Cutting-edge SiC Manufacturing:
Beyond Chemical-Mechanical Constraints

