scia Trim 200
Ion Beam Trimming

Allan Biegaj

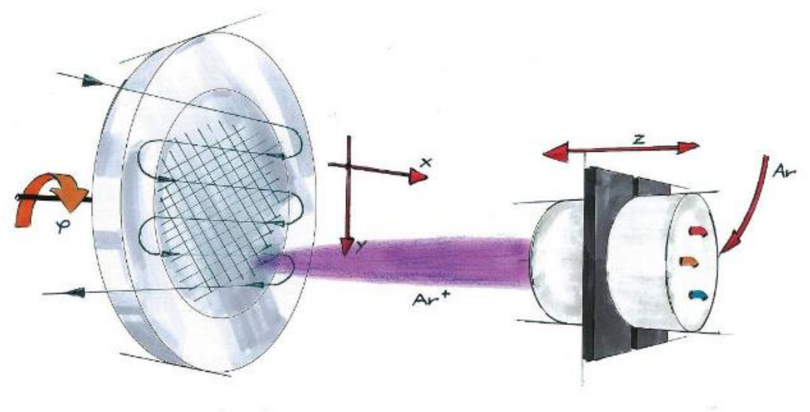
July 2017

Background

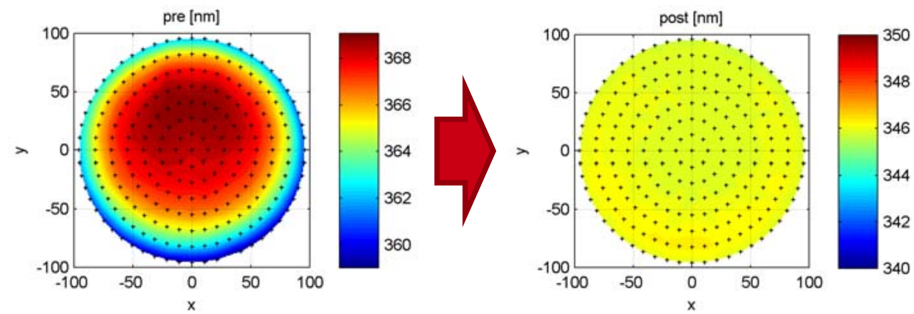
Principle of Ion Beam Trimming (IBT)

Principle of Ion Beam Trimming

- Localized wafer polishing (trimming) by focusing of broad ion beam
- Non-contact, high vacuum process with precision to nearly single atomic layer
- Ion beam scanned across wafer surface, varying dwell time to remove exactly desired amounts at each location on wafer
- Dwell time map automatically calculated based on incoming wafer topology map



Principle of Ion Beam Trimming



Thickness data before (left) and after (right) ion beam trimming

Ion Beam Trimming as Complement to Semiconductor CMP

Background and Potential Applications

Overview of CMP and IBT

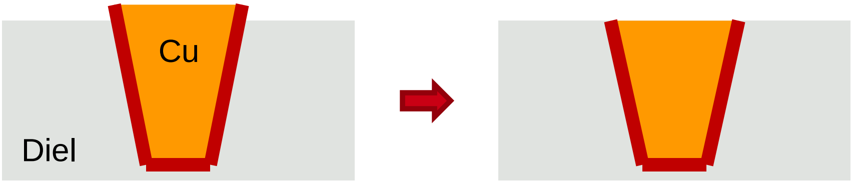
- CMP has good removal rates and planarization efficiency
- IBT can remove material locally and selectively with nanometer precision.
  - => Complementary strengths
- Trimming useful for post-CMP reduction of imperfections
  - Can improve control of dimensions, topography, and surfaces

Dimensional Control

- CMP may create thickness variations
  - Radial dependence of removal (WIWNU)
  - Variation in mean amount of removal (WTWNU)
- IBT for use after high removal CMP applications
  - WIWNU often proportional to amount removed
  - Interlevel Dielectric CMP (memory), Cu CMP for semi-global and global interconnects, W via CMP
- IBT for use after lower removal CMP applications
  - These have tight final thickness control requirements
  - FinFET Poly CMP, Poly-Open-Polish CMP, Metal Gate CMP, Cu minimum pitch levels
- IBT for correction of final thickness through localized trimming
  - Demonstrated ability to precisely control removal mean and profile

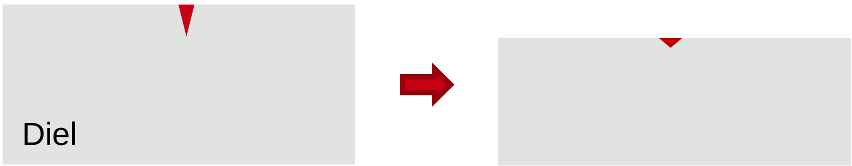
Topography Control

- CMP has to handle increasingly complex film stacks
  - May not always achieve perfect selectivity, leading to step heights differences
  - More critical for low removal CMP applications
  - Need to create planarity with less and tighter film loss
- IBT Trimming technology can aid planarization
  - Metal to dielectric selectivity may be adjusted



