A Fixed Abrasive CMP Model

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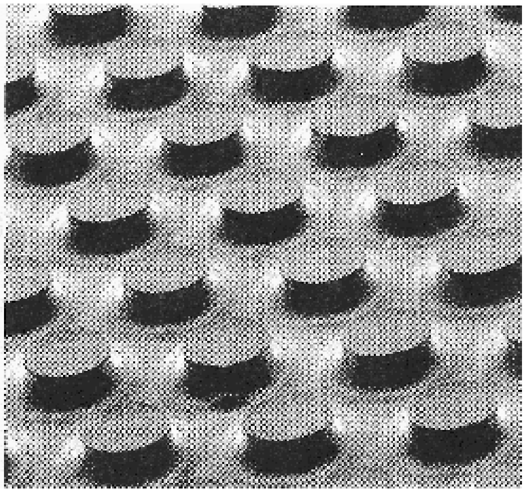
Outline

- Introduction
  - Motivation
  - Fixed abrasive pads
  - Previous models
- Fixed Abrasive Model Derivation
  - Removal rate diagrams
  - Decoupling patterned and blanket removal rates
  - Patterned rate dependence on density
- Characterization Methodology
- Experimental Description and Results
- Conclusions and Future Work

Motivation

- Fixed abrasive pad has exhibited behavior that is different from conventional pads
- Propose a model that is based on conventional density-based approaches, but seeks to capture key effects of the fixed abrasive CMP process



Römer, et al, CMP-MIC 2000

Previous CMP Models

- Previous models capture conventional CMP processes well
  - Effective pattern density effect
  - Step height dependency

- Additional effects seen in fixed abrasive CMP experiment results are not captured
  - Extremely low blanket removal rate
  - Strong response to topography

Effect 1: Pattern Density Dependence

Key Ideas

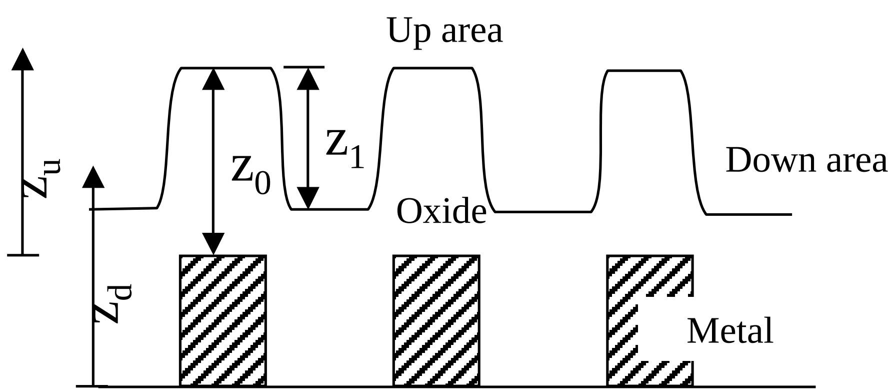
- Importance of “pattern density” in CMP
- Derived from Preston’s glass polishing equation
- Key relationship:

$$RR = \frac{K}{\rho}$$

RR: Patterned removal rate
K: Blanket removal rate
ρ: Effective pattern density

Stine, “A Closed Form Analytic Model for ILD Thickness Variation in CMP Processes,” CMP-MIC 1997

Density-Based CMP Model*



$$z_u = z_0 - \left(\frac{Kt}{\rho_0(x,y)} \right) \qquad z_u \geq z_0 - z_1$$

$$z_u = z_0 - z_1 - Kt + \rho_0(x,y) z_1 \qquad z_u \leq z_0 - z_1$$

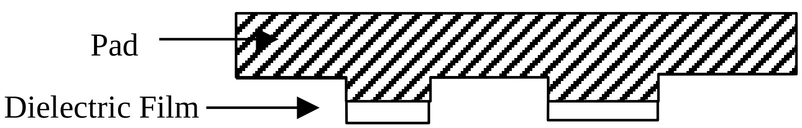
Stine, "A Closed Form Analytic Model for ILD Thickness Variation in CMP Processes," CMP-MIC 1997.

