Novel Approaches for FEOL Process Control: Recent Developments in PolySi Reactive Liquids

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FEOL is an inflection point for CMP

- We need a path forward for order of magnitude improvement in control in topography of all processes.
- Shifting to wafer scale control rather than just die scale control requires a major change in consumables design. HKMG and FINFET for sub-32nm will require thickness control of <2% at every point on the wafer for proper transistor function. This is largely beyond current CMP process capability.
- Increasing conflict between wafer throughput (drives high removal rates) vs. control (low removal rate preferred)

Changes in CMP processes needed to move ahead

- OOM improvements in contact pressure regulation across the wafer over the process lifetime.
- OOM improvements in control of hydrodynamics and liquid transport w/in the lubrication layer over the process lifetime
- OOM improvements in control of interaction forces for control of rate and material damage.
- OOM improvements in topography control
- **Changes in process kinetics to simplify the control requirements of the process, especially for CMP of heterogeneous surfaces**

Poly CMP applications and challenges

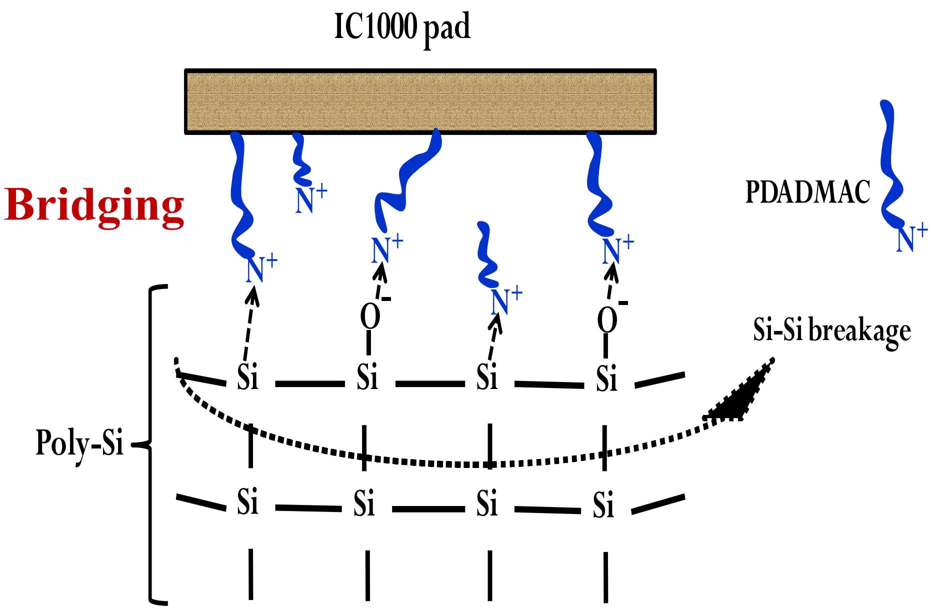
- **FinFET poly CMP:** planarization of poly-Si topography and stop at desired poly-Si thickness
  - Extremely high PE to correct very low topography
  - Uniform step height reduction and uniform poly-Si thickness across a range of feature densities
  - End point control or self-stopping behavior
- **HKMG, poly open process:** planarization of polySi topography plus tunable selectivity to nitride and oxide
- **MEMS poly CMP, DRAM poly CMP3D-RCAT poly CMP** requires planarization of poly-Si topography and stop on the underlying oxide or nitride layer with no erosion and minimal dishing.

All processes will require global feature-independent erosion and topography control

New removal Mechanism for particle-free polySi

- Use designed polymers to form a strong bridging interaction between the films being polished and the polishing pad. This allows atomic scale removal without mechanical force, with zero removal on any other material

E(-Si-Si-) < E(Bridging) < E(-Si-O-&-Si-N-)



Bond	Bond Energy (Kcal/mole)
Si-Si	54
Si-O	113
Si-N	105

Ref: Penta et al., Langmuir, 27 (2011) 3502

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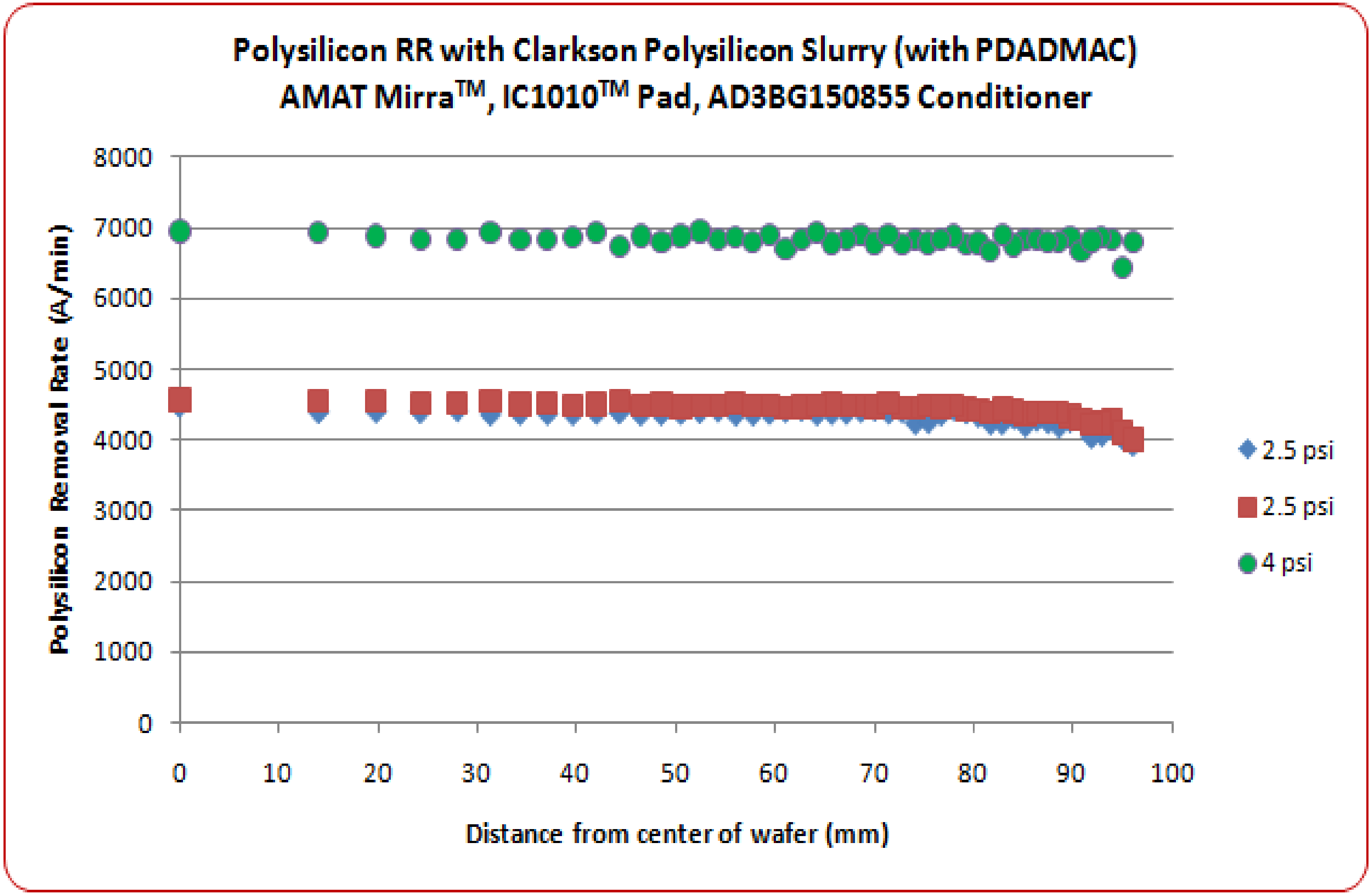
Blanket wafer responses



