Nano-sized ceria abrasive for advanced polishing applications in IC manufacturing

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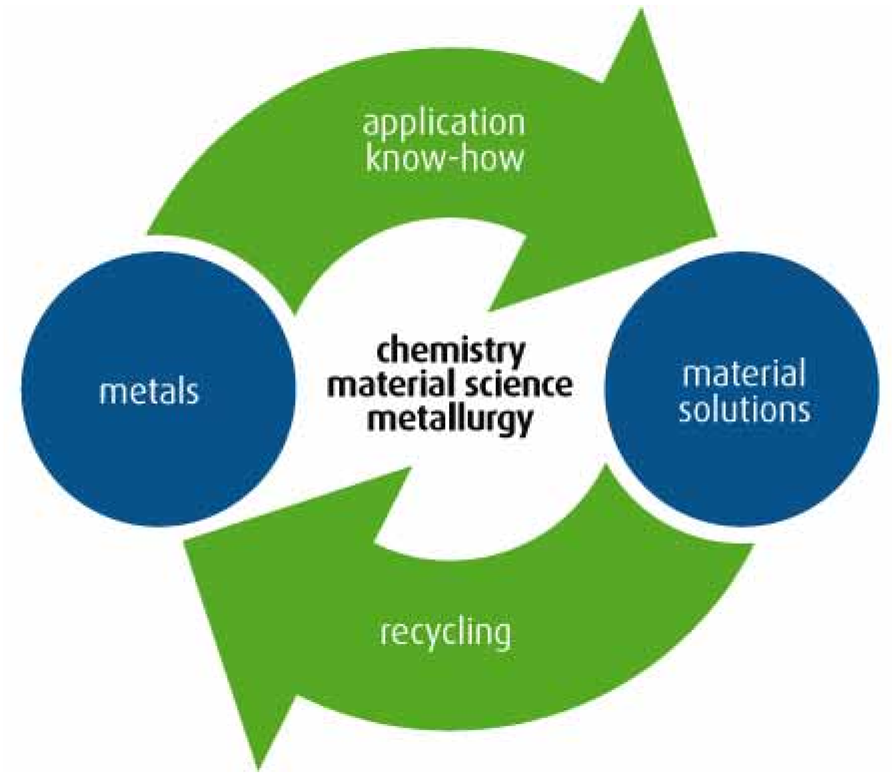
Outline

- Introducing Umicore nanomaterials
- Nano-powder synthesis
- Dispersion technology
- Case study – nano-ceria for CMP applications
    - CMP application
    - Development of nano-ceria for CMP
- Summary & conclusions

The Umicore approach to materials technology



Introducing Umicore

Umicore today provides …

- the automotive catalysts for almost 1 in 4 cars produced in the world
- key materials for the rechargeable batteries for more than 30% of all cell phones and laptops sold this year
- the semiconductor substrates for more than 60% of all satellite solar cells in the last 2 years
- recycling services for electronic scrap, batteries and spent catalysts to gain over 20 different metals

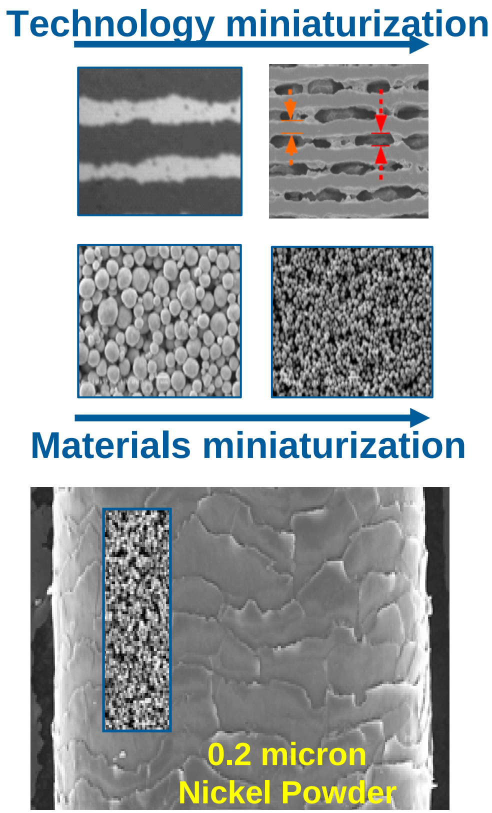
Umicore in a nutshell …

- 15,000 people
- 50 industrial locations worldwide
- 1.9 B € revenue in 2006

Nano: Hype or future?

- Umicore started nano activities ~ 8 years ago

- Nano creates a Win³ situation:
  - Device maker:
    - Miniaturisation (e.g. MLCC)
    - Enables new technologies
  - Supplier:
    - Added value products
    - Decommoditisation
  - Society:
    - Sustainability: more function with less materials



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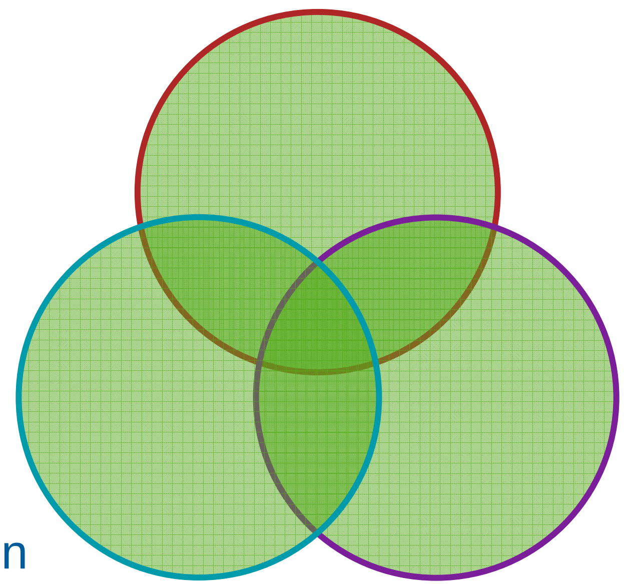
Technology development for nanomaterials production



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Powder synthesis

Particle synthesis and development

Particles or functional particles are developed in function of the application

- Functionality
- Quality
- Cost

On the basis of this, a synthesis technology is developed, Umicore has developed a range of synthesis and production technologies for the development of nanomaterials

- Gas phase synthesis (evaporation + reaction + quenching)
    - Mainly for oxide materials
- Precipitation techniques
- Milling techniques

Umicore precipitation Technology

- **large economy of scale**
- **patented process**

Process:

Metal solution + reduction

↓

Precipitated Metal

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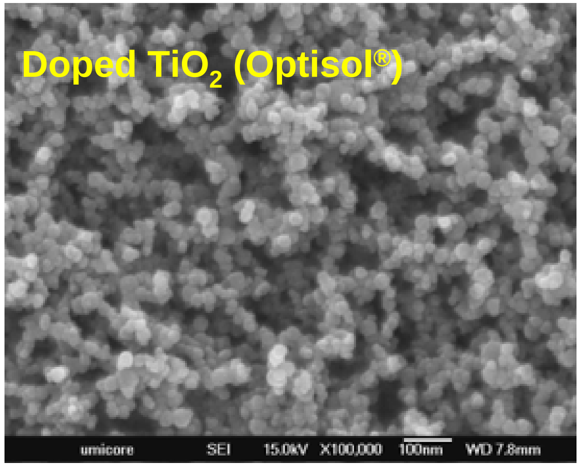
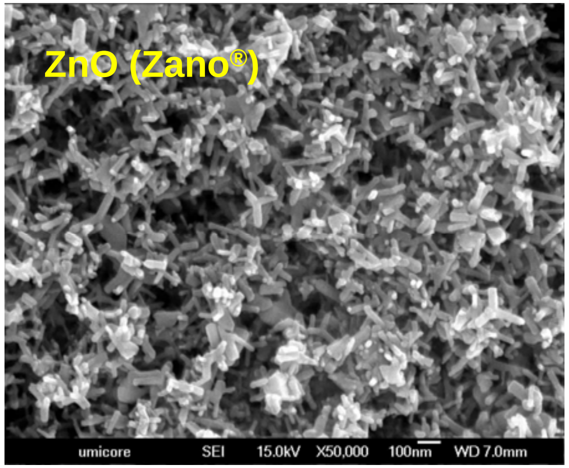
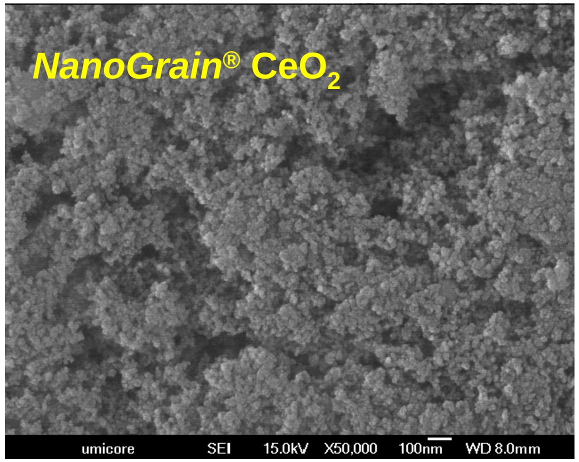
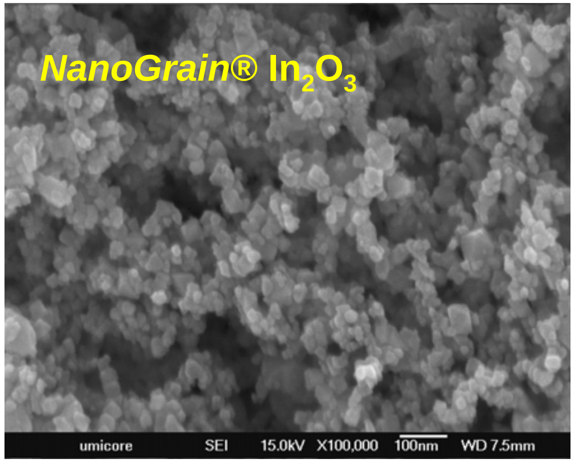
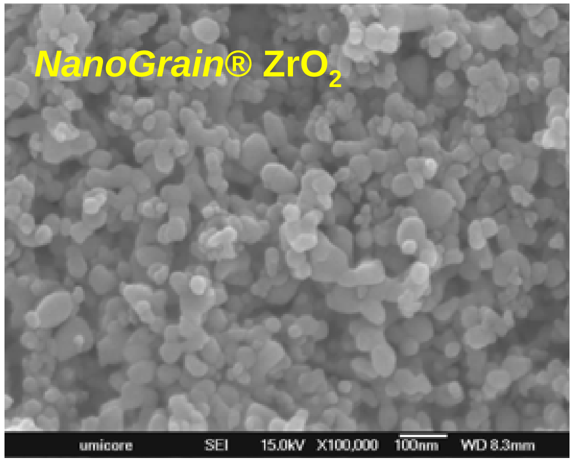
Umicore NanoMaterials particles, oxides











Others

Anatase, Rutile, GeO_2, ITO, doped ZnO, Al_2O_3, ...

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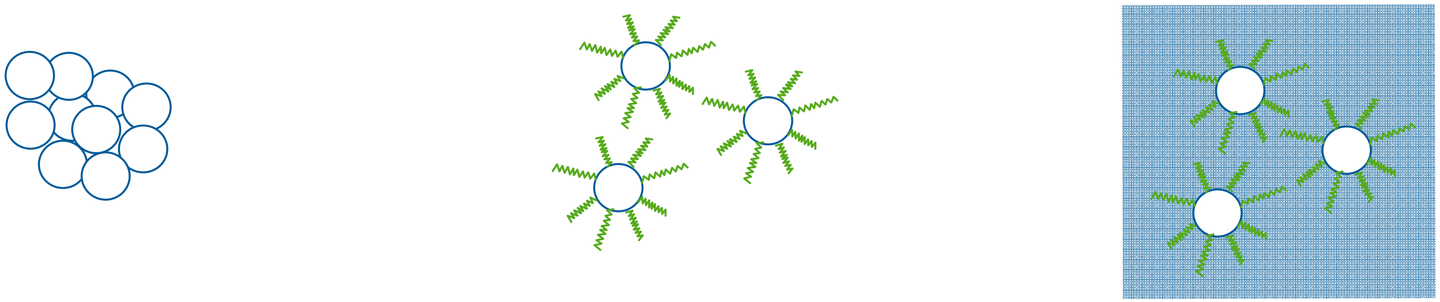
Dispersion technology

Dispersion technology

- Dispersion technology is key link to the application

Powder development and synthesis → **Dispersion and stabilisation** → **Application compatibility**



Dispersion technology

- De-agglomeration of particles:
  - Apply the right amount of energy to obtain desired results

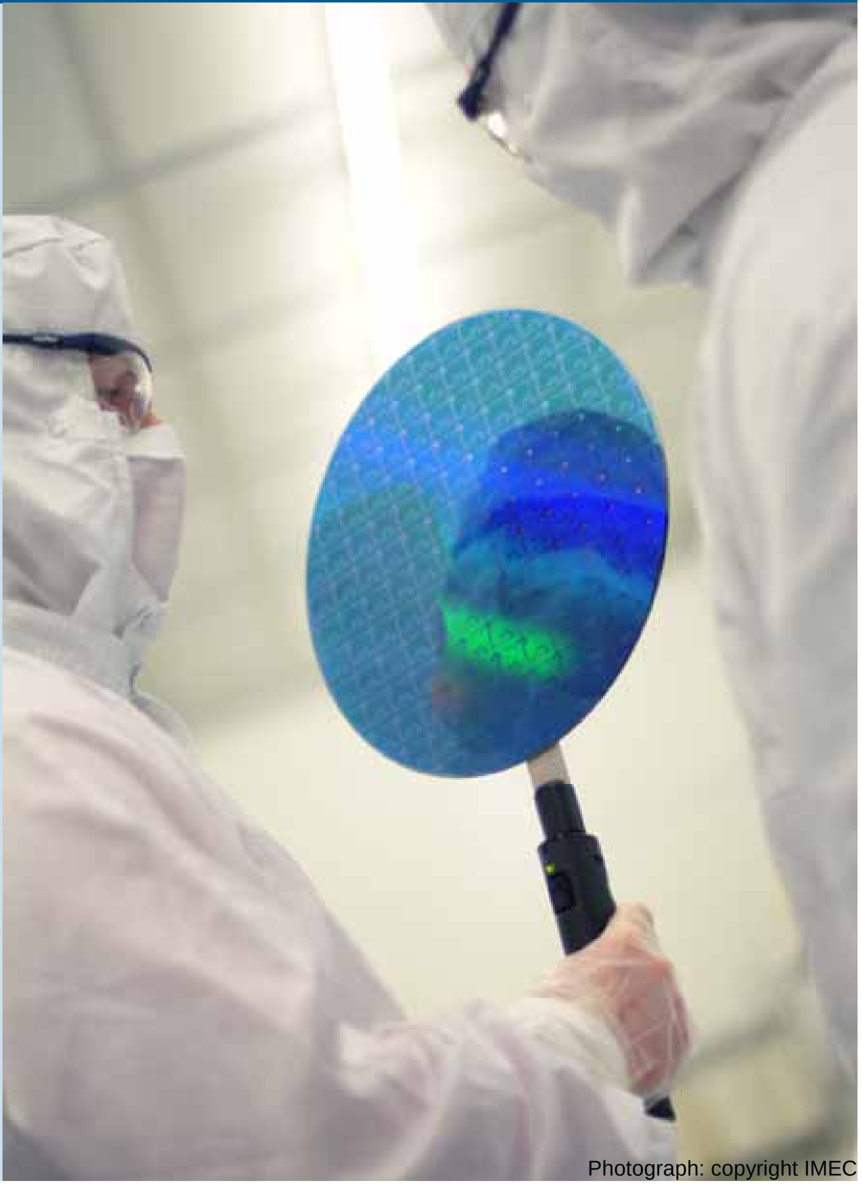
Low	**Intermediate**	**High**
• Used to prepare pre-mixes • De-agglomeration not optimal • Examples: •dissolver	• Low solids loading • De-agglomeration • Examples: • ultrasonication • rotor-stator	• High solids loading • De-agglomeration and milling • Examples: • bead mills • ball mills

- Stabilisation e.g. with additives – need for compliance with application!