Surface Control

- CMP may sometimes leave the surface less than ideal condition, with residues, scratches, or roughness.
- Trimming can change surface roughness
  - Effect depends on the energy used and the material being trimmed
  - IBT lowering roughness could enable more aggressive CMP
  - IBT increasing roughness could help subsequent layer adhesion
- Residues can be reduced
  - Surface oxidation from CMP and cleaning can be removed
- Removal without chemical effects can reduce scratches
  - Shallow micro-scratches can be altered



Applications

Process Examples and Typical Results

Applications in dimensional Trimming

Devices with Critical Dimensions:

- Bulk Acoustic Wave (BAW) devices
- Surface Acoustic Wave (SAW) devices
- Bulk volume quartz resonators
- Thin Film Head (TFH) devices in magnetic storage
- Silicon on Insulator (SOI) wafer

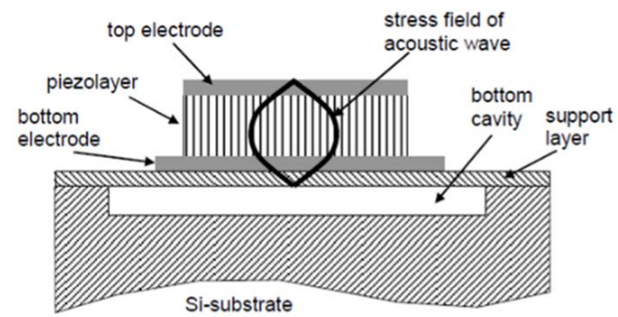
Hard drive using TFH devices

Mobile phones using BAW and SAW devices

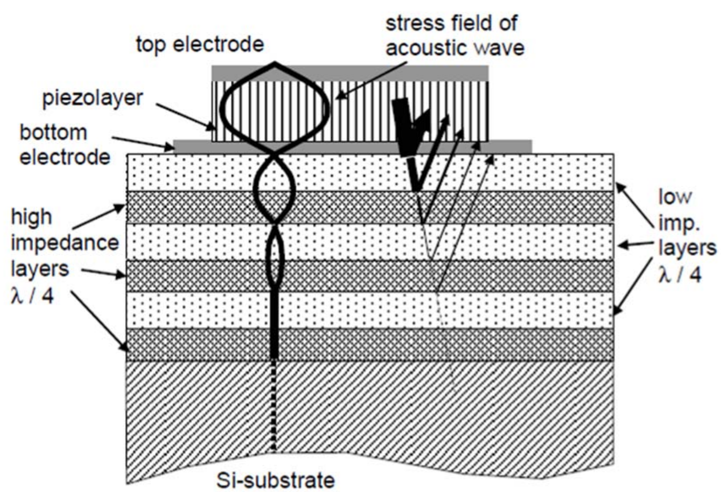
scia systems

Bulk Acoustic Wave (BAW) Filters

- Usage of piezoelectric materials like Aluminium Nitride (AlN) for conversion of electromagnetic to acoustic domain
- Bulk Acoustic Wave (BAW) designed to run vertical wave in a $\lambda/2$ resonator
- Free Bulk Acoustic Resonators (FBAR) utilize a cavity for separation of the acoustic wave from the wafer
- Solidly Mounted Resonators (SMR) utilize an acoustic Bragg mirror of alternating $\lambda/4$ high and low acoustic impedance films.
- Especially SMR devices have extensive need for trimming



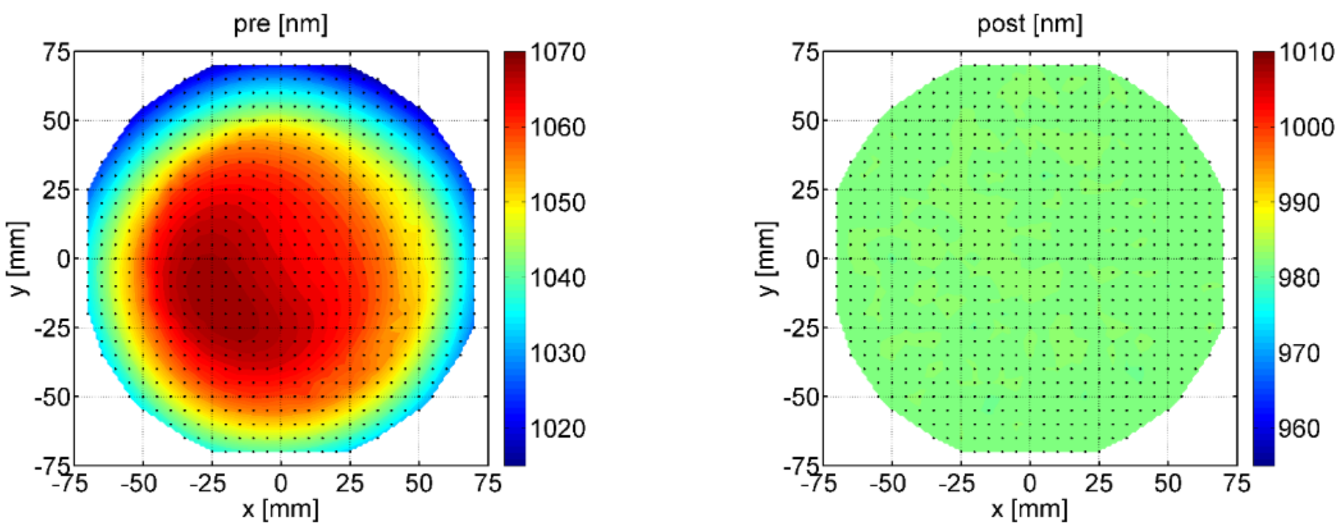
Free Bull Acoustic Resonator (FBAR)