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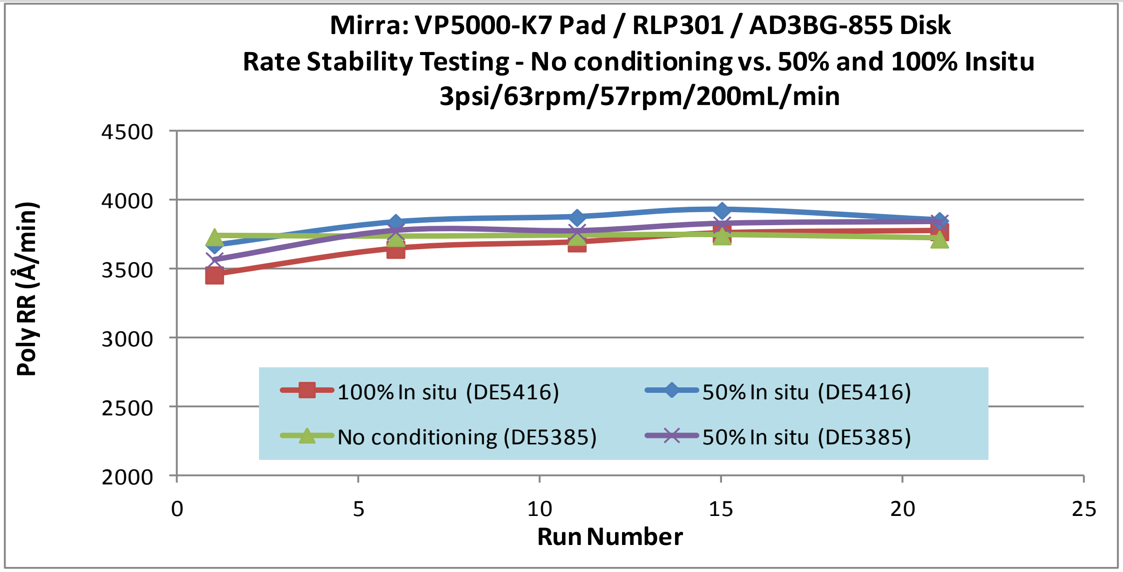
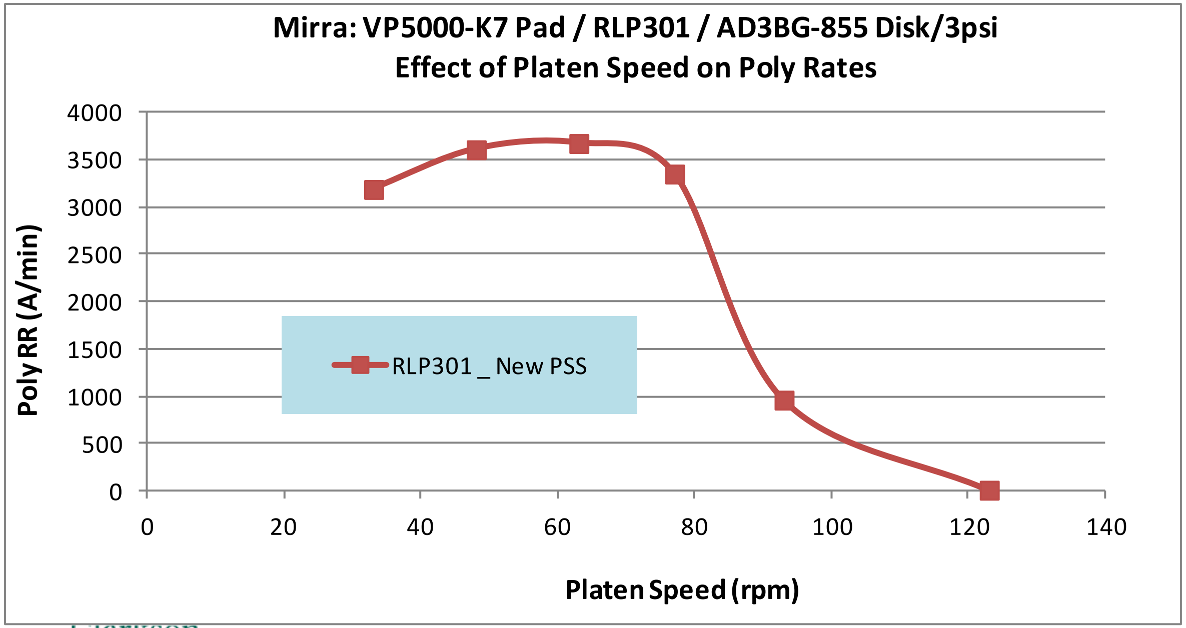
Abrasive-free polySi: Conditioning and hydrodynamics



No effect of conditioning on RR, no observed asperity wear for all polymers and MWs tested