Case study:

Nano-ceria for
CMP applications

1 – CMP application



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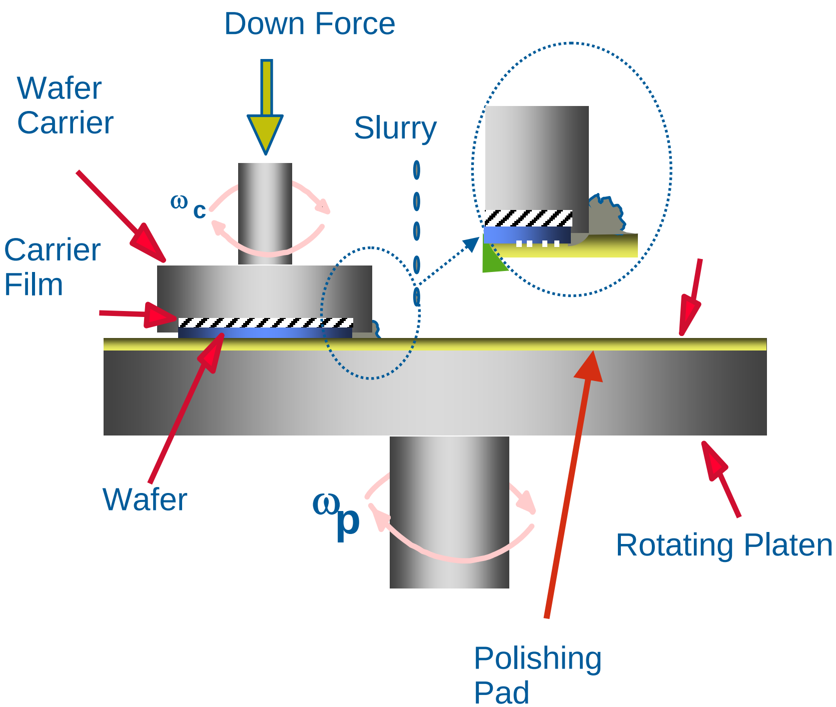
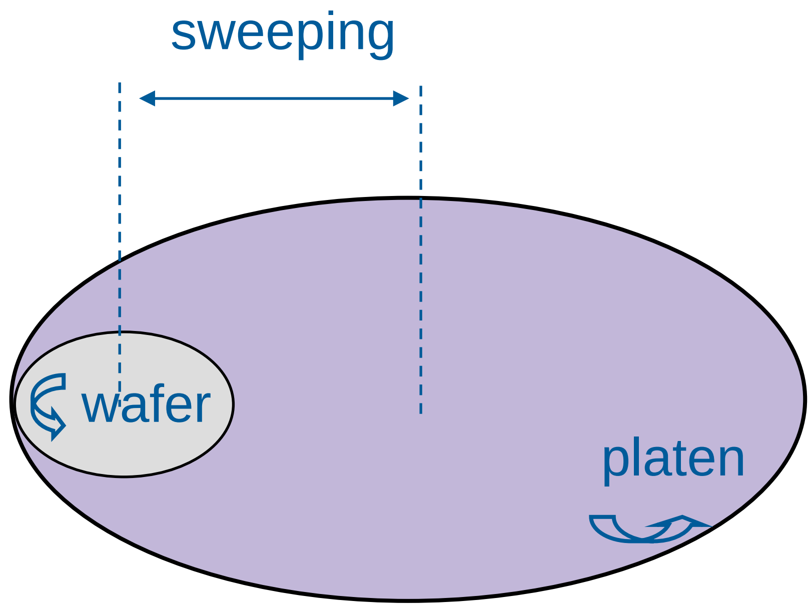
Chemical mechanical planarization (CMP)

- A technology used in the manufacturing of integrated circuits (IC's)
- Wafer is pushed against a polishing pad
- Pad and wafer rotate
- A polishing slurry is continuously fed to the process
- The slurry contains nanoparticles