Solidly mounted BAW device (SMR)

Trimming of AlN-Resonator for BAW

- AlN piezoelectric film for bulk acoustic wave (BAW) devices
- Final frequency adjustment happens in trimming of Si_3N_4 passivation



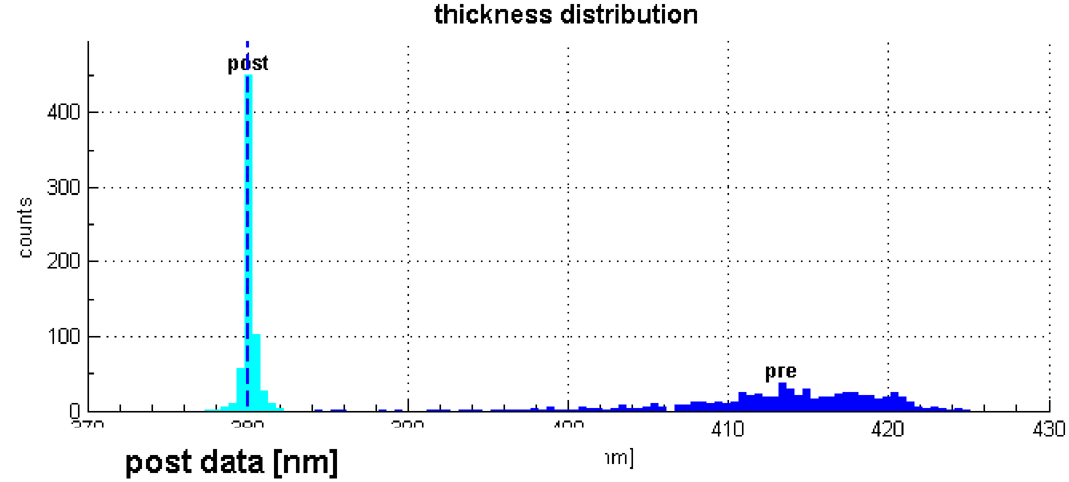
Pre and post thickness data for AlN layer

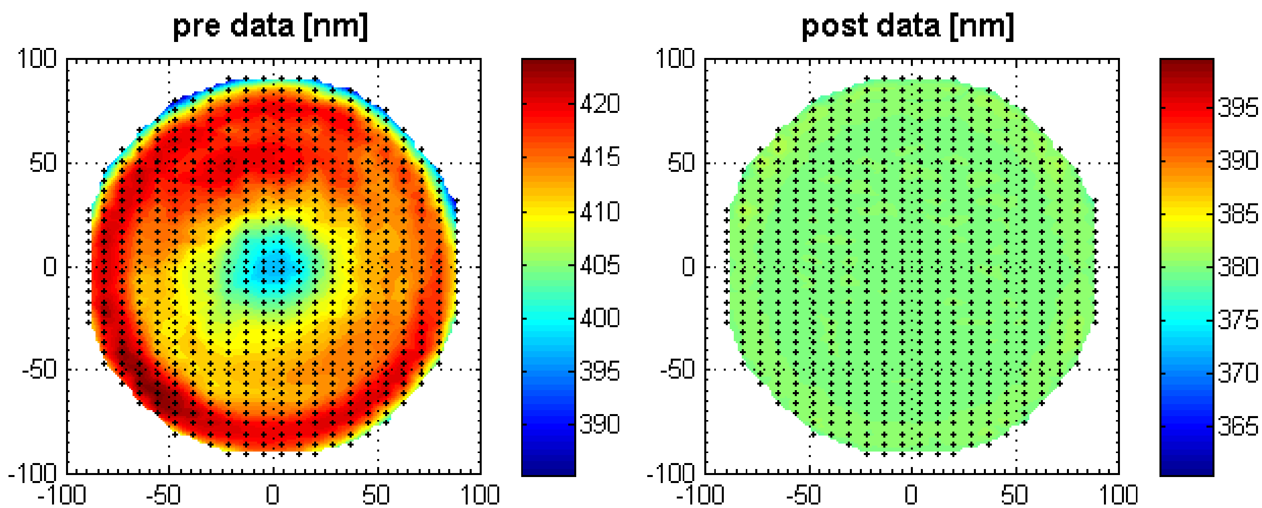
Standard Deviation	*pre: 13.3 nm*	*post: 0.3 nm*	*factor 41.6 improvement*
Average Thickness	*pre: 1049.9 nm*	*post: 982.3 nm*	*(target: 982.0 nm)*