Effect 2: Step Height Dependence*

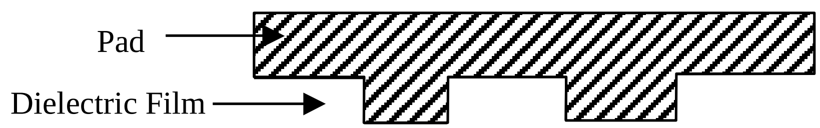
<u>Key Ideas</u>

- Two phases of CMP process
  - Phase 1: Before "contact height" is reached, polish behaves as in pure density model
  - Phase 2: After "contact height" is reached, removal rate becomes a function of both pattern density <u>and</u> step height

Phase 1

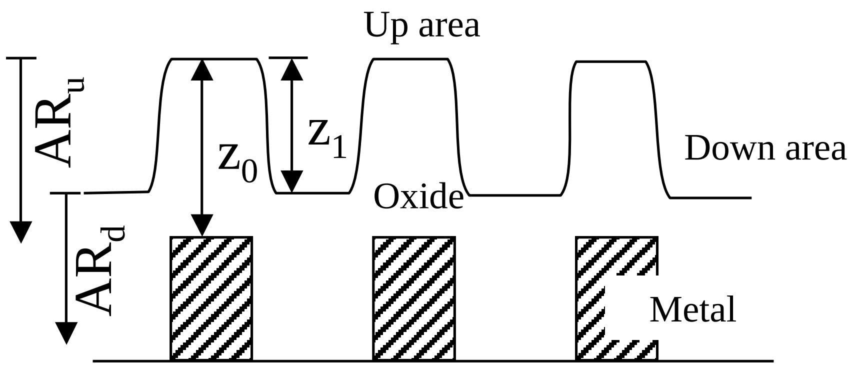


Phase 2



Smith, "A CMP Model Combining Density and Time Dependencies," CMP-MIC 1999.

Density-Step Height CMP Model*

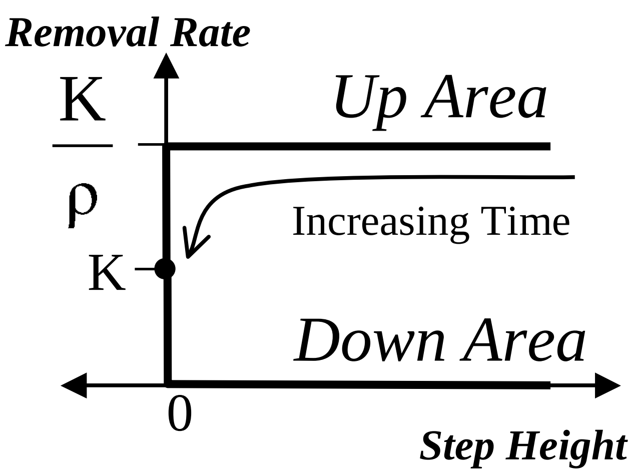


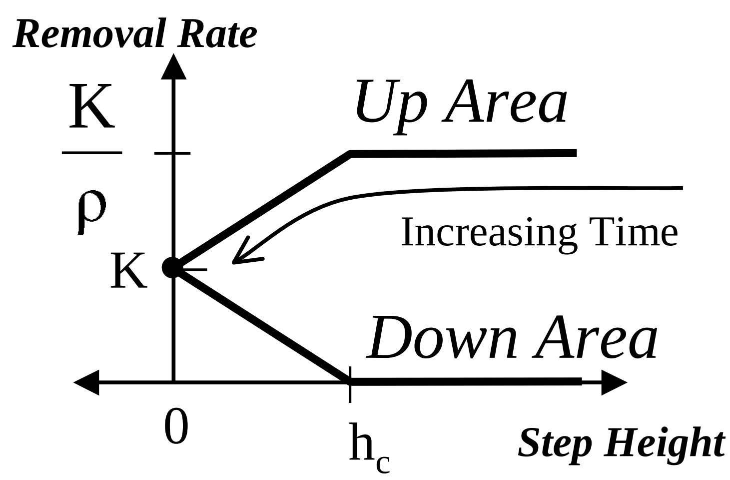
$$AR_u = t_c \frac{K}{\rho} + K(t - t_c) + (1 - \rho)\frac{h_c}{\tau}\left(1 - e^{-\frac{(t - t_c)}{\tau}}\right)$$

$$AR_d = K(t - t_c) - \rho \frac{h_c}{\tau}\left(1 - e^{-\frac{(t - t_c)}{\tau}}\right)$$

Smith, "A CMP Model Combining Density and Time Dependencies," CMP-MIC 1999.

