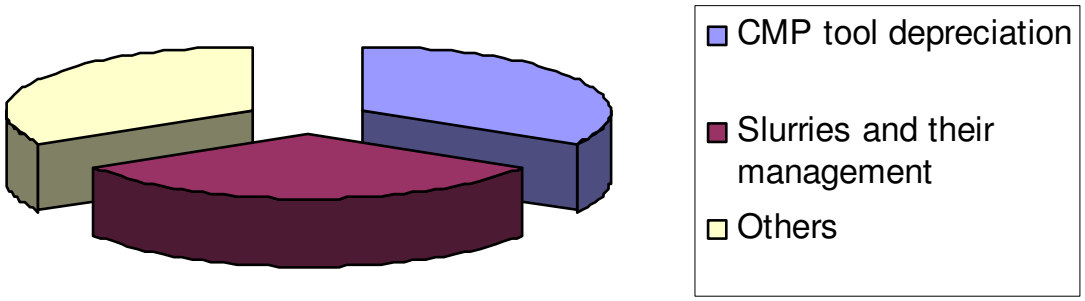
Volume Production Proven Advanced Nanometer Slurries for CMP Applications, Capable of Recycling and Extendable to Larger Si Wafer Sizes and Future IC Technology Nodes

Raymond R. Jin, X. L. Song, S. M. Jin, X. D. Shi, H. Y. Dong*, G. L. Wan**
Adcon Lab Incorporated
6110 Running Springs Road, San Jose, CA 95135 USA
www.adconlab.com, (408)531-9187 (phone), (408)532-8886 (fax),
Raymond_Adcon@adconlab.com (e-mail)

**GRINM Semiconductor Materials Co., Ltd., 2 Xinjiekouwai Street, Beijing, 100088, China*

Importance of CMP Slurry in Semiconductor Fabs

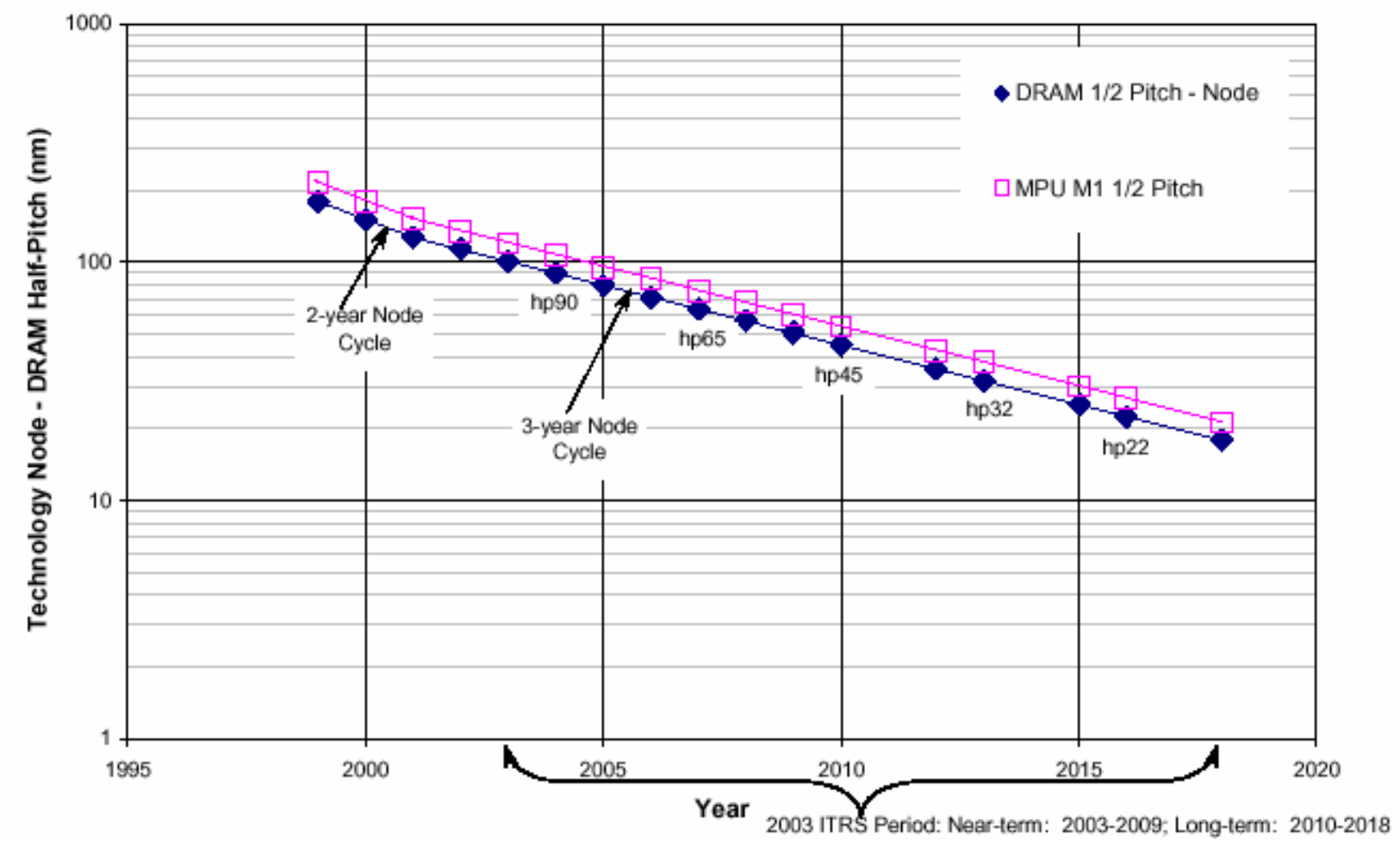
- **CMP is an enabling technology since 250nm technology node**
  - Every IC chip with advanced technologies goes through up to 20 CMP steps before going to market
- **Nearly 1/3 of CMP Cost of Ownership (CoO) in a typical IC fab attributes to CMP slurry and management**