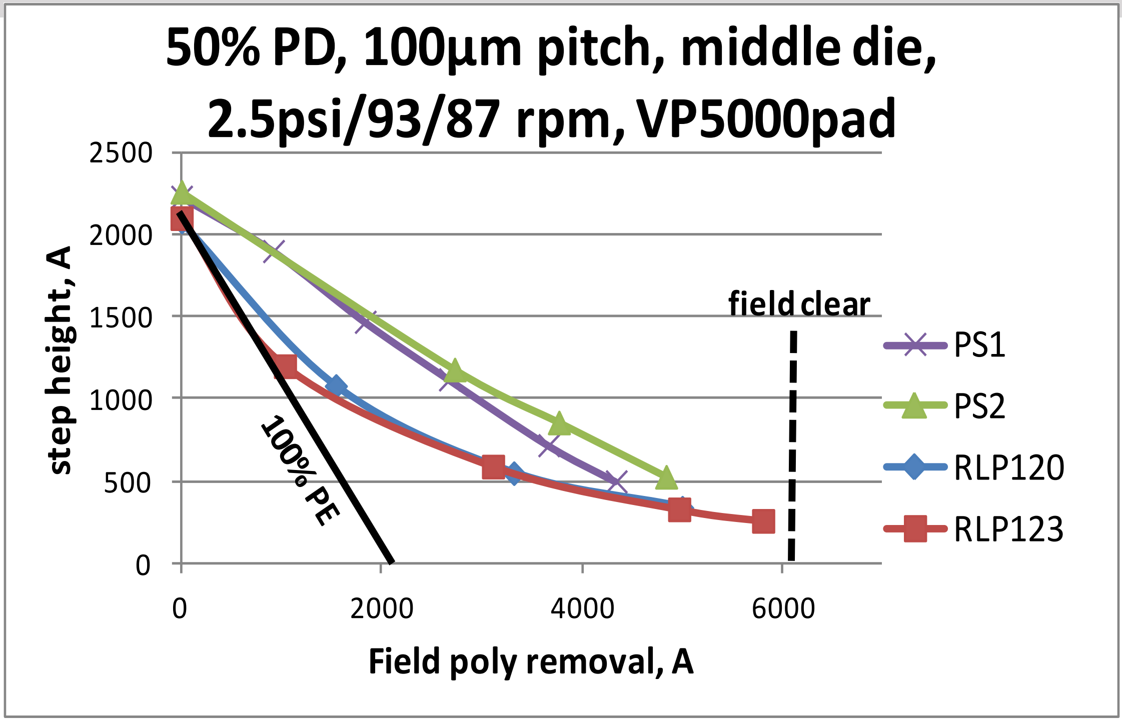


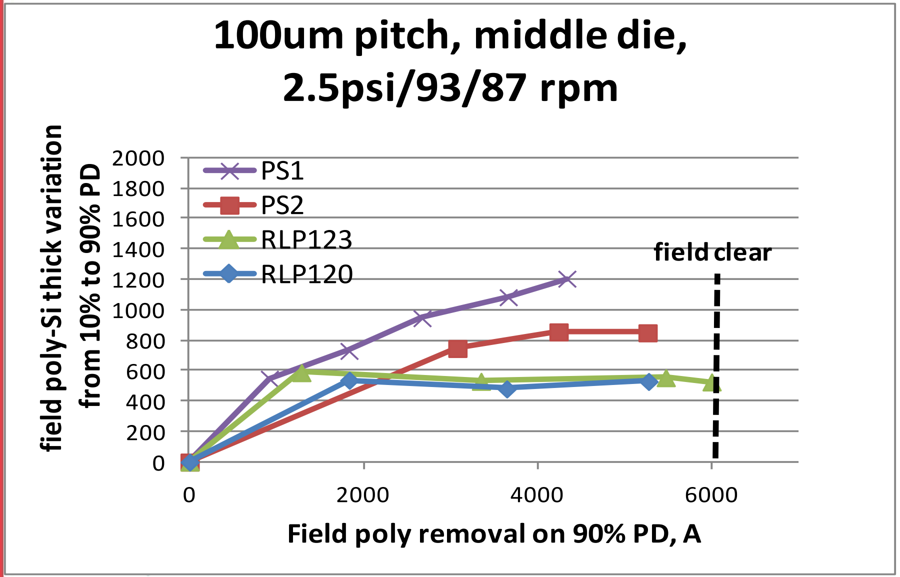
Low MW shows pronounced velocity effect on rate that is not observed for high MW components. This is consistent with MW effects on bridging distance in the mechanism