Summary: Conventional CMP Models





Pure Density CMP Model

Density-Step Height CMP Model

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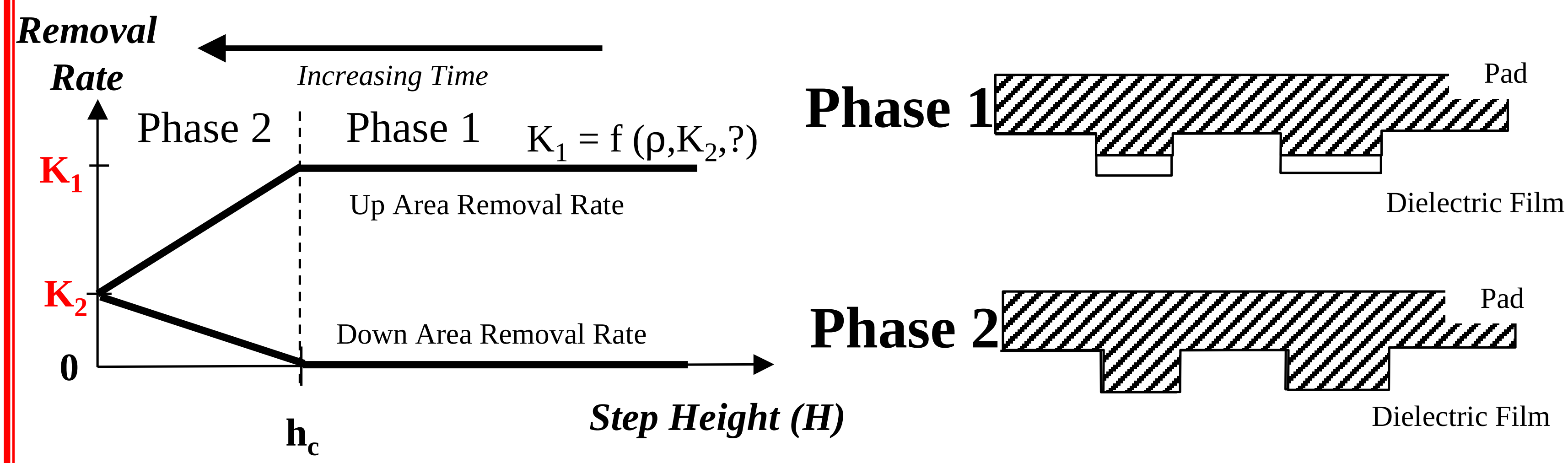
Fixed Abrasive Model



- Two phases: before and after pad contacts the down areas
- Generalize patterned (K_1) and blanket (K_2) removal rates

Fixed Abrasive Model

$$AR_u = K_1 t_c + K_2 (t - t_c) + h_c \left(1 - \frac{K_2}{K_1}\right)\left[1 - e^{-\frac{(t - t_c)}{\tau_{ox}}}\right]$$

$$AR_d = K_2 (t - t_c) - h_c \frac{K_2}{K_1}\left[1 - e^{-\frac{(t - t_c)}{\tau_{ox}}}\right]$$

K_1: *Patterned film removal rate*
K_2: *Blanket film removal rate*
τ_{ox}: *Dielectric step height time constant*
t_c: *Contact time*
h_c: *Contact height*