Why Nanometer Abrasives for CMP Slurries?

- **A simple math and the trend in technology roadmap**
  - Current commercial IC chip is already at 130nm and functional IC chip at 90nm and beyond
  - Abrasive participates in three-body contact (wafer/abrasive/pad) during a majority of CMP processes
  - Slurries using abrasives in the nanometer range are desirable to achieve the planarity and remaining step-height control within the die for critical CMP step also at nanometer range
- **Flexibility in abrasive engineering and benefits in defect reduction**
  - Flexible in designing different particle sizes, shapes, and size distributions in the size range comparable to the feature size on IC device wafers
  - Minimize and eliminate the yield killers: micro-scratches and particles

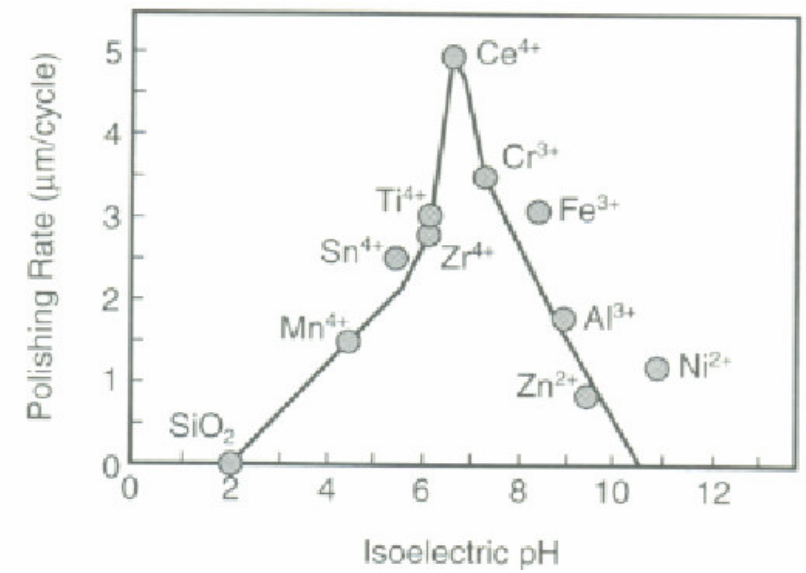
2003 ITRS Technology Roadmap



Why Adcon NanoCeria™?