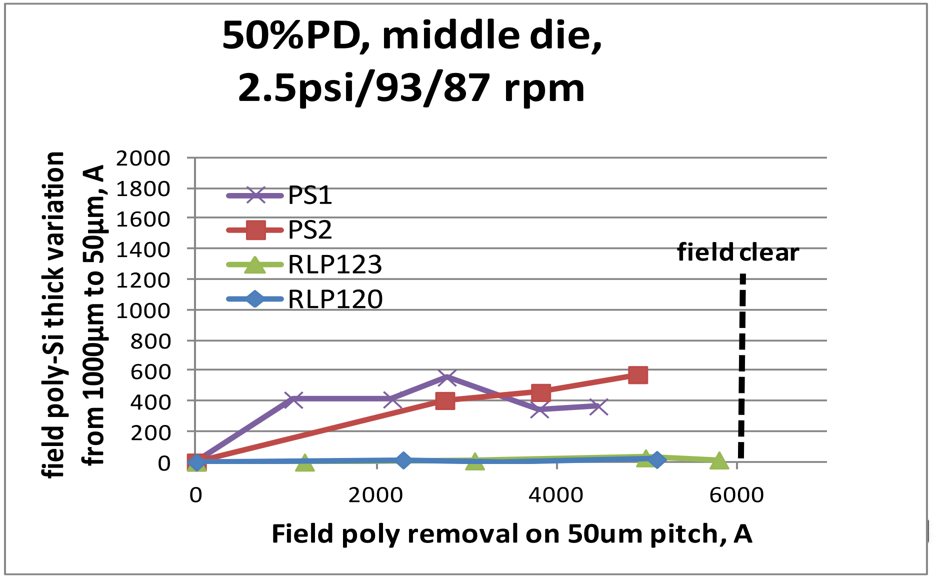
Pattern wafer response

Comparison of RL vs. conventional slurries on P1

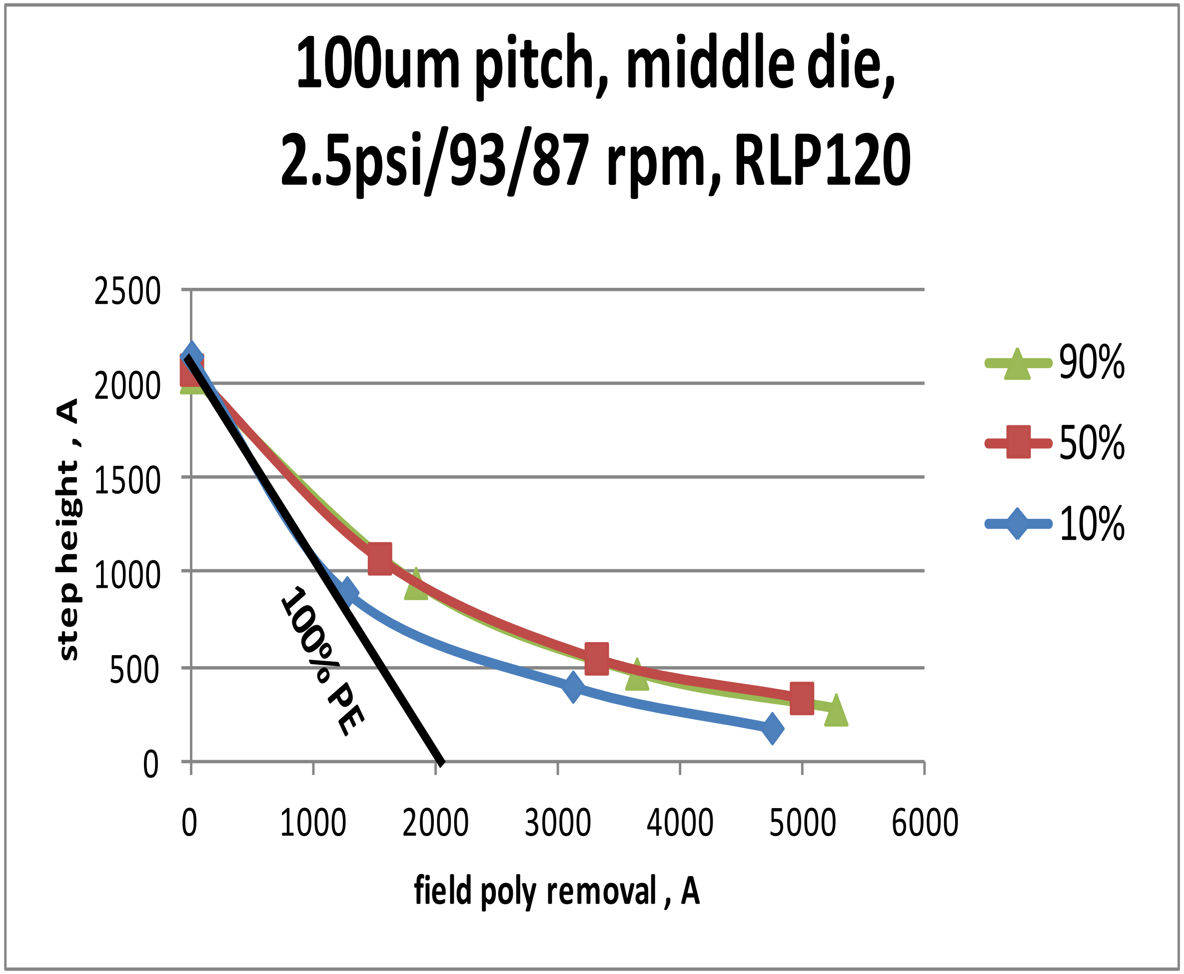
P1 & P2 are platens 1 & 2
PSI & PS2 are abrasive-contained slurries
RLP120 & RLP123 are abrasive-free solutions