Decoupling K_1 and K_2

Patterned Rate　　Blanket Rate

$$K_1 = \frac{K_2}{\rho}$$

$$K_1 = f(\rho, K_2, ?)$$

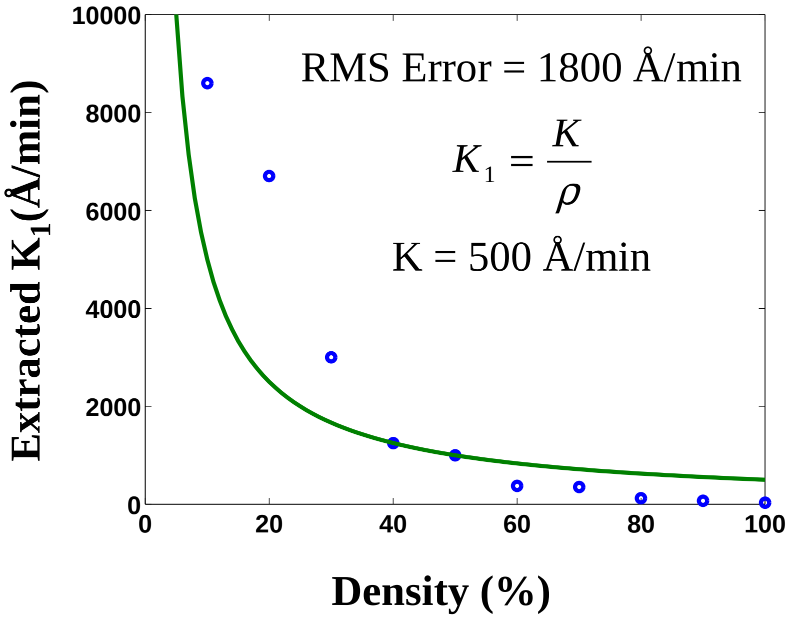
undefined relationship

<u>Conventional Model</u>

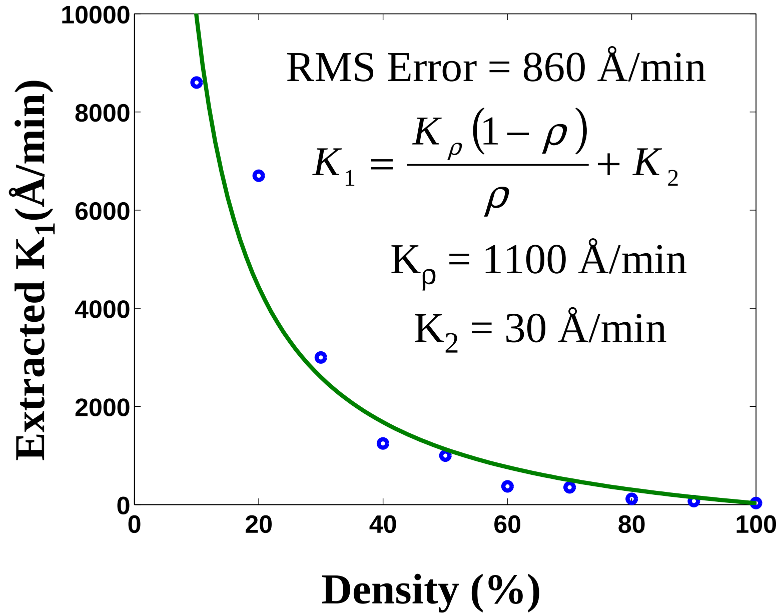
<u>Proposed Model</u>

Removal Rate Dependencies

Pure inverse density dependency

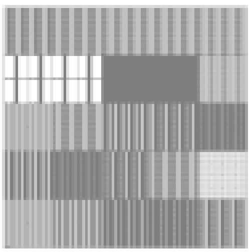


Alternative dependency



- Data points from fixed abrasive pad experiments

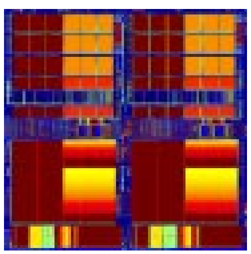
Characterization Methodology