scia systems

Trimming of Si_3N_4 Passivation for BAW

- In general same process performance like AlN





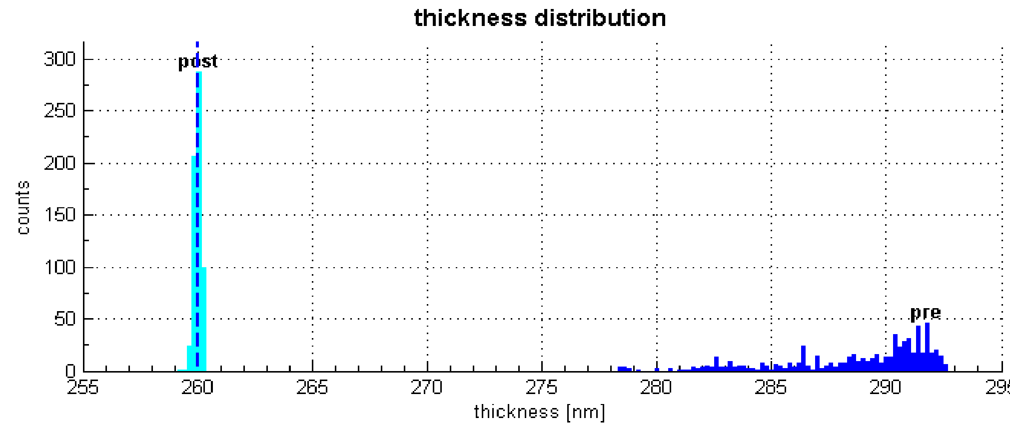
Pre and post thickness data for SiN layer

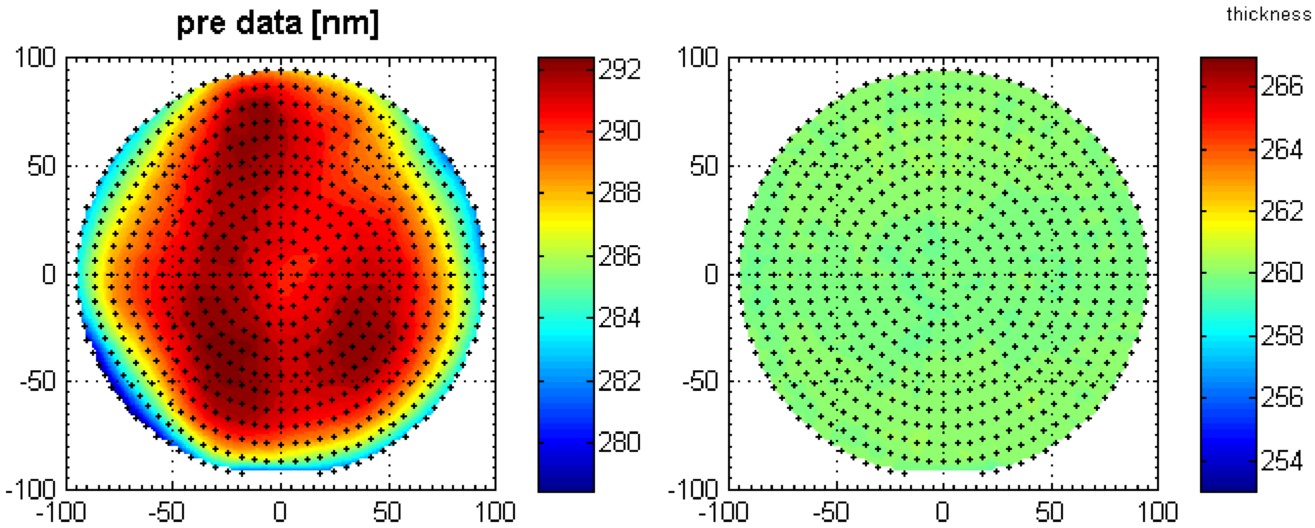
Standard Deviation	*pre: 6.60 nm*	*post: 0.45 nm*	*factor 14.6 improvement*
Average Thickness	*pre: 413.2 nm*	*post: 380.1 nm*	