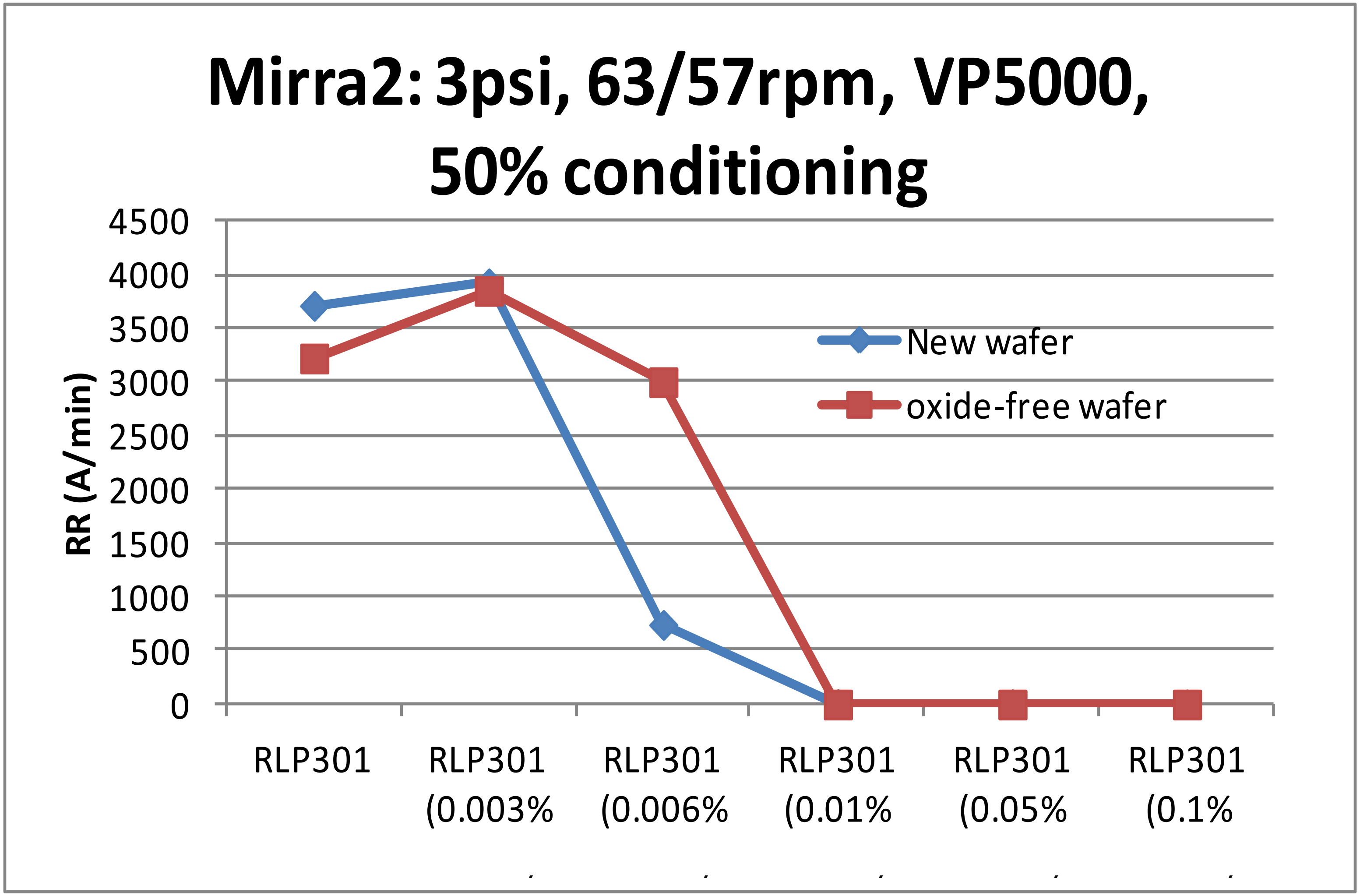




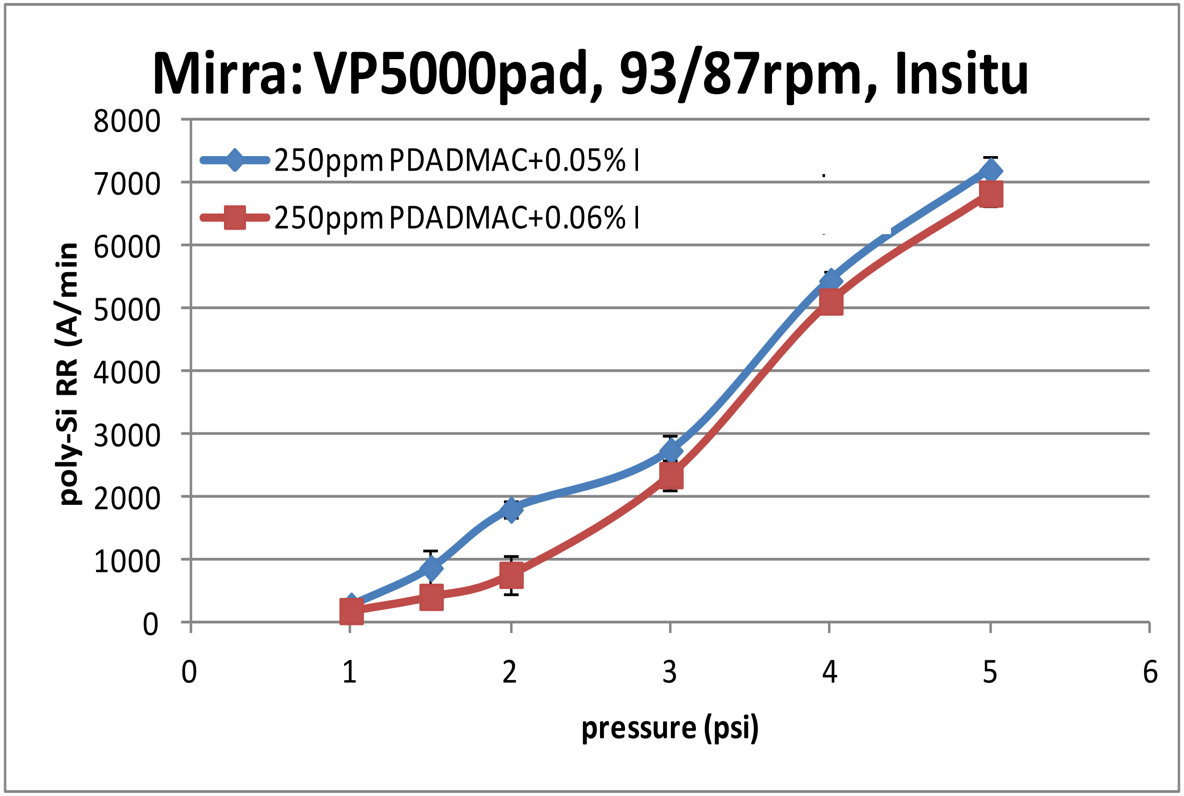
Pattern Density Effect



Effect of inhibitor addition to RLP on poly-Si rates



Inhibitor-induced Non-prestonian behavior



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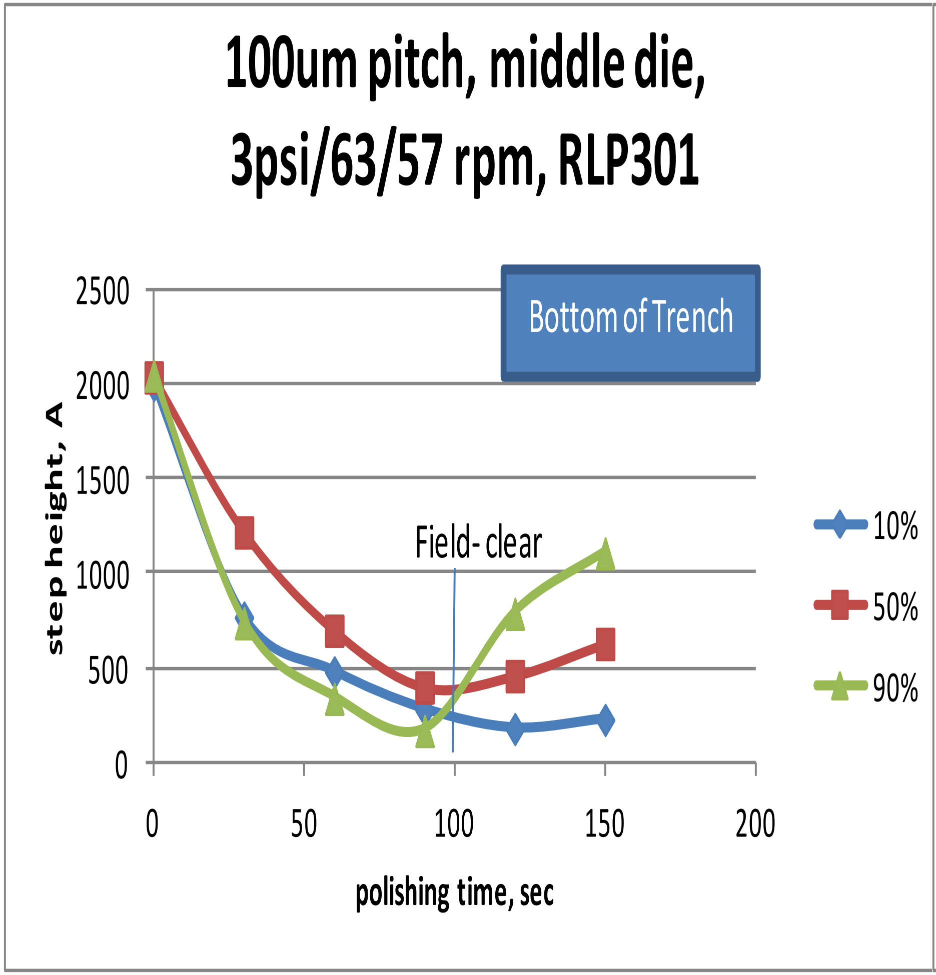
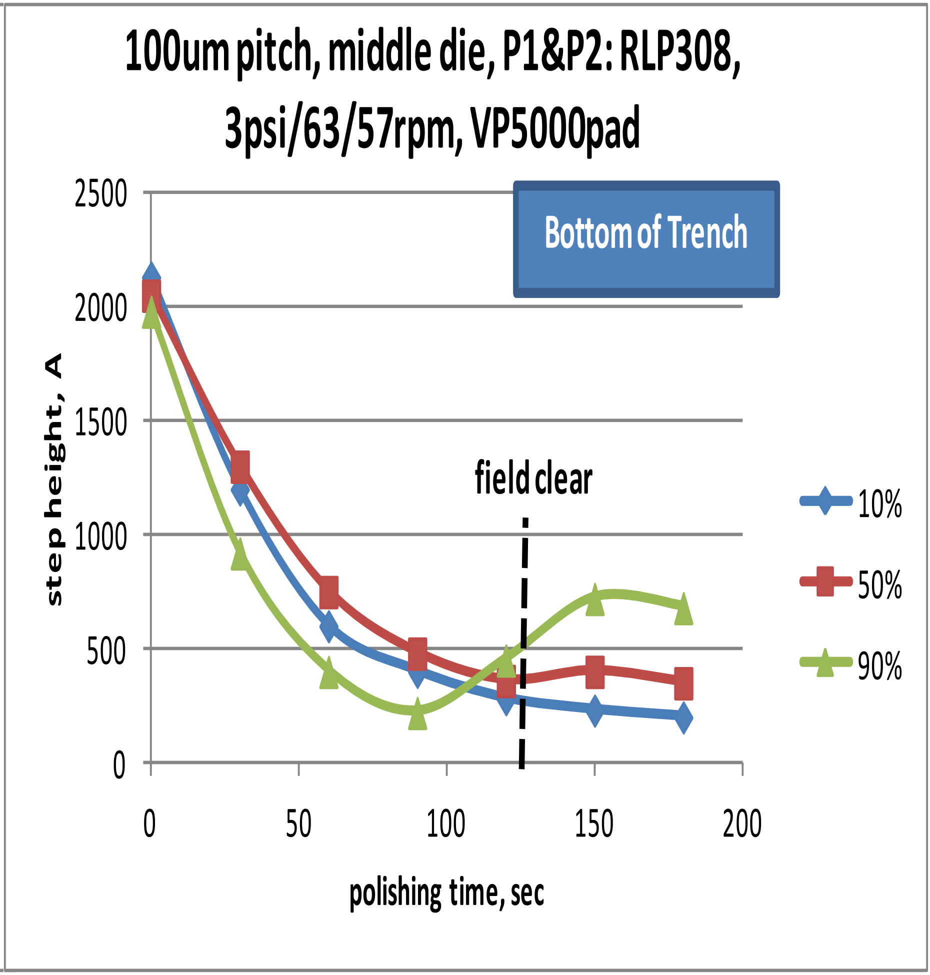
Effect of inhibitor on trench response: low MW P2





