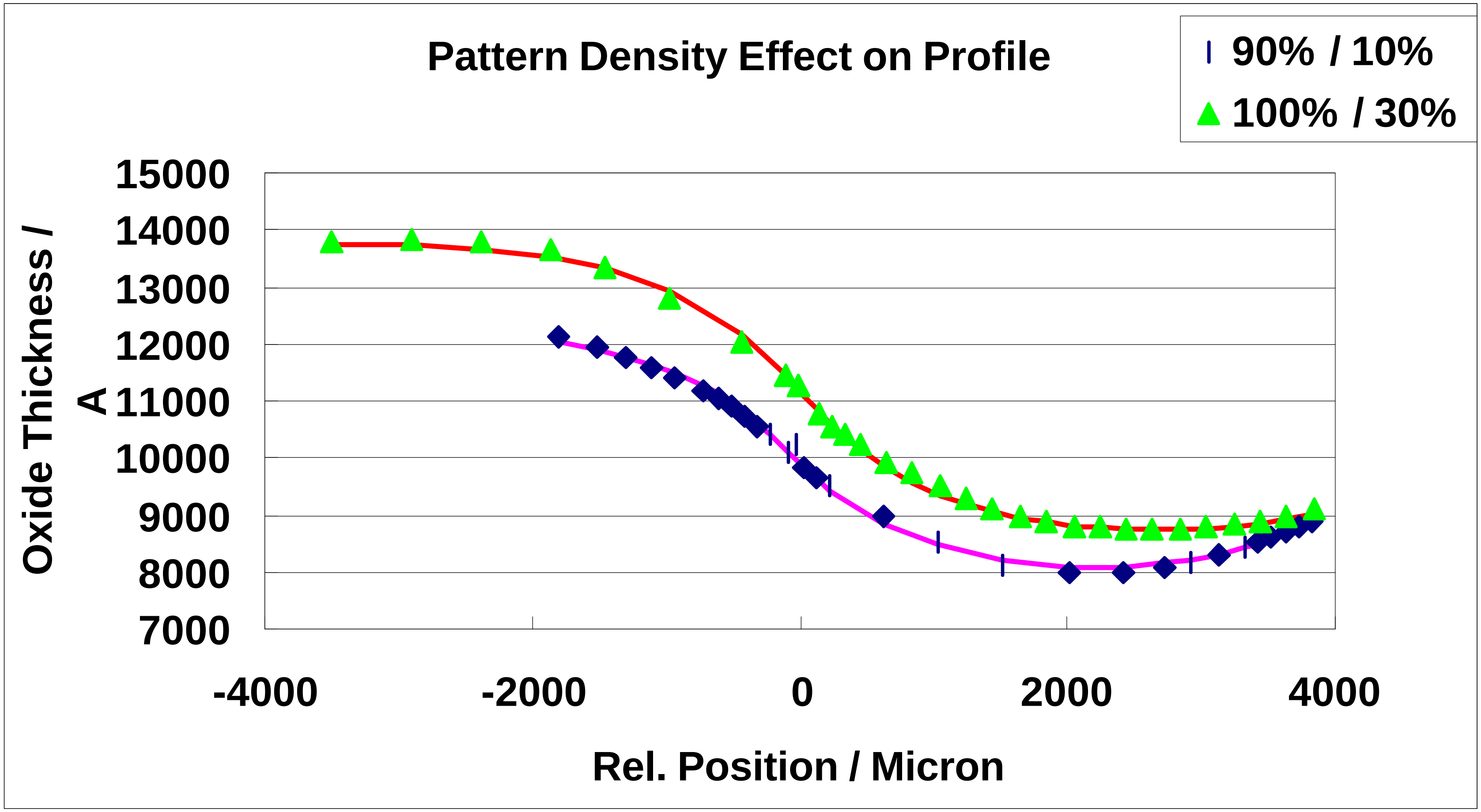
Profile Transition – Pad B and C



Relaxation constants: pad B 0.0015 um^{-1}; pad C 0.0013 um^{-1}

Slurry has no effect on relaxation constant

Profile Transition –IC Pad



Relaxation constant is 0.0011 um^{-1} for all fittings

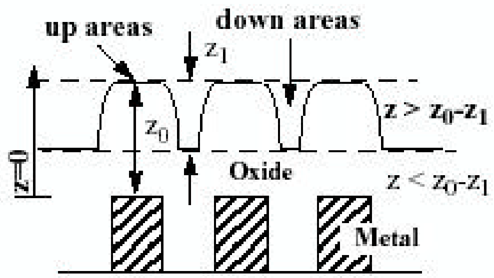
Relaxation Length

Pad	A	B	C	C /fumed	IC
C / um^{-1}	0.0017	0.0015	0.0013	0.0013	0.0011
RL / um	590	670	770	770	910

Relaxation length is independent of pattern density
Relaxation length is independent of slurry type
Relaxation length is sensitive to the pad performance

Planarization Length (MIT)

Oxide CMP Pattern Dependent Model (Stine et al. '97)