scia systems

Trimming of Mo Contact for BAW

- Excellent process performance for metal trimming



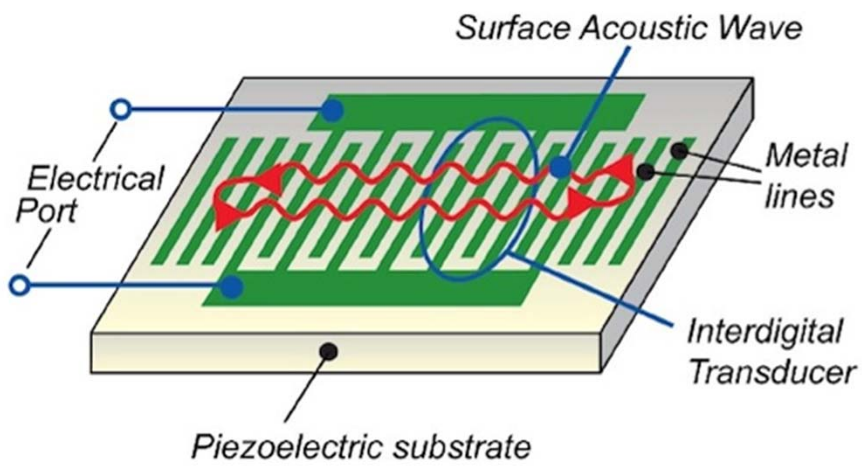


Pre and post thickness data for Mo layer

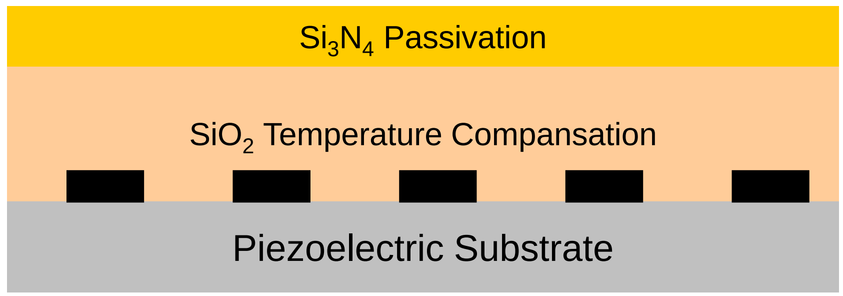
Standard Deviation	*pre: 3.26 nm*	*post: 0.15 nm*	*factor 21 improvement*
Average Thickness	*pre: 288.8 nm*	*post: 260.0nm*	

Surface Acoustic Wave (SAW) Filters

- Surface Acoustic Wave (SAW) utilize surface wave
- Distance of inner digital transducer electrodes defines wavelength
- Negative effect of higher thermal coefficient improved by temperature compensation film of material with opposite thermal expansion coefficient resulting at -15 ... 25 ppm/K
- Temperature compensation and passivation used for frequency trimming



Principle of a SAW device

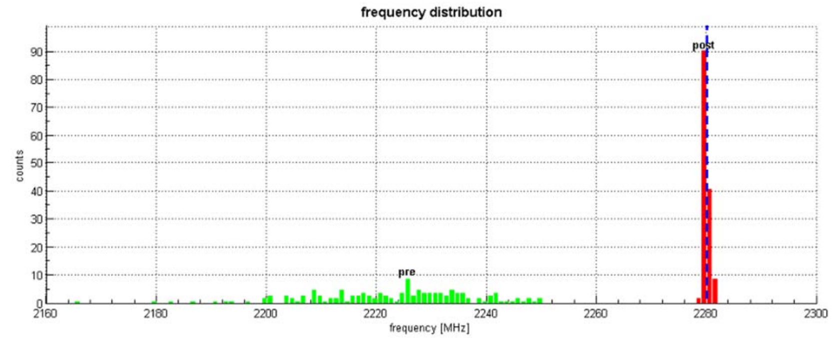


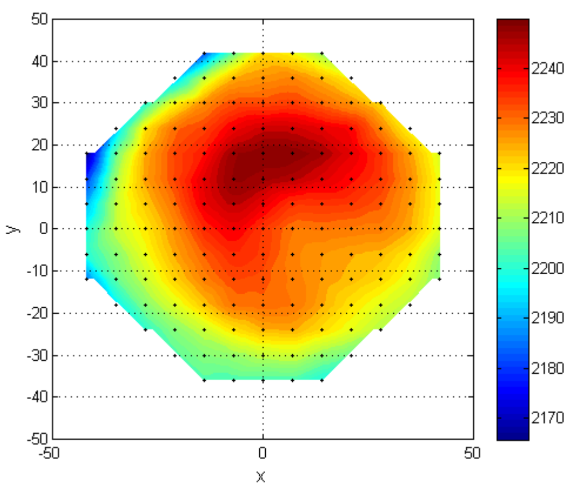
Film stack of a temperature compensated SAW device

