Replacement of rare earth elements in semiconductor production

Chemical Mechanical Polishing (CMP) of Stop on Nitride (SON) processes without cerium oxide abrasives

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- Chemical Mechanical Polishing (CMP) is the process with the second highest CO_2 e footprint in semiconductor manufacturing
- Abrasive particles in CMP are usually silicon oxide (silica) or cerium oxide (ceria)
  - Ceria as a rare earth element has a significantly higher CO_2 e footprint
  - Ceria is suspected of being carcinogenic
  - Global supply of Ceria as a rare earth element is critical [1]
- Polishing steps that selectively stop on a silicon nitride layer (SON) are often implemented with Ceria slurries in advanced technologies

- Process results in the CMP process depend on the structuring of the chips
- In particular, the production of diverse chips is currently not possible with silica-based SON polishing steps
- Diversification of microelectronics requires diverse chips

2 MotivationState of the art

- CMP for Stop on Nitride (SON) structures must remove silicon oxide defined via silicon nitride High line densities ensure long
- polishing time until active oxide is removed
  - Low densities next to high densities are polished longer than necessary
    → stop on nitride (SON) must work very well
  - Wide density range = high input topography = high SON requirement

  Variation of the process result
- via structure densities [2]
  - Ceria slurry for a wide density range in the target window
  - Silica slurry only with a very narrow density range in the target window

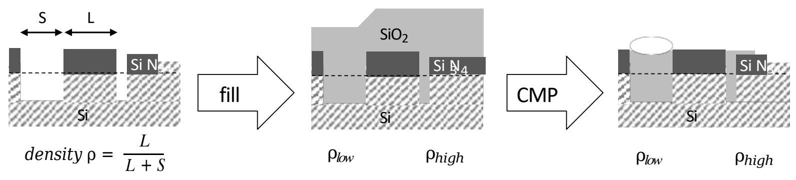

Fig. 1: SON process flow

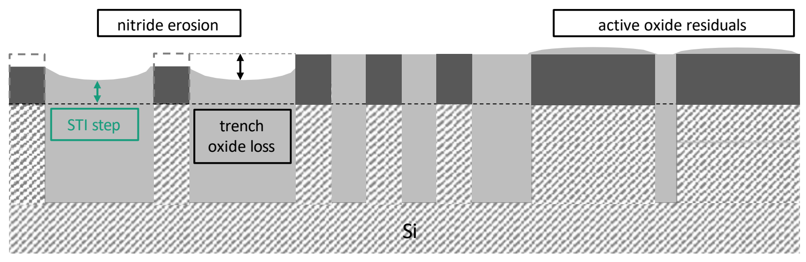

Fig. 2: Structure-dependent CMP process result with SON CMP

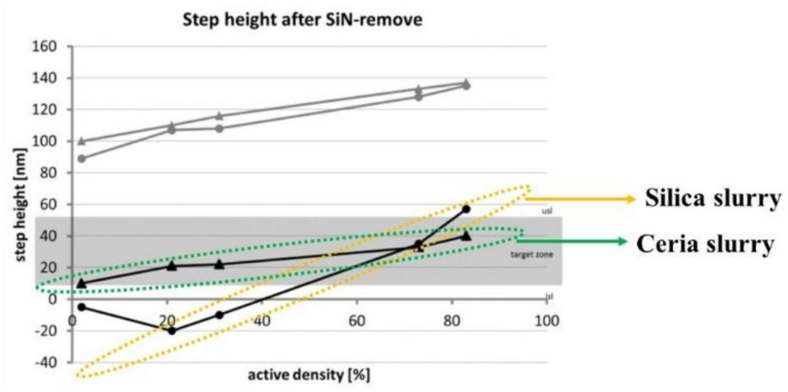

Fig. 3: Ceria slurry shows significantly lower structural dependence than silica slurry [2]

3 Cerium oxide-free STI CMP

- Polishing in two steps: pre-polishing and final polishing
  - Pre-polishing: Leveling the structures, reducing the difference between high and low densities
  - Final polishing: SON polishing with selective, environmentally friendly silica slurry
- Optimization of pre-polishing Reduce topography (=density dependency) and thus reduce SON requirements
- Three options for better pre-polishing
  - More oxide for longer polishing
  - Lower polishing pressure
  - Dividing the polishing time into 30s intervals
    → Reduced topography (WIDNU) = reduced density dependency
- Lower density dependence and topography remains after SON/final polishing (WIDNU correlated)

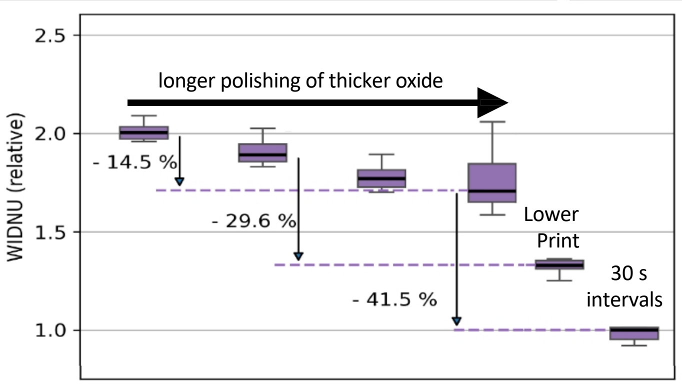

Fig. 4: Improved topography (=density dependence) through adapted pre-polishing

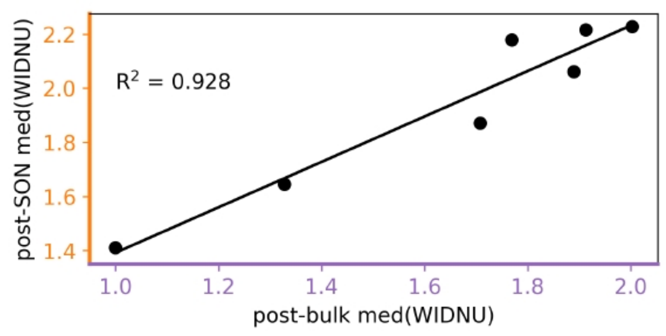

Fig. 5: Correlation of the density dependency after pre-polishing and final polishing

Conclusion: Process

- Final polishing result can be significantly improved by adapting the pre-polishing process
- Limitations due to silica abrasives (stronger density dependence) can be addressed by adapted pre-polishing
- Various pre-polishing options offer variance in process customization depending on the required products

Conclusion: Environment

- STI CMP for various chips of advanced technologies without rare earths is possible
- CO_2 e footprint of the central consumable CMP Slurry can be reduced

[1] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, M. Grohol, and C. Veeh, Study on the critical raw materials for the EU 2023 - Final report. Publications Office of the European Union, 2023.
[2] Andreas Krüger, Andreas Trusch, Marco Lisker, "Comparison of Silica-and Ceria-Slurry for Direct STI-CMP,"

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