Test Mask

Calibrate

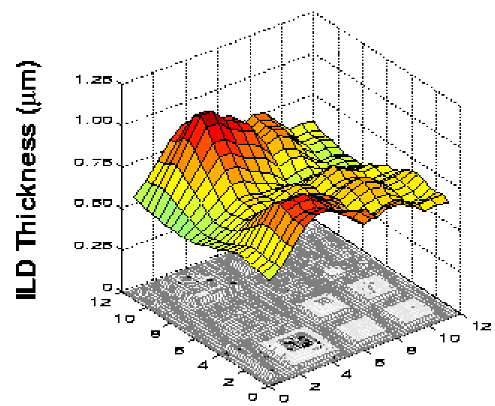
Model Parameters



Arbitrary
Layout

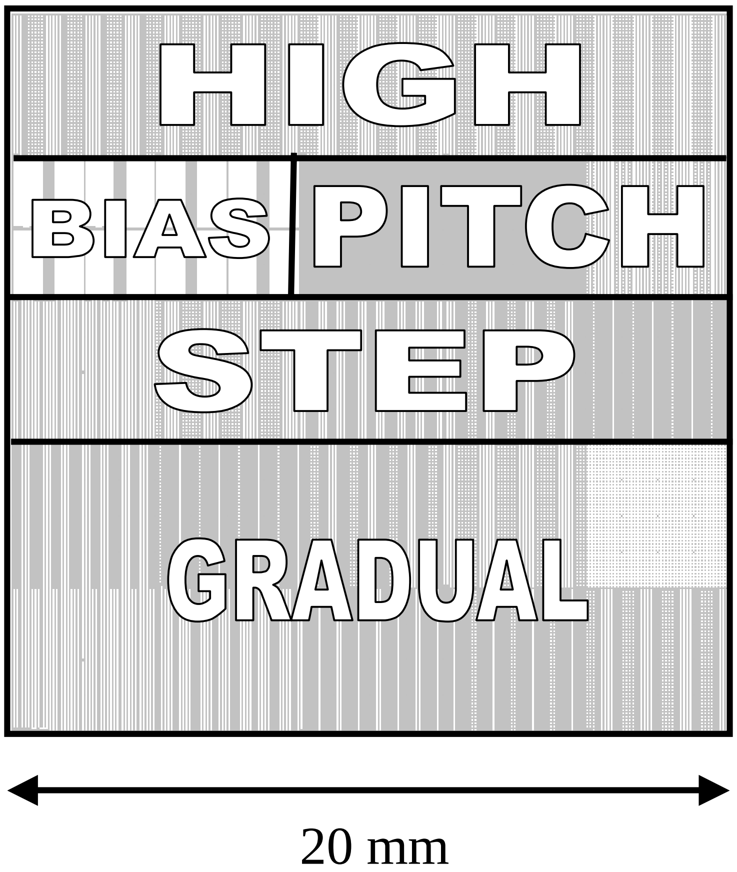
Dielectric

CMP Model



Final Film
Thickness Prediction

Test Mask

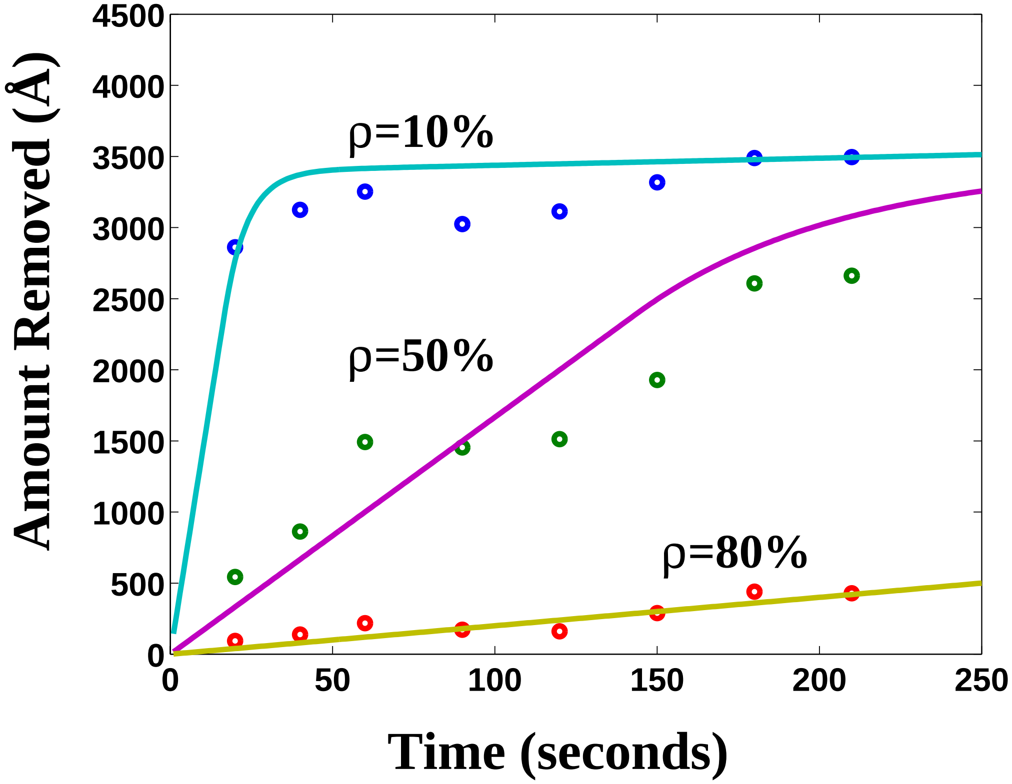


- High Density Structures
- Pitch Structures
  - Down area polish study
- Bias Structures
  - Measure deposition characteristics
- Step Density Structures
  Gradual Density Structures
  - Planarization length characterization
  - Structures from 10% to 100% density