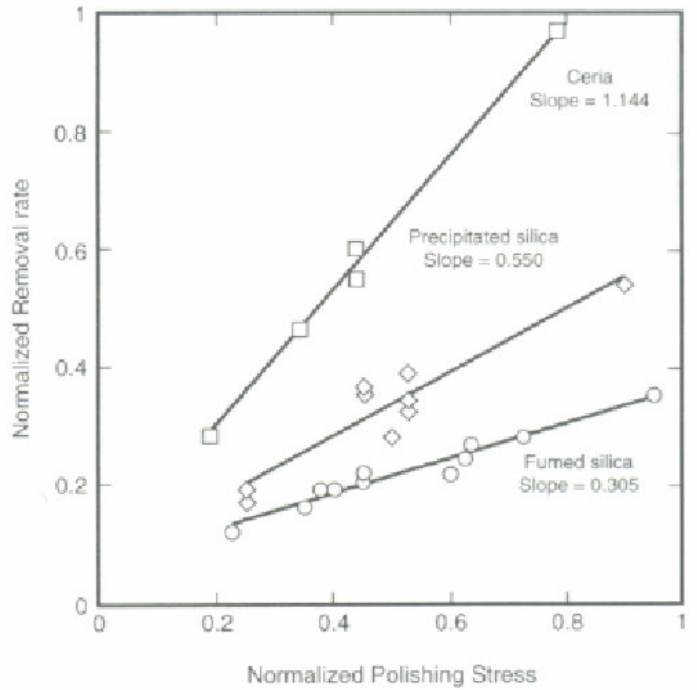
- **Yield improvement potential by reducing and eliminating μ-scratches and other yield-killers: defects and particles**
  - Equivalent to potential value >$2 billions a year if an average 2% IC device yield improvement is achieved
- **$25/wafer manufacturing cost reduction by eliminating reverse mask steps**
  - Equivalent to potential value >$14 billions over next 5 years, perceived by global IC manufacturers
- **The 1st commercially available product in the world with designed manufacturing capacities of 20,000 lbs solid equivalent a year, already sold to six multi-billion $ global companies**
- **Different controlled shapes (including round shapes), customer-specified size or size distribution, ranging from 10nm to 120nm**
- **Unique self-stopping features by properly formulated NanoCeria™-based slurry, after reaching planarization**

Higher Removal Rate Potential by Ceria Slurry



Removal rate of glass vs. IEP of abrasives

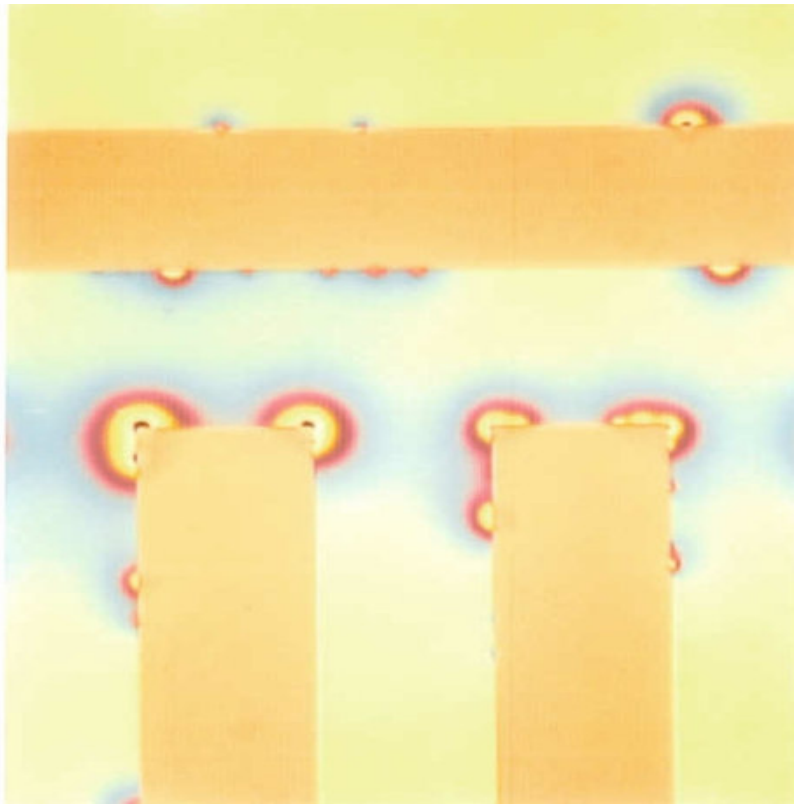
A. Kaller, Mschr. Feinmech. Opt. 79, 135 (1962).