No inhibitor

With Inhibitor

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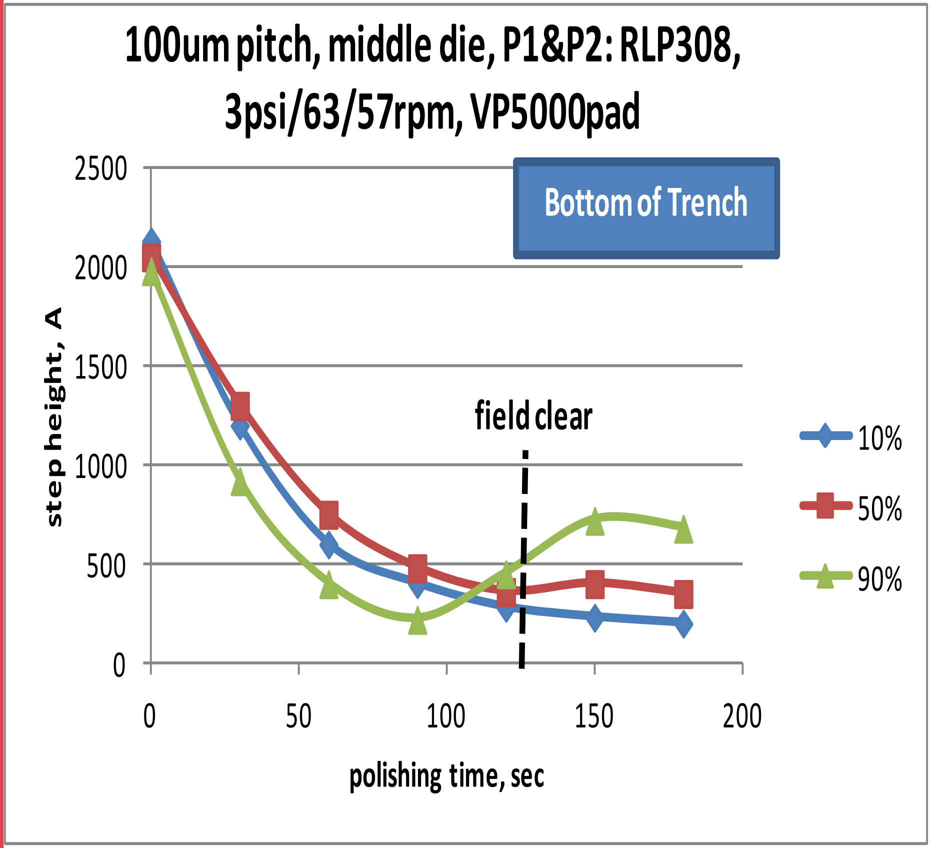
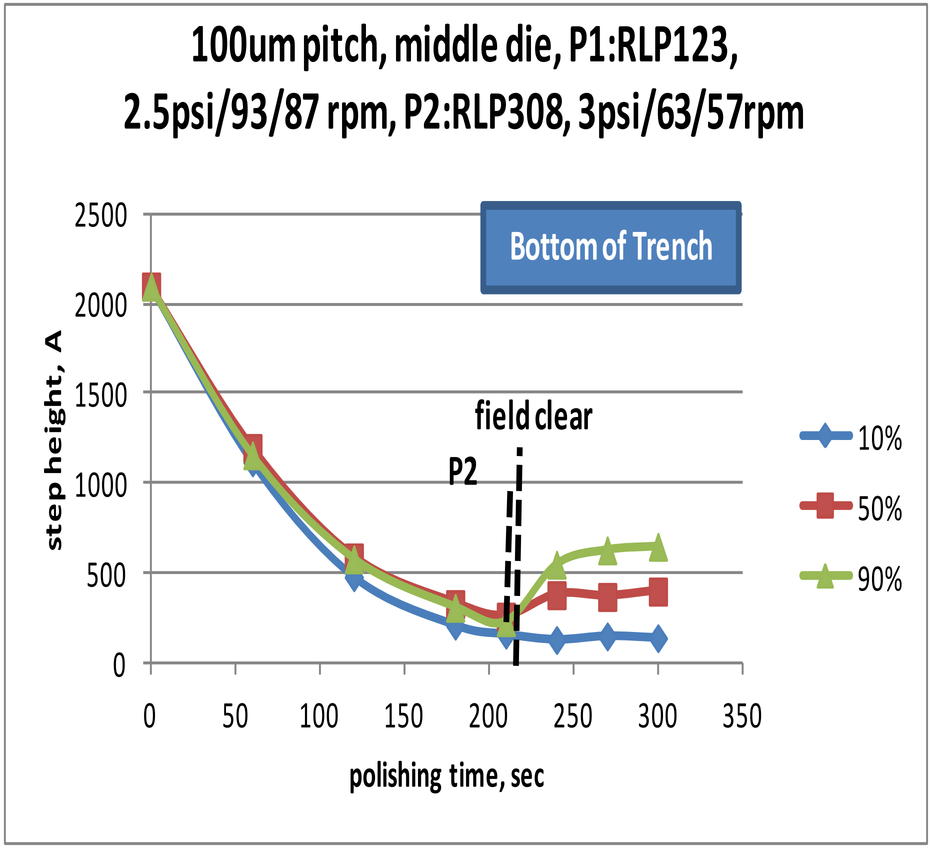
Effect of P1 slurry on P2 slurry dishing: low MW P2