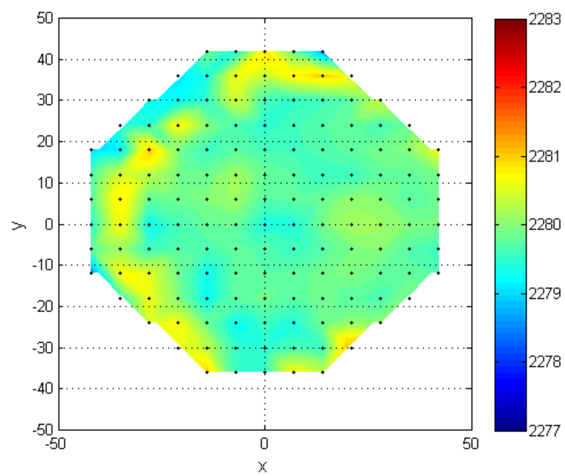
scia systems

Trimming of SiO_2 TC in SAW

- Frequency trimming of SiO_2 temperature compensation
- Direct import of frequency data using transfer function $\Delta f = f(d)$







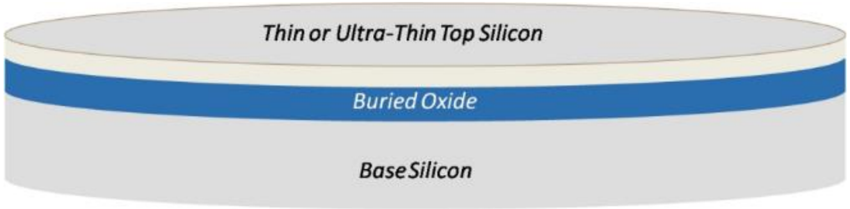
Pre and post frequency trimming of a SiO2 temperature compensation film of a 100 mm wafer

Standard Deviation	*pre: 15.3 MHz*	*post: 0.5 MHz*	*factor 30 improvement*
Average Frequency	*pre: 2.223 GHz*	*post: 2.280 GHz*	

Silicon on Insulator (SOI) Wafers

- SOI Wafer Fabrication:
  - Growth of thermal oxide on Silicon handle wafer
  - Bonding of second Silicon wafer on top
  - Grinding down and polishing of Silicon top wafer
  - Mechanical polishing may still leave thickness non-uniformity
- Ion Beam Trimming applied for further improvement

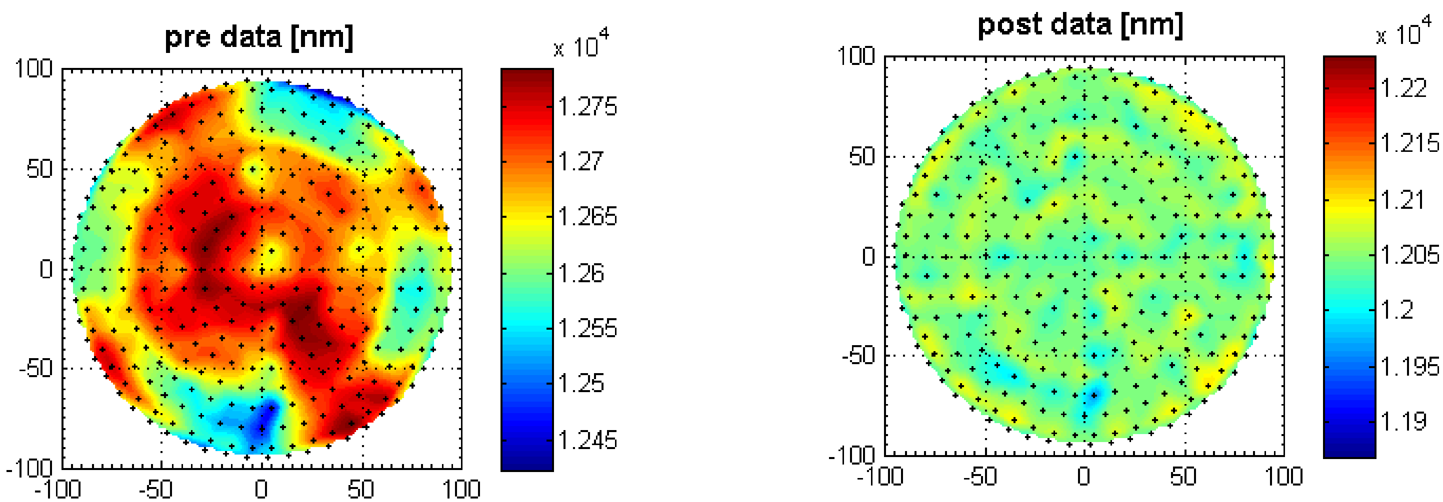
Bonded and ground SOI wafer



- Used for:
  - Pressure sensors
  - Microfluidic components
  - MOEMS
  - Flow sensors
  - Actuators
  - Accelerometers (3-axis)
  - Gyroscopes
  - Silicon microphones
  - Silicon oscillators