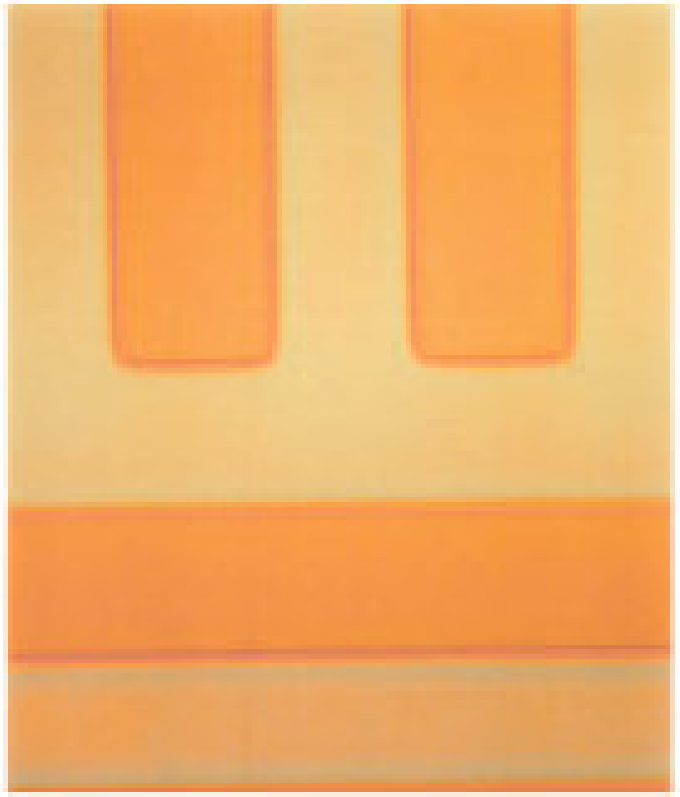
Normalized oxide removal rate vs. normalized polishing stress

R. Jairath, et al., Mat. Res. Soc. Symp. Proc. 337, 121 (1994).

Eliminating Pitting/μ-Scratches by Adcon NanoCeria™



Conventional Ceria, μm



Adcon NanoCeria™, nm

C. Shang et al., 8th Annual International CMP CMP Conf., 9/29/2003

Lower Cost Structure in Supplying CMP Slurry Solution

Lower cost by design in Asia Pacific Regions (mainly China, Taiwan, Korea, Singapore, Malaysia), where >50% of current worldwide WFE orders come from

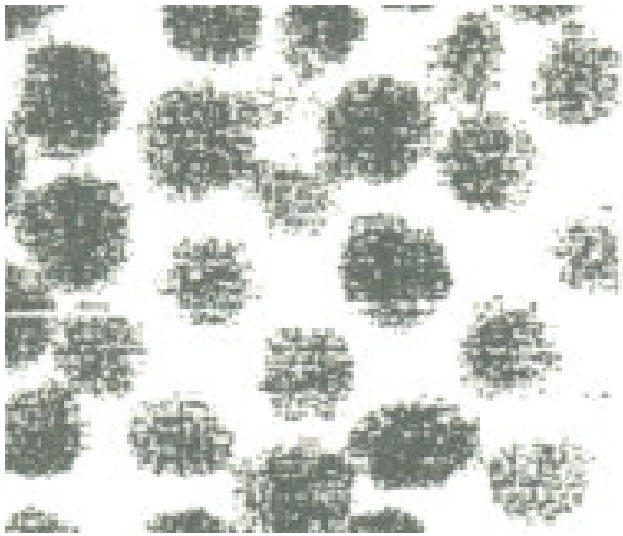
- **Conventional approaches in supplying slurry:**
  - Completely mixed and diluted slurry (solid content as low as <1%), ready to feed onto conventional CMP tool
  - Designed for developed countries or regions of high labor costs
- **Desirable alternatives, as compared to shipping bulky slurry (already diluted) across oceans:**
  - **Off-site (closer to IC manufacturing center):**
    - Formulate the slurry and/or chemical mixes as much concentrated as possible
    - Develop BKM of effective slurries for specific CMP applications (including mixing, dilution, and recycling if feasible)
  - **On-site (at semiconductor fab):**
    - Supply DI water, mixing tank, trained workers who can follow BKM