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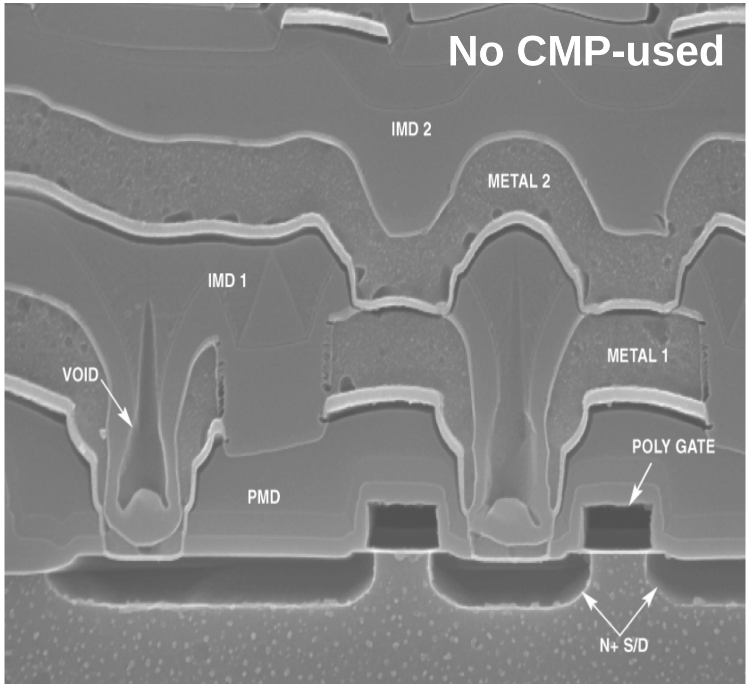
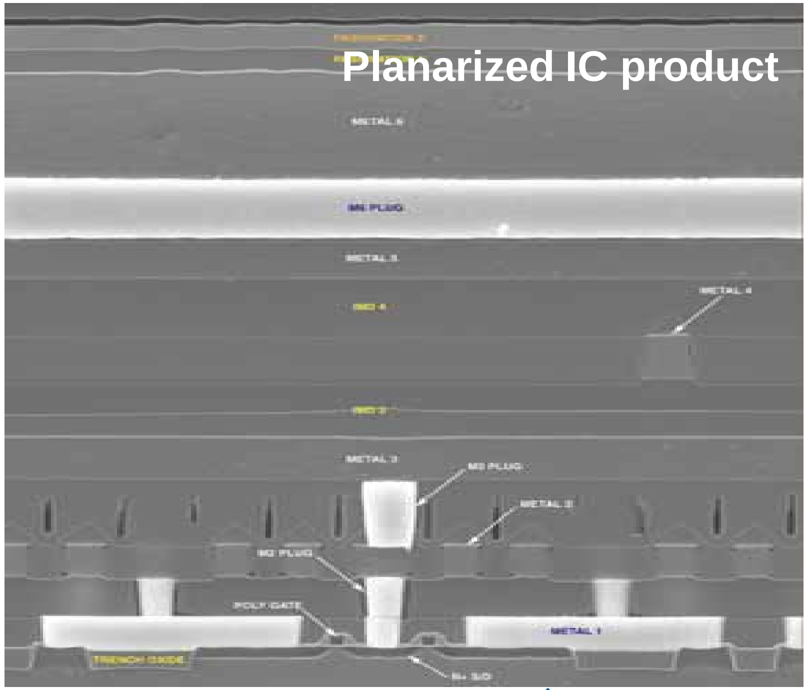
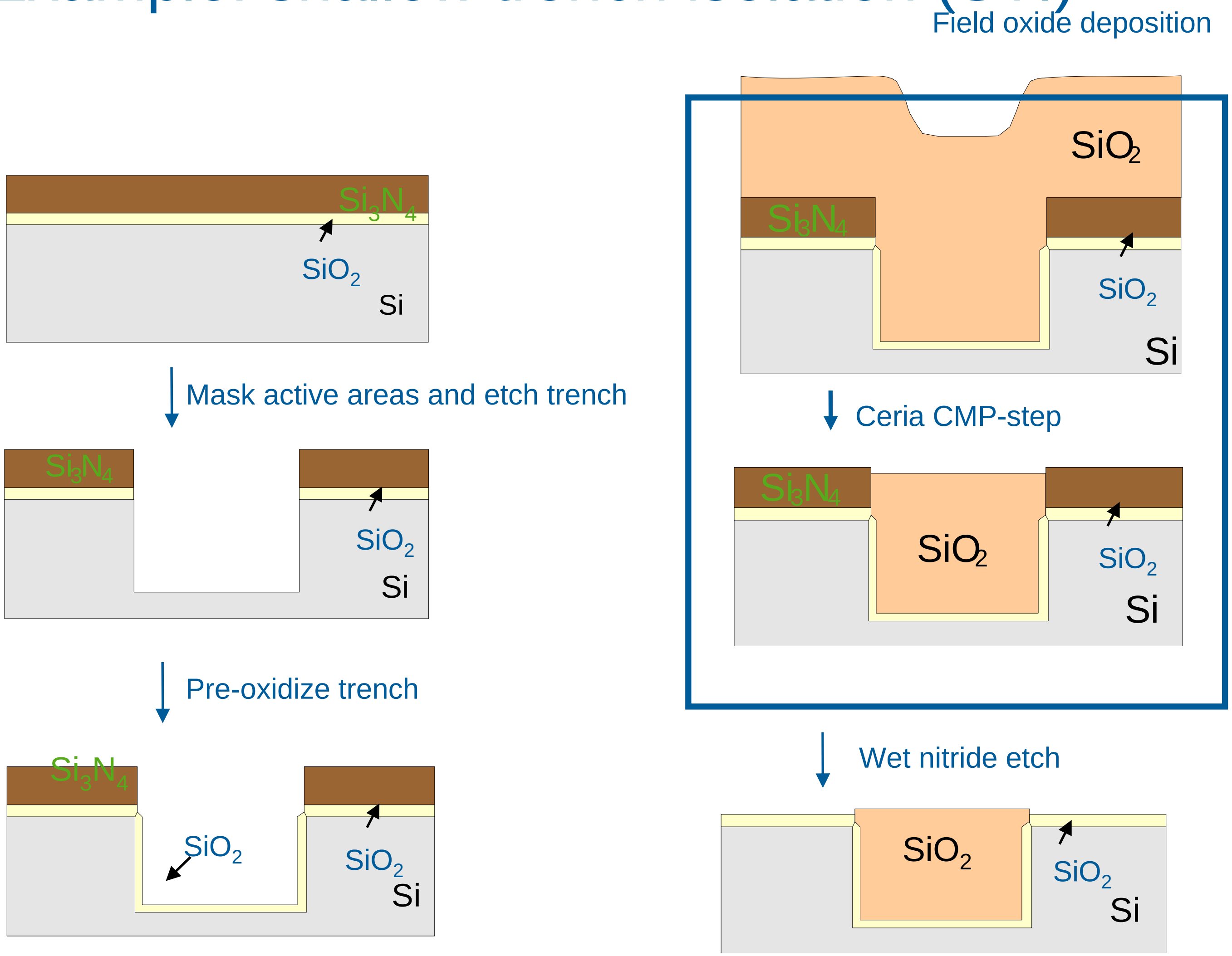
CMP: an enabling technology in IC manufacturing

- More and smaller transisitors on single chip = increasing # interconnecting layers
- Accumulated topology of different layers exceeds lithography depth of focus
- Solution is planarisation of layers by CMP, invented by IBM in the 1980's
- Developed into enabler for many of the new technologies in e.g. Intel's processers





Example: shallow trench isolation (STI)



STI CMP slurries contain ceria

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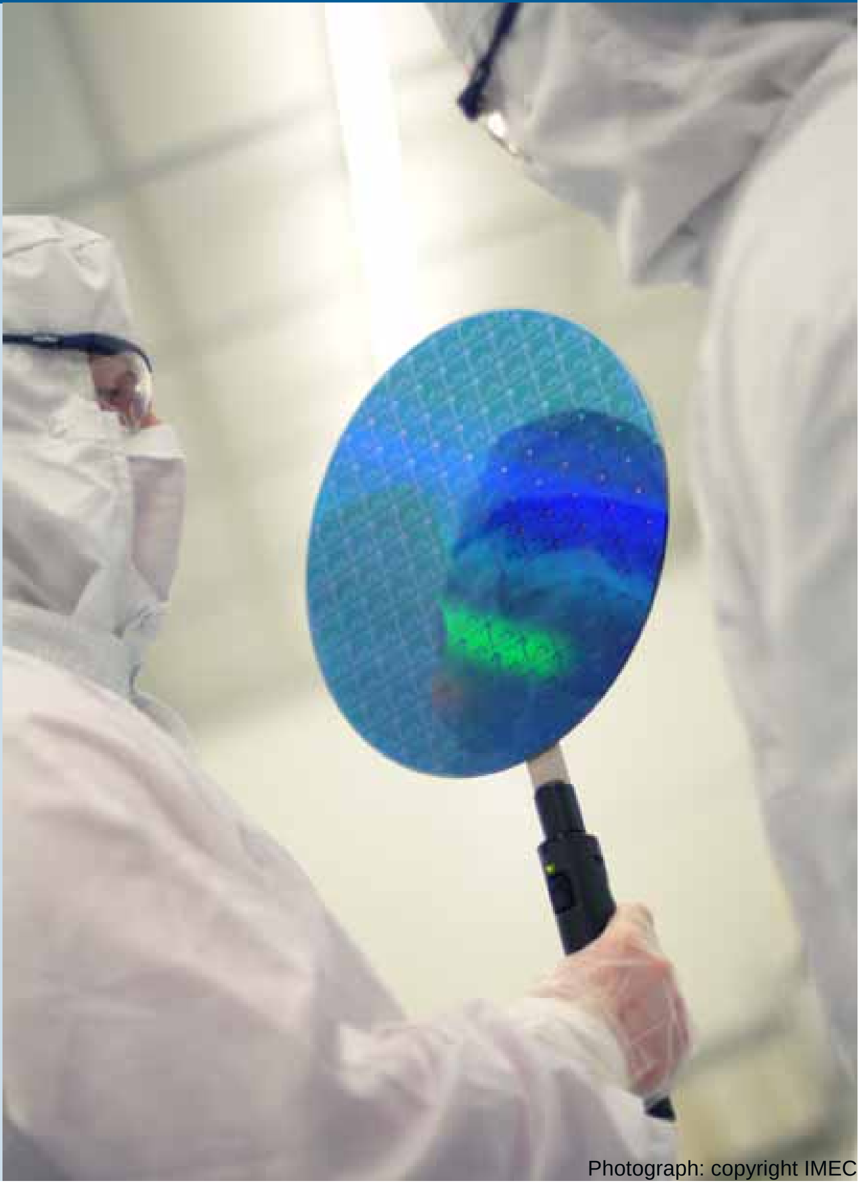
Case study:

Nano-ceria for CMP applications

2 – Development of nano-ceria for CMP



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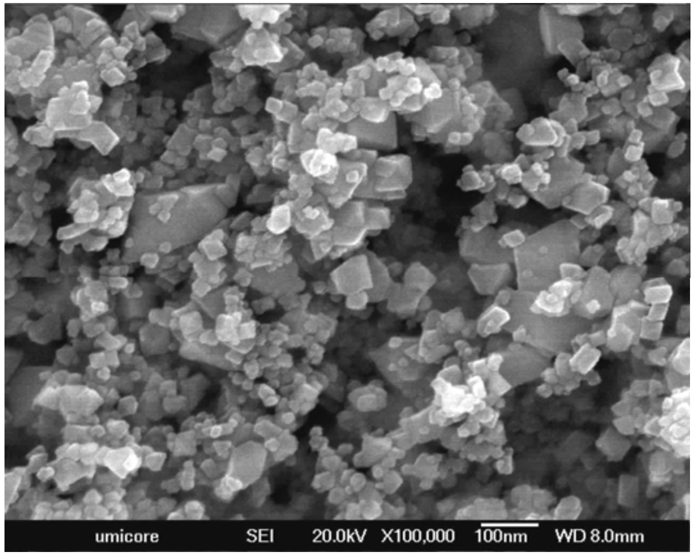
Objective and approach

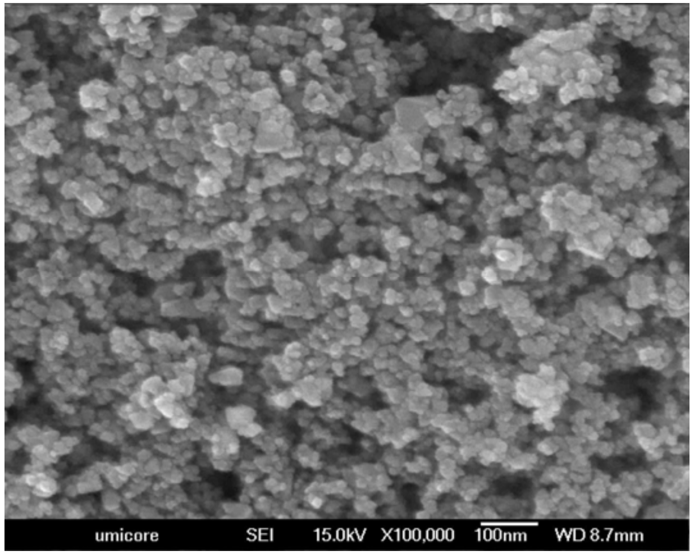
Development of ceria particles with low defectivity for STI CMP

- Development of synthesis route to control ceria properties
- Testing of ceria particles with different properties in CMP
  - Impact of specific surface area
  - Impact of large particle tail
  - Impact of particle shape
- Feedback of CMP results to synthesis
- Establishment of consistency for best product

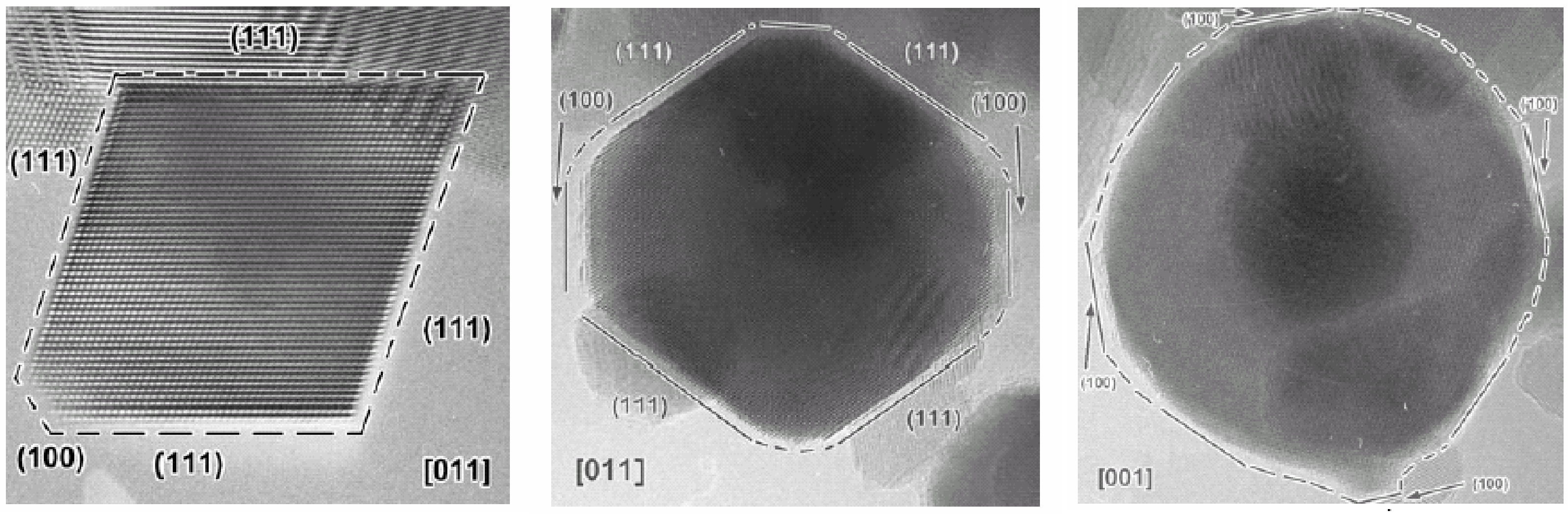
Ceria particle size/specific surface area

- Specific surface area in range 20 to 85 m²/g
  Equivalent average primary particle size range: 10 to 40 nm
- Primary particles not sintered: no hard agglomerates
- 100 % cubic crystalline