Experimental Description

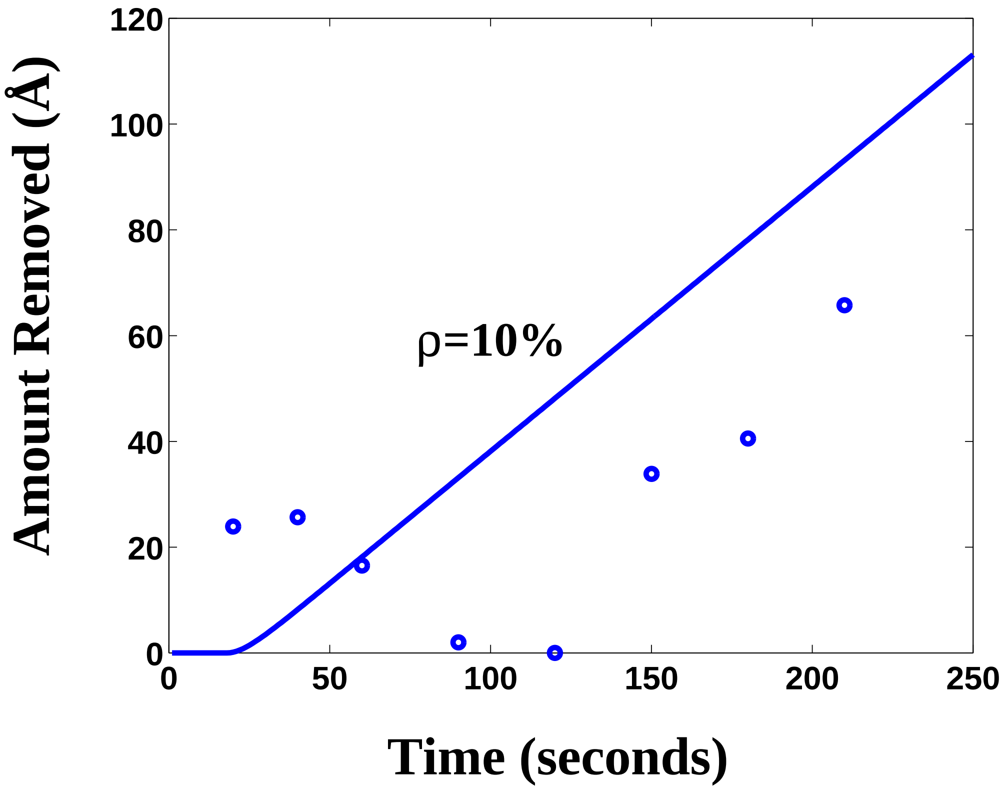
- STI wafers with test pattern
  - Trench depth 3100 Å, nitride/oxide stack 1160 Å
- HDP oxide deposited to 4300 Å
- Obsidian Flatland 501 CMP tool
- 3M fixed abrasive pad
  - Ceria particles in a cylinder matrix
- Eight time steps
  - 20, 40, 60, 90, 120, 150, 180, 210 seconds

Experiment Data vs. Model (Up Area)



- After step is removed, polish rate dramatically decreases
- Model predicts trends in data

Experiment Data vs. Model (Down Area)



- ρ = 50%, 80% not shown (no material removed during this time duration)

Model Results

ρ (%)	K_1 (Å/min)	Up Area Error (Å)	Down Area Error (Å)	ρ (%)	K_1 (Å/min)	Up Area Error (Å)	Down Area Error (Å)
10	8600	223	30	60	375	140	10
20	6700	287	40	70	350	145	12
30	3000	374	24	80	120	60	7
40	1250	495	11	90	70	43	29
50	1000	355	15	100	30	27	n/a

- h_c = 1000 Å
- K_2 = 30 Å/min, K_ρ = 1100 Å/min
- PL = 2.3 mm

$$K_1 = \frac{K_\rho (1-\rho)}{\rho} + K_2$$

Conclusions and Future Work

- Demonstrated generalized model for dielectric CMP process
  - applicable to fixed abrasive CMP
- Examined relationship between patterned and blanket removal rates
  - proposed possible dependency
- Future: Examine the nature of the FA effect
  - fixed matrix nature of abrasive?
  - ceria or particle nature?