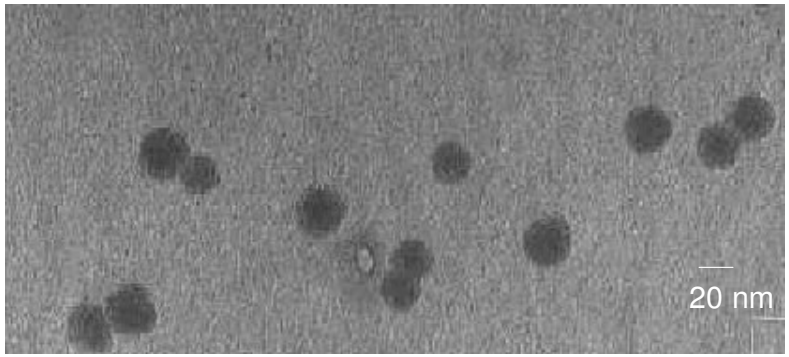
Cost Reduction Potential by On-Site Slurry Mixing/Recycling

- **Significant reduction in shipping cost and/or inventory cost**
  - On average, contributing to **10 to 20%** of CoO/CoC reduction, considering shipping using heated container during winter (October to April) and/or building excess inventory for entire winters
- **Significant reduction (10 to 20%), by qualifying the local suppliers of raw materials, DI water and packaging materials, in stead of going through conventional chemical distributors in developed countries, who originally procures the same chemicals and other raw materials in the regions**
- **Significant CoO/CoC reduction (30 to 90%) by reducing fresh slurry feed and waste disposed, when recycling is feasible and qualified**
- **Significant labor cost reduction (up to an order of magnitude lower) in training locally-recruited staffs for manufacturing slurries and managing their fab operation**