- Removal rate inversely proportional to density:

$$\frac{dz}{dt} = -k_p p v = -\frac{K}{\rho(x, y)}$$

- Density assumed constant (equal to pattern) until local step has been removed:

$$\rho(x, y, z) = \begin{cases} \rho_0(x, y) & z > z_0 - z_1 \\ 1 & z < z_0 - z_1 \end{cases}$$

- Final oxide thickness related to effective density:

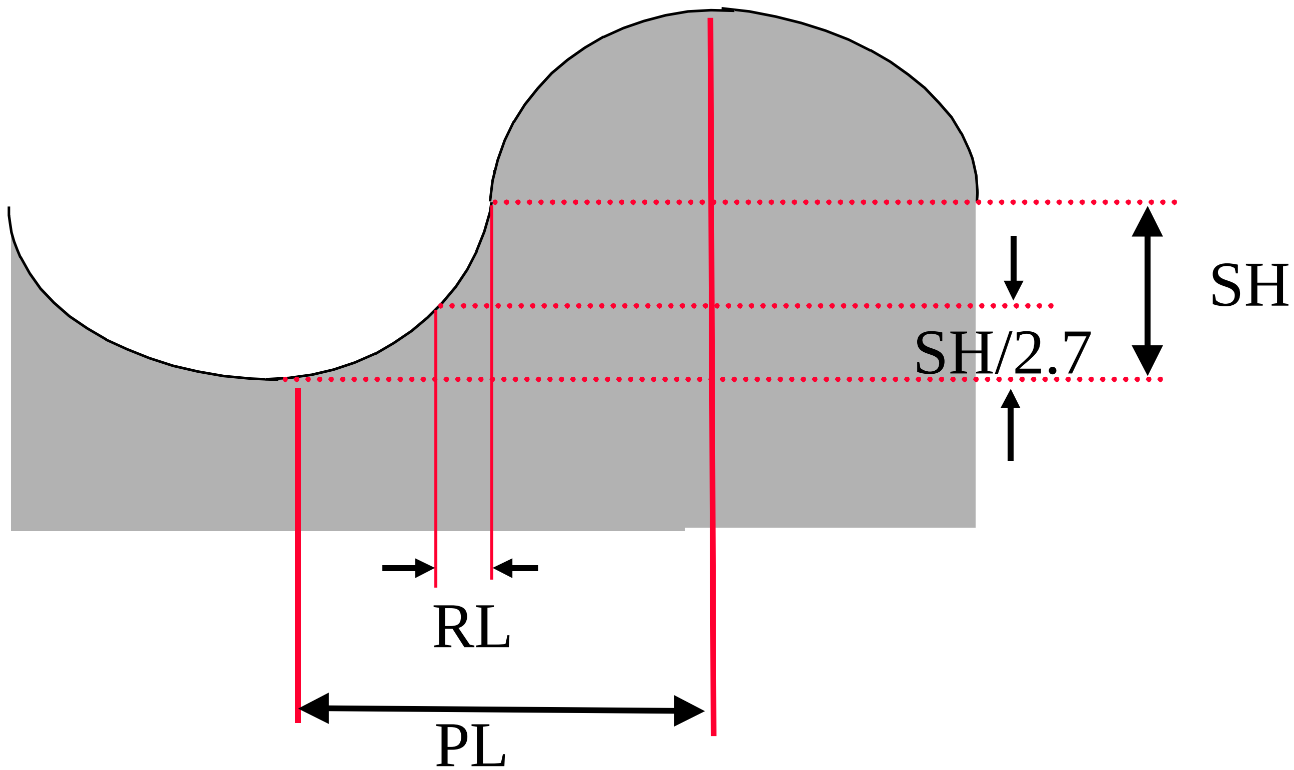
$$z = \begin{cases} z_0 - \left(\frac{Kt}{\rho_0(x, y)}\right) & Kt < \rho_0 z_1 \\ z_0 - z_1 - Kt + \rho_0(x, y) z_1 & Kt > \rho_0 z_1 \end{cases}$$

z = final oxide thickness over metal features
K = blanket oxide removal rate for a die of interest
t = polish time
ρ_0 = local pattern density

- Evaluation of pattern density $\rho_0(x, y)$ is key to model development

The interaction length (PL) for IC1400 is 3.2 ~ 3.6 mm

Relationship between Relaxation Length and Planarization Length



Relationship between Relaxation Length and Planarization Length

If 90% of step height will be used to calculate PL,

PL ~ 4.6 RL

If 85% of step height will be used to calculate PL,

PL ~ 3.8 RL

Pad	A	B	C	IC
RL / um	590	670	770	910
PL (0.9) / mm	2.7	3.1	3.5	4.2
PL (0.85) / mm	2.2	2.5	2.9	3.5

Based on MIT work, the PL of IC1400 is about 3.2 – 3.6 mm. This PL is equivalent to 85% of step height.

Summary

- Local planarization: different approaches could result in conflict conclusion.
- Global planarization:
  - Planarized wafer surface may not be *really* flat.
  - Planarization length is difficult to define the exact physical meaning.
  - Relaxation length could be a better terminology to define the pad long range planarization capability, no assumption involved.
  - Planarization length and relaxation length can be correlated.