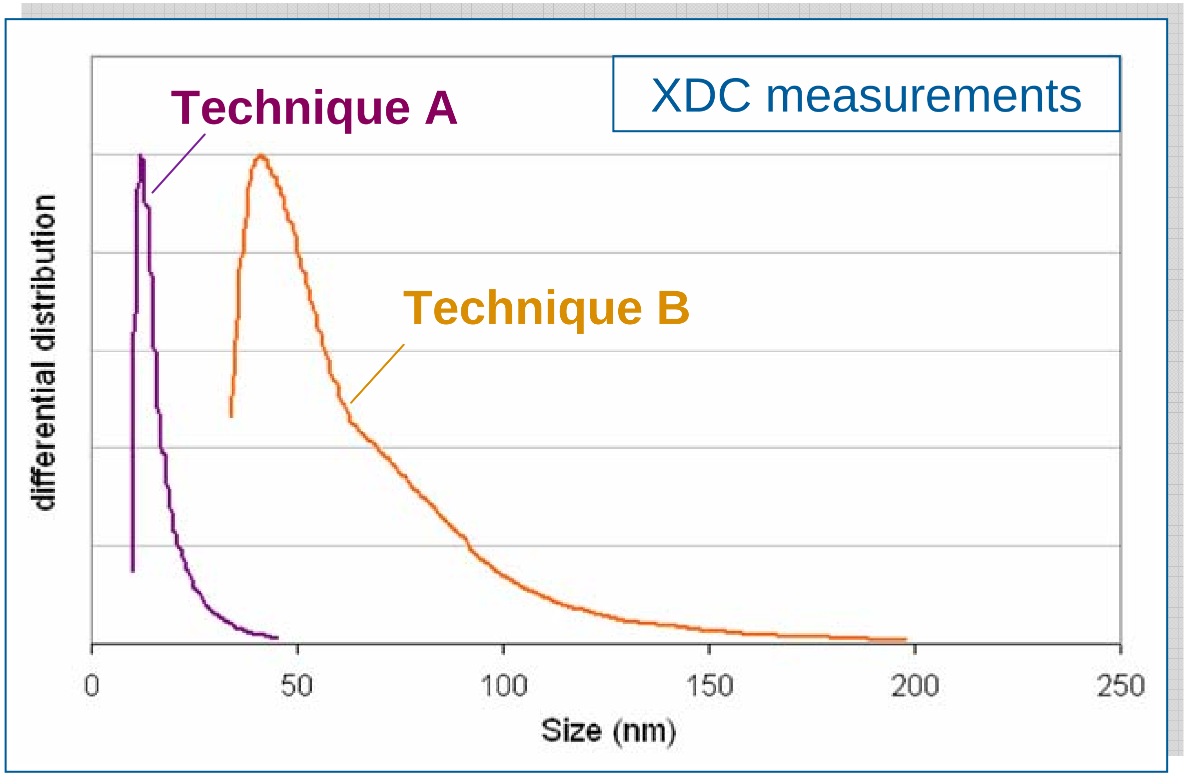
Control of particle morphology



Particle morphology can be controlled through processing conditions

Ceria dispersion properties

Particle size distribution in dispersion determined by dispersion technique used



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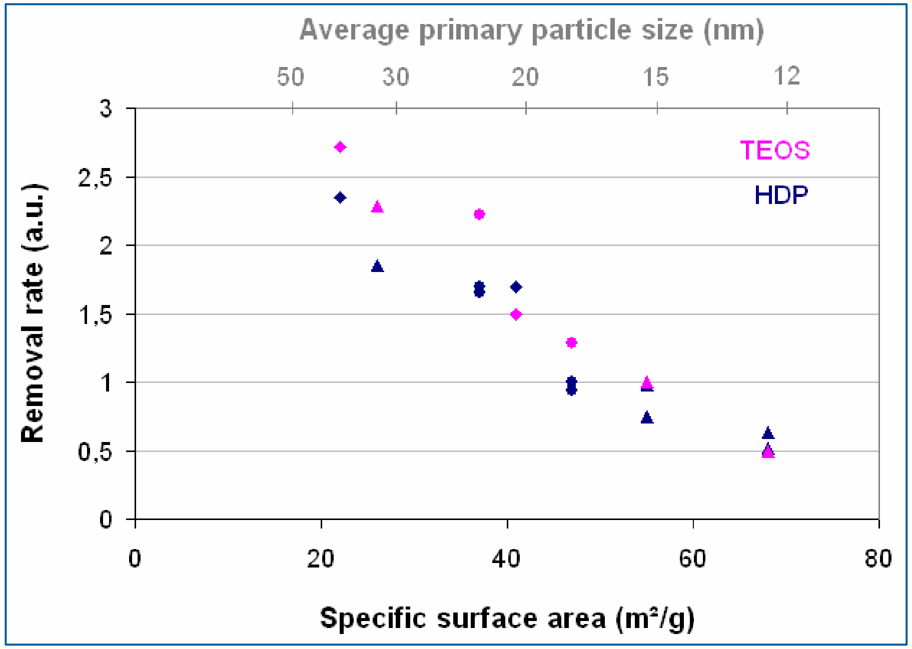
CMP evaluation

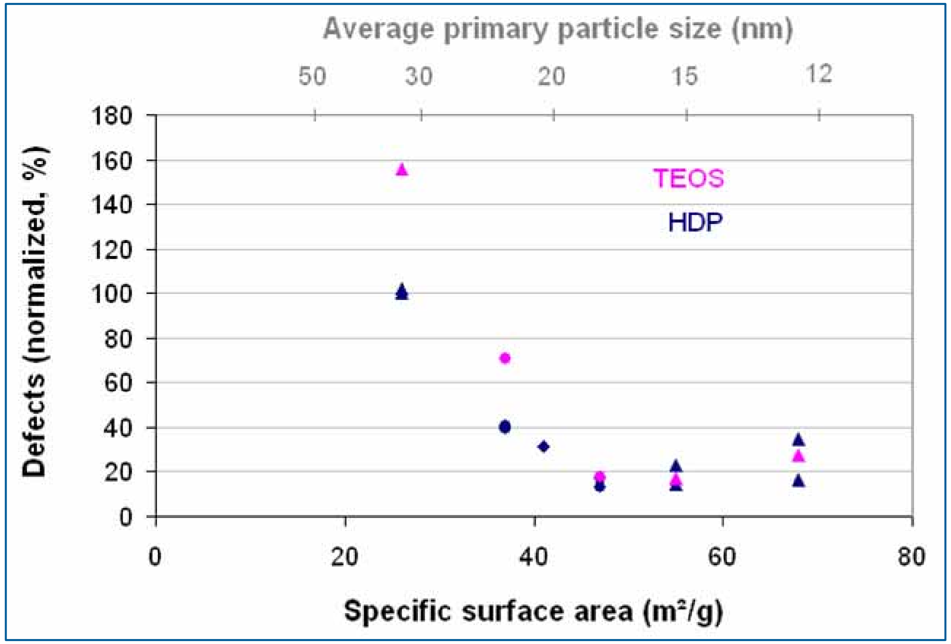
- Key performance parameters for STI CMP
  - High removal rate for SiO_2
  - Smooth, defect free surface finish (= low defectivity)
- Stabilizer added to dispersions (no other additives)
- Pre and post CMP characterization
  - Film thickness: spectroscopic ellipsometry (ASET-F5, KLA Tencor)
  - Defectivity: dark field laser light scattering (SP-1, KLA Tencor)
- Defectivity evaluation
  - Minimum defect size 0.15 µm
  - Focus on scratches as particles can be removed during further processing

Impact of specific surface area

Removal rate



Defectivity



- Strong correlation between particle size and removal rate
- Lower defectivity for smaller particle size, but plateau below 20 nm