Nanometer Abrasives Used in AdconSi Slurry

NanoCeria™

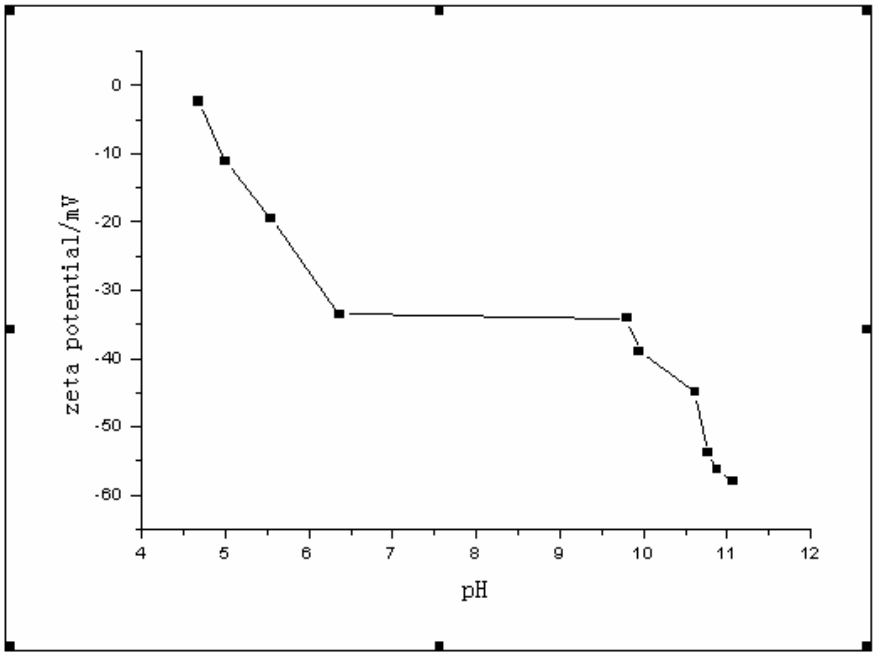




NanoSilica

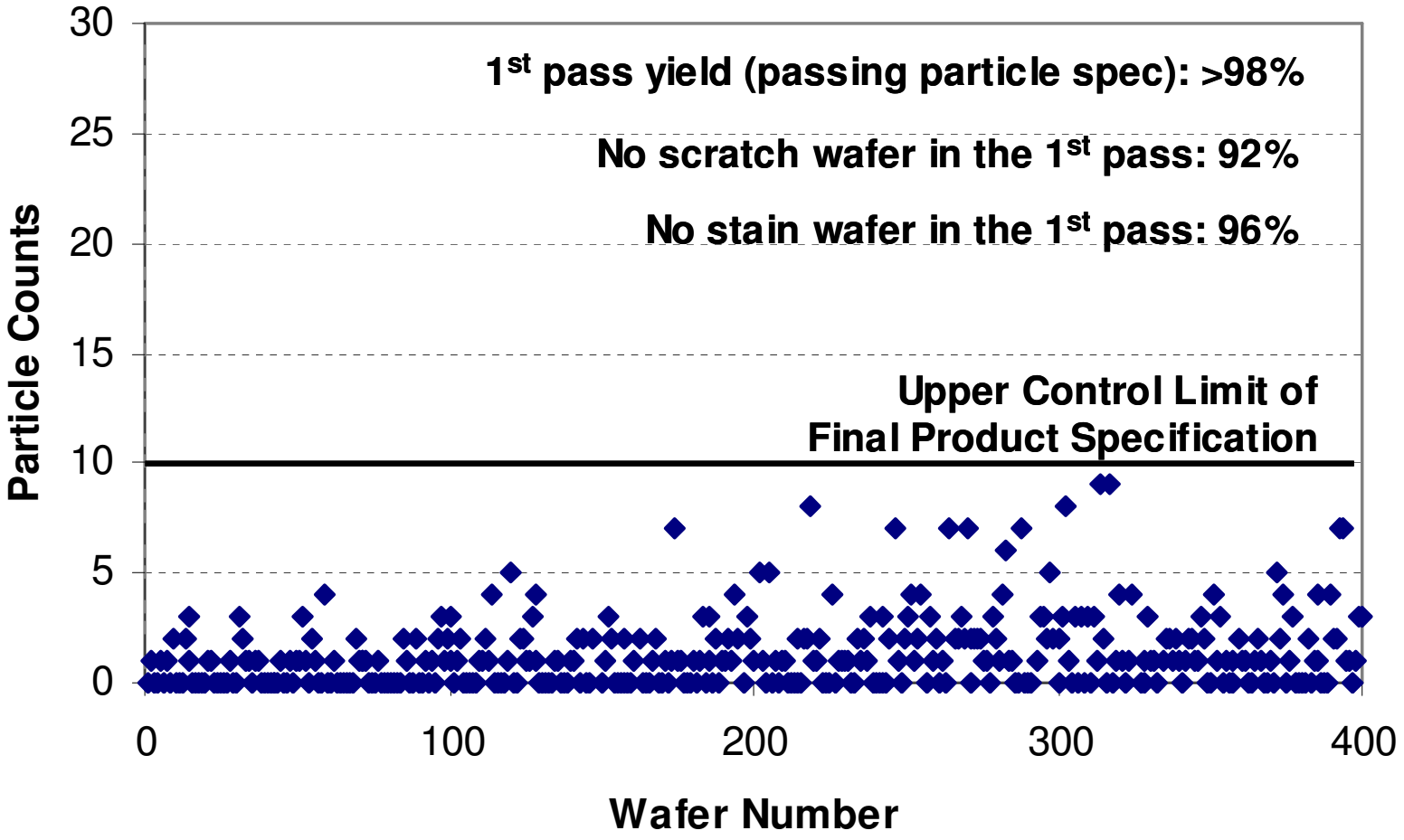
CMP Improvement by Controlling Interaction

– **Forces based on DLVO theory & beyond:**
  - Electrical interaction and intra-action between nanometer ceria particles of controllable shape and size distribution and the dielectric films being removed
  - Chemical or other specific interaction and intra-action between nanometer ceria particles and the dielectric films being removed, as induced or impacted by additives
  - Any interaction and intra-action forces (including van der Waal's, steric hindrance) under specific rheological and tribological conditions with specific pad, conditioning disk, and CMP platform/process