Trimming of SOI Wafers

- Trimming of SOI wafer with ~0.6 µm average removal
- Wafer trimming at 45 deg. for improved rate
- Control of ion energy to avoid surface damage

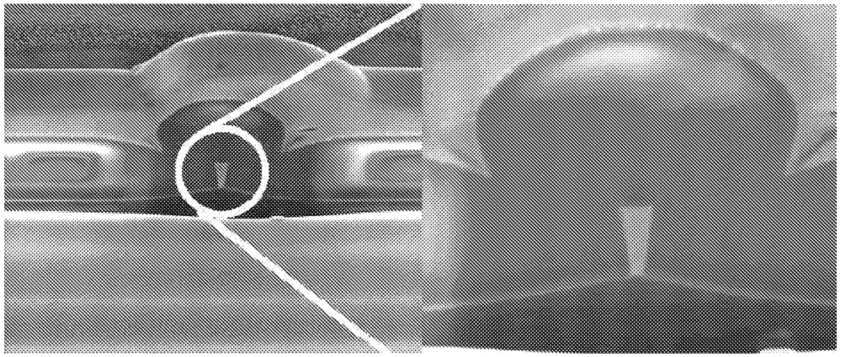


Pre and post trimming film homogeneity of a SOI film on a 200 mm wafer

Standard Deviation	*pre: 73 nm*	*post: 20 nm*
Average Thickness	*pre: 12660 nm*	*post: 12050 nm*

Thin Film Head (TFH)

- TFH are used in hard drives for data storage
- Track width on hard disc depends on magnetic flux or width of magnetic pole
- Size of magnetic pole adjusted by CMP
- Final correction with Ion Beam Trimming



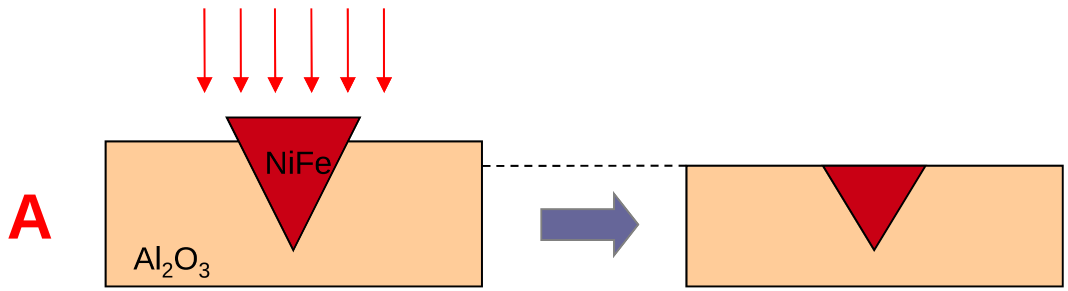
TEM photograph of a pole structure of a read/write head of a hard disk drive

scia systems

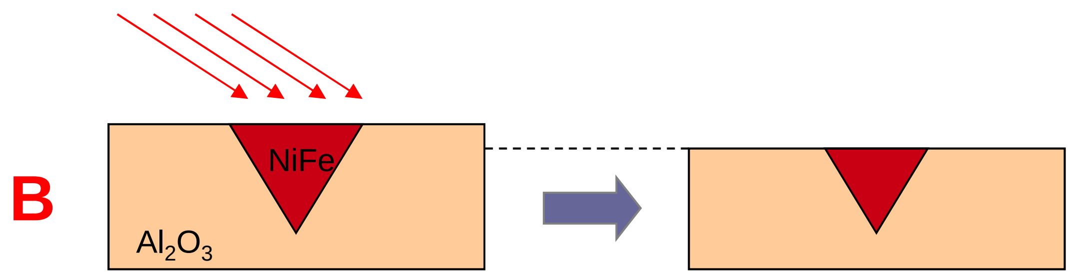
Localized Pole Trimming in TFH

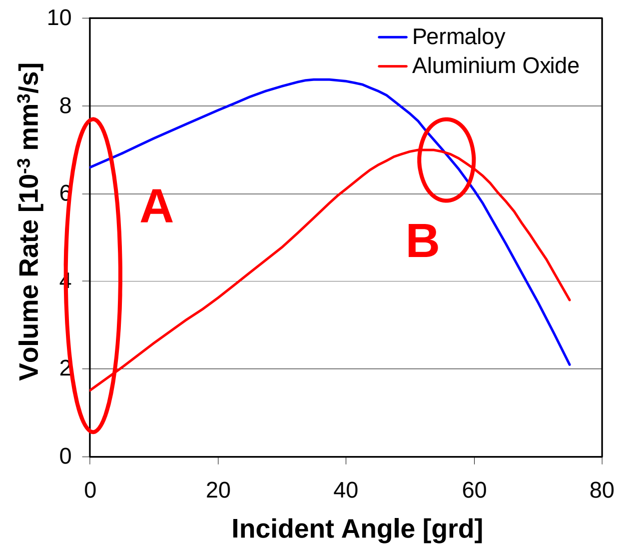
- Ion incident in pole trimming used for
  - Selectivity between materials
  - Rate enhancement