Low MW P1



High MW P1

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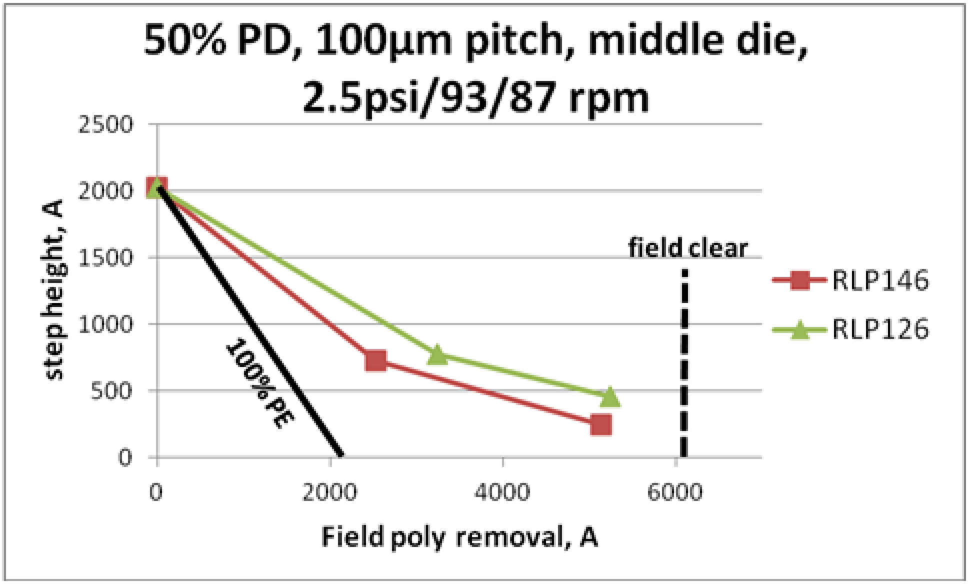
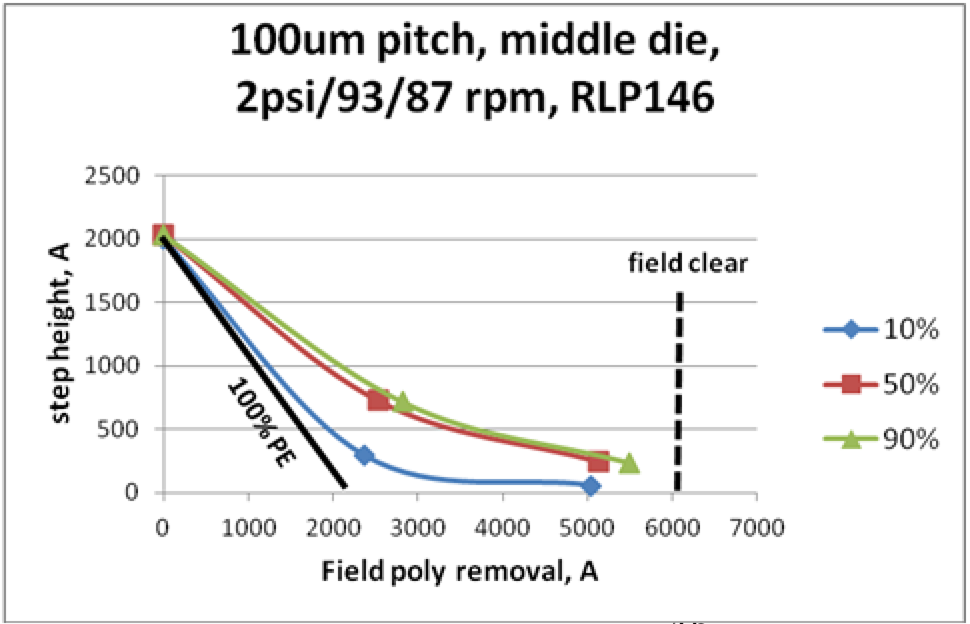
Inhibitor effects on P1 planarization