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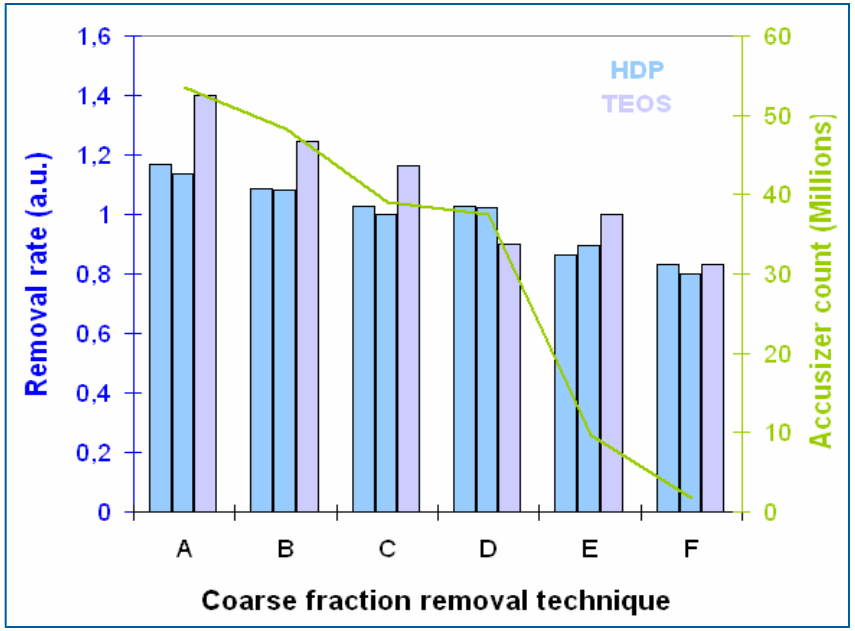
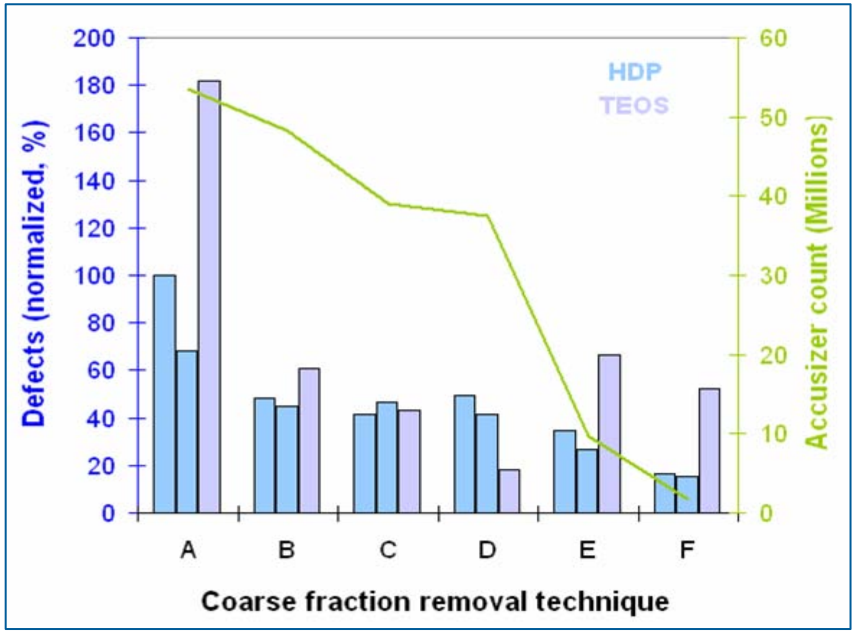
Effect of various coarse fraction removal techniques on large particle count and polishing results

Removal rate



Defectivity



A : reference (as sonicated) **B..F : different techniques**

- Large particle count controlled by coarse fraction removal technique

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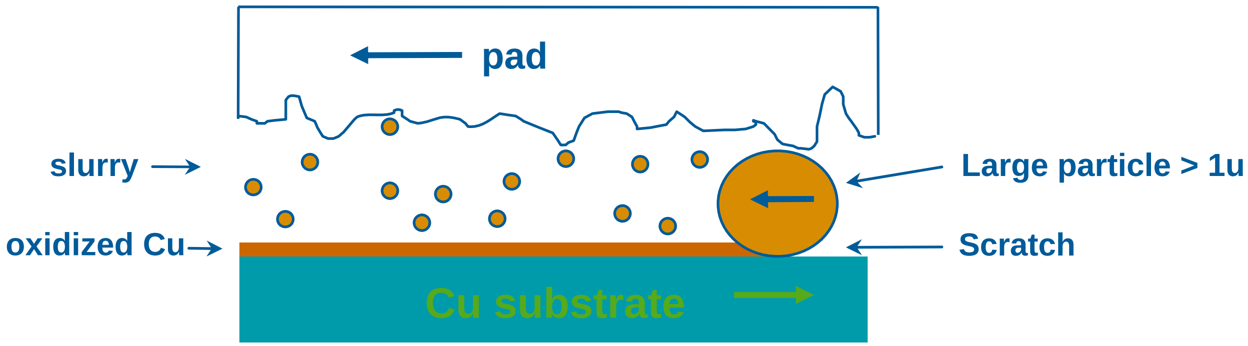
Importance of large particle count for defects

CMP Scratch Formation



- Unwanted large particles dig too deep
- Damage causing particles cannot be easily detected

- Excellent control of large particle tail required!

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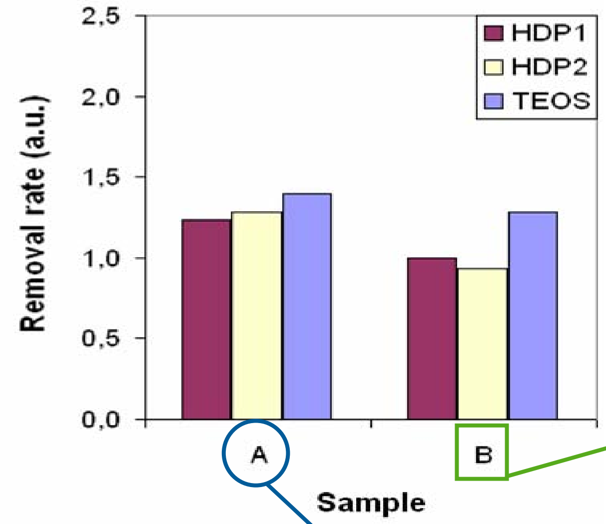
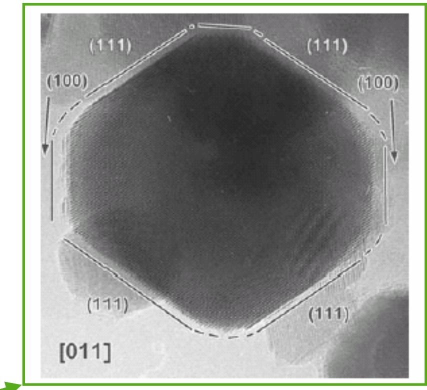
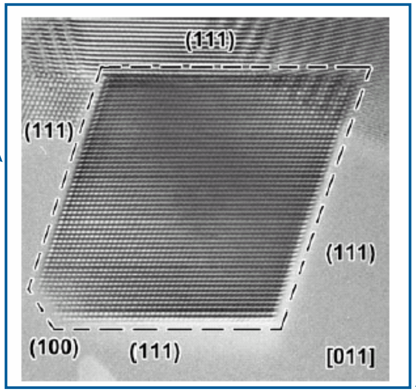
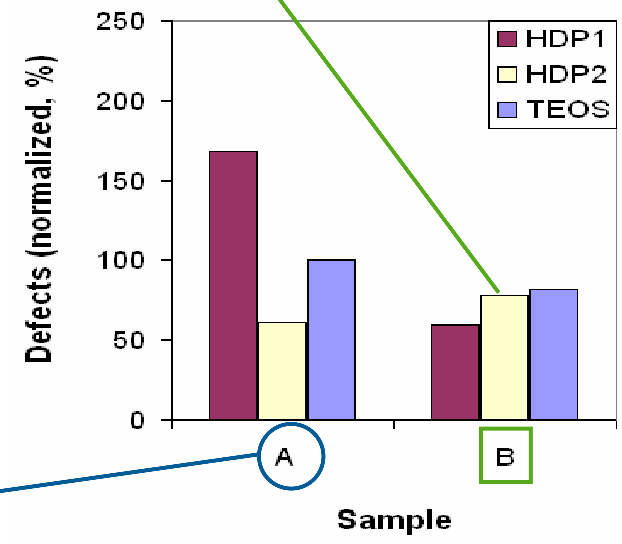
Impact of particle shape I