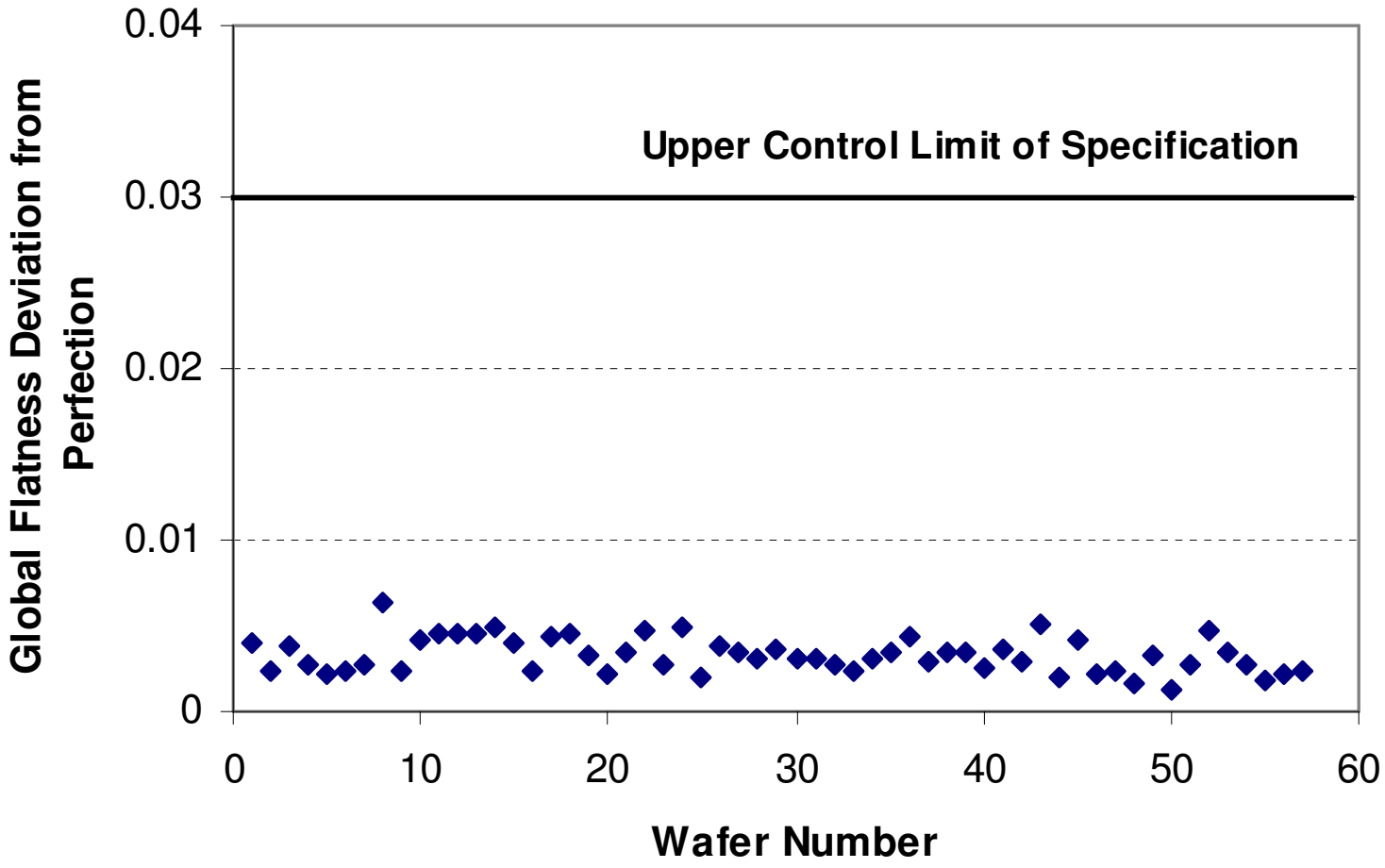


C. Shang et al., 8th Annual International CMP CMP Conf., 9/29/2003

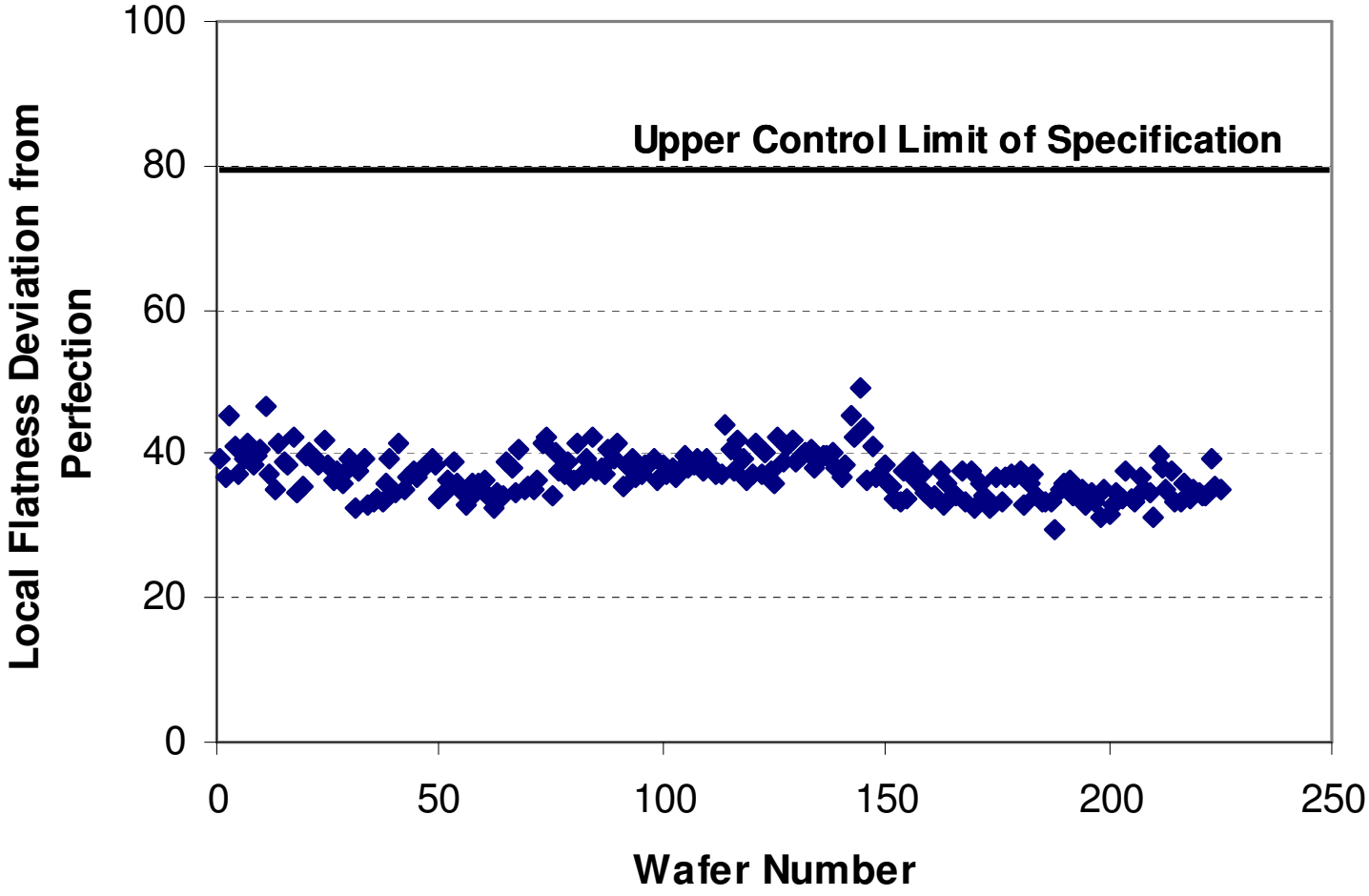
Particle Counts Measured during Volume Production



Global Planarity Measured during Volume Production



Local Planarity Measured during Volume Production



Summary

- More than 50% CoO/CoC reduction and improved planarity and reduced defects were achieved by using the 1st-ever locally manufactured CMP slurry, AdconSi, at semiconductor volume production fab in China and recycling the slurry during Si wafer production
- CoO/CoC reduction was attributed to lower cost by design: on-site manufacturing using concentrated slurry and locally procured and prepared chemical mix and DI water by locally trained staffs, as well as recycling
- Improved planarity and defects were mainly attributed to advanced Adcon nanometer abrasive technologies employing 20nm and 60nm silica particles and minute amount of Adcon NanoCeria™ (as an option for improved CMP performance), as well as Adcon formulation chemistry

Acknowledgements

- Adcon R&D and manufacturing teams
- Adcon customer support team
- Gritek production team
- Gritek/GRINM management team
  - Dr. Hailing Tu, Mr. Qigang Zhou, Mr. Tiger Zhang, Dr. Jing Wang, and Mr. Wish Tan
- Professor Dianzuo Wang
  - Head of Chinese Academy of Science and Engineering and a member of American Academy of Engineering