Step height reduction after CMP with 3:1 selectivity



Localized pole trimming with 1:1 selectivity



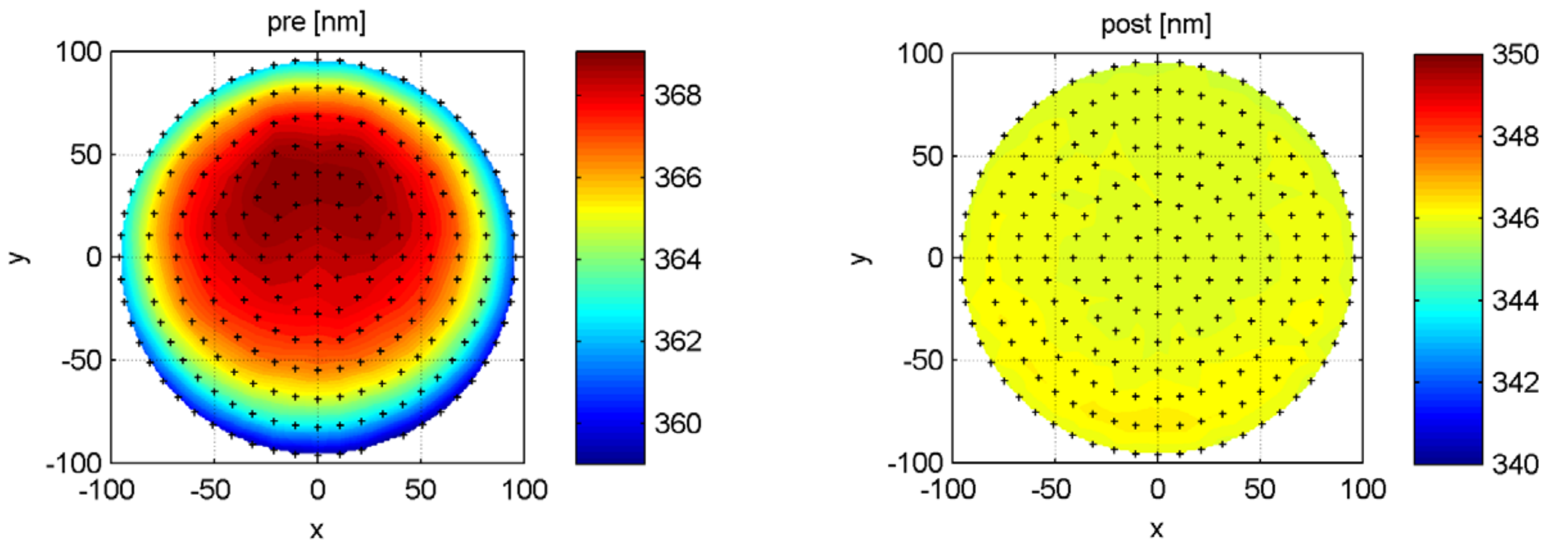


Capabilities for selectivity adjust between FeNi and Al_2O_3 by the ion incident angle

scia systems

Trimming of Al_2O_3 in a TFH Application

- Typical average removal of between 10 … 100 nm with process times of in between a few to 30 min
- Improvement of film homogeneity by a factor of typically 10 … 30



Pre and post trimming film homogeneity of a Al_2O_3 film on a 200 mm wafer

Standard Deviation	*pre: 3.0 nm*	*post: 0.13 nm*	*factor: 21 improvement*
Average Thickness	*pre: 365.3 nm*	*post: 345.0 nm*	

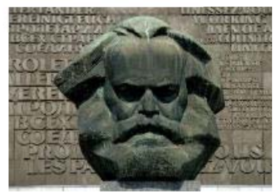
Benefits

Summary of Key Features

Benefits

- Film thickness homogeneity adjustable down to nearly atomic level of 0.1 nm.
- No limitations in film and wafer materials to be processed.
- All standard wafer sizes up to 300 mm possible.
- Cluster tools with two process chambers and two cassette load-locks available.
- Fully automatic and production proven solution with cassette loading, vacuum aligner and wafer ID reader.
- Throughput and maintenance optimized design.
- Outstanding performance in uniformity achieved and essential for handling yield limited process steps.
- Many potential applications following CMP processes.

Please see product flyer
„scia Trim 200 for Ion Beam Trimming (IBT)"



Thank you for your attention!

scia Systems GmbH
Annaberger Straße 240
09125 Chemnitz
Germany

Phone: +49 371 5347-780
Fax: +49 371 5347-781
info@scia-systems.com
www.scia-systems.com