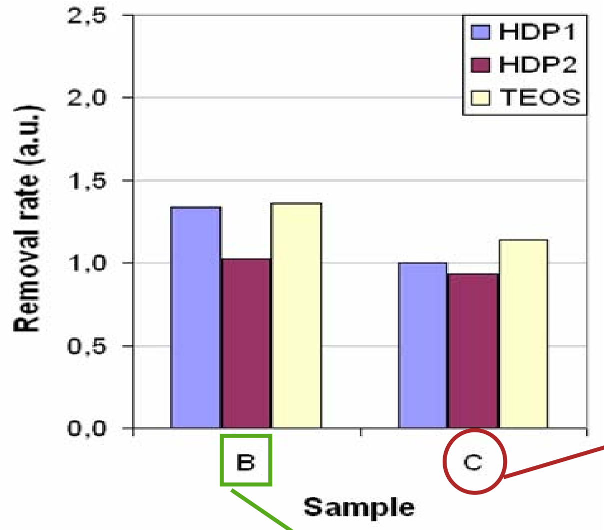


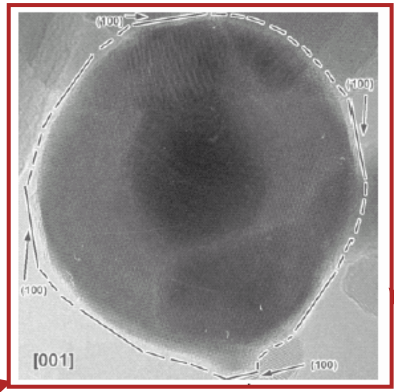


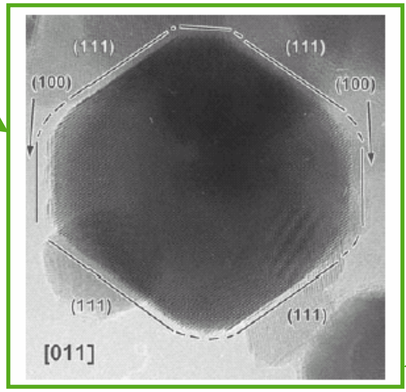


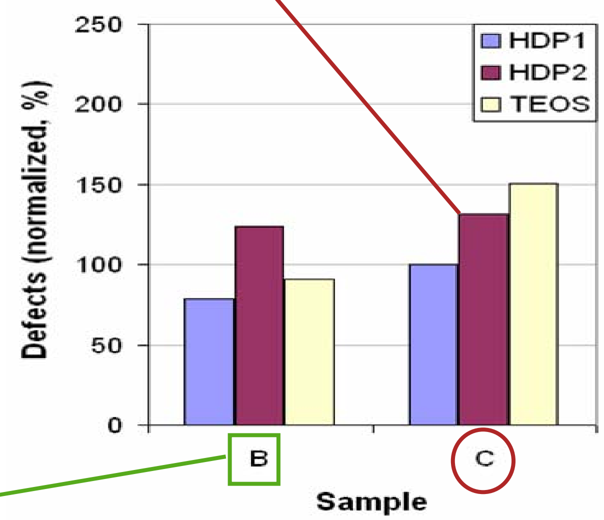
Sharp particles have slightly better CMP performance than truncated particles

Impact of particle shape II









Rounded particles
lower removal rate
& higher defectivity

Unexpected result!

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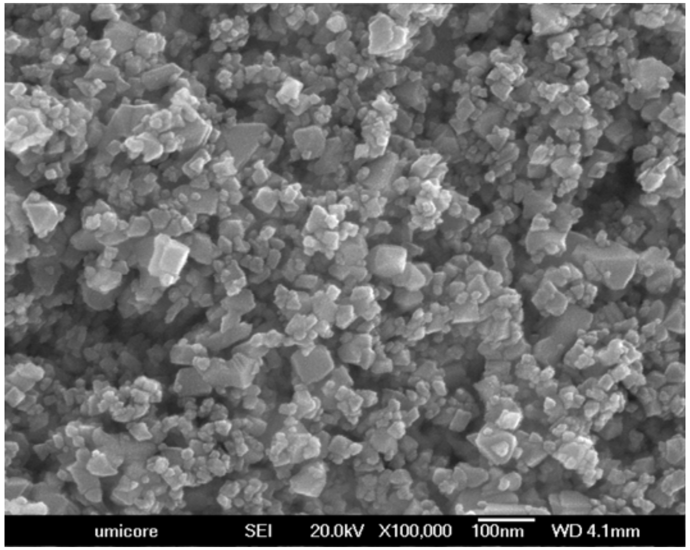
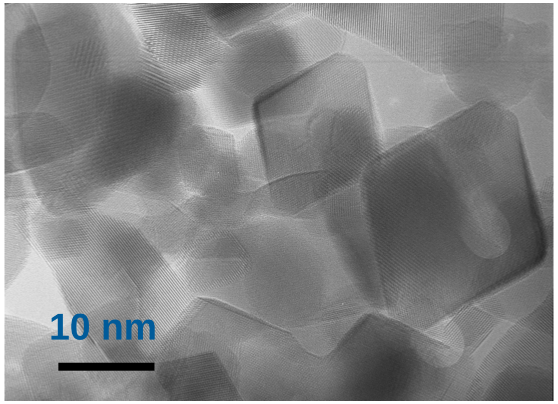
Final selected product

- Adjusted particle size
- Controlled large particle tail
- Controlled morphology



- Excellent combination of removal rate and defectivity

- Excellent reproducibility
- Low cost potential



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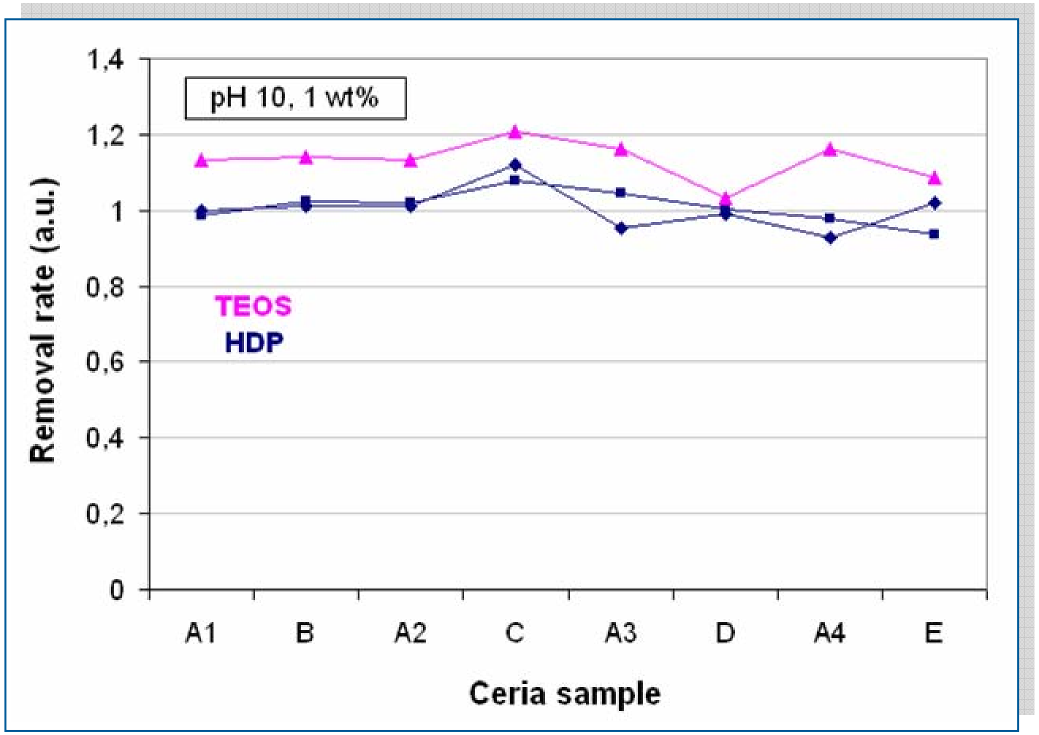
Consistency



- 5 Production batches (A thru E) tested in CMP
- Good consistency of CMP results

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Summary and conclusions

- Development of new nanomaterials for large scale production requires dispersion and application knowledge
- Gas phase synthesis process was developed to gain flexible control over particle size, distribution and morphology

- Nano-ceria particles for CMP were developed allowing
  - Better defectivity
  - Good removal rate
  - Good batch-to-batch and within-batch consistency

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Thank You

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