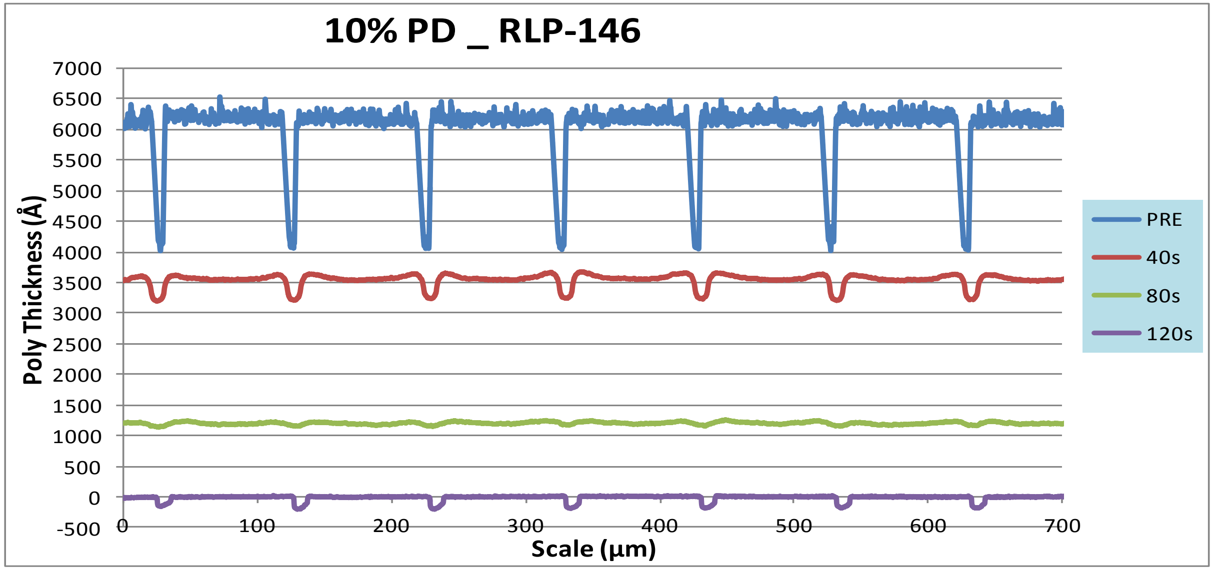


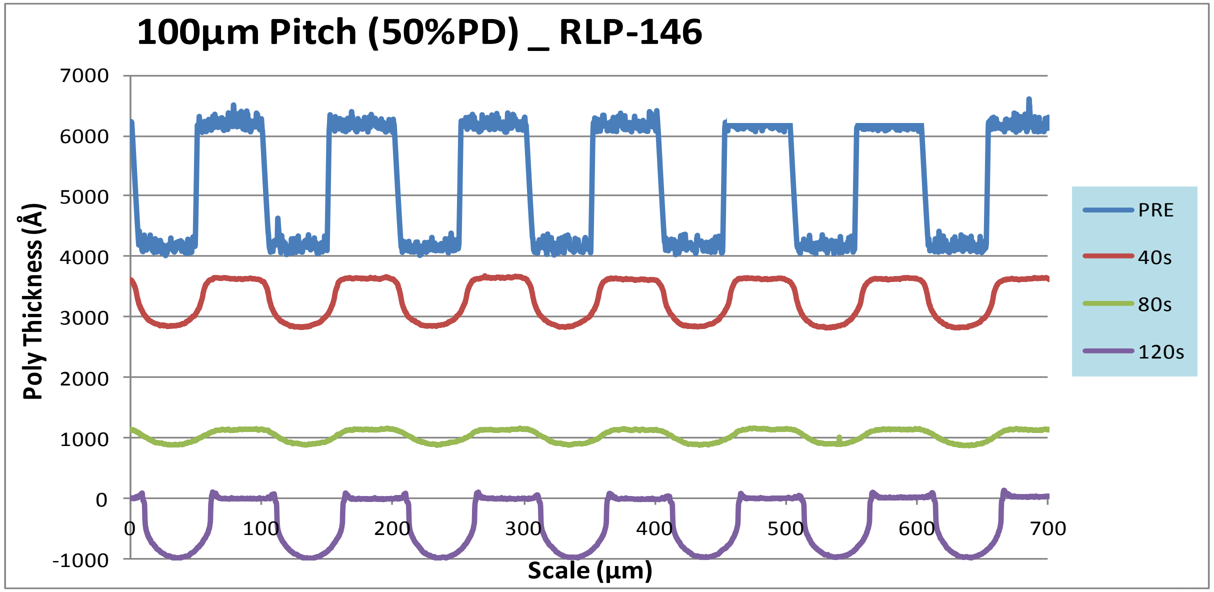
No inhibitor



With inhibitor

Planarization Sequence for PolySi PW (w/ Inhibitor)





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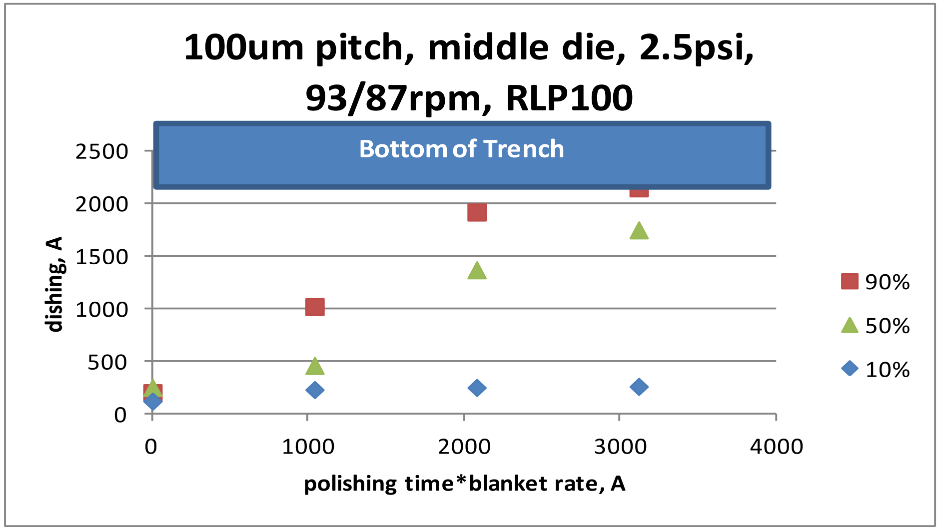
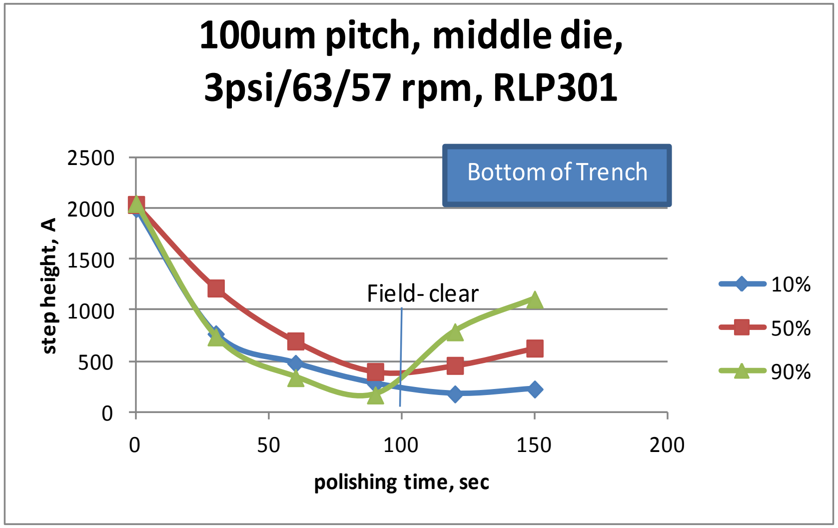
Effect of molecular weight on trench kinetics (250K)





- High MW best for planarization on P1, low MW best for trench control

Basis for molecular weight effects on dishing control

- Asperity separation distance cannot exceed a critical value for maintenance of the bridging complex.
- The critical separation distance decreases drastically with decreasing molecular weight. This forces rate shutdown in the trench.

Current work focus

- Custom design of complexing agent and inhibitor structure
- Developing PW baseline
- PW screening for control of topography
  - Planarization of overburden and implementation of robust self-stopping behavior (FinFET and memory)
  - Control of post-clear topography (memory focused)

Conclusion

- A novel removal mechanism for CMP of Si films has been developed which shows considerable promise for FEOL and memory applications.
- The bridging complex removal mechanism is very flexible. It can be modified to control pattern wafer planarization and dishing kinetics through chemical design rather than by exploiting mechanical effects. The nature of the mechanism also yields a pronounced insensitivity to pattern density and linewidth effects, which we feel is characteristic of fully chemistry-dominated removal mechanisms.
- The high purity, freedom from abrasives, lack of asperity wear make it attractive for FEOL application
- We hope to present further progress on a full self-stopping polySi process at ICPT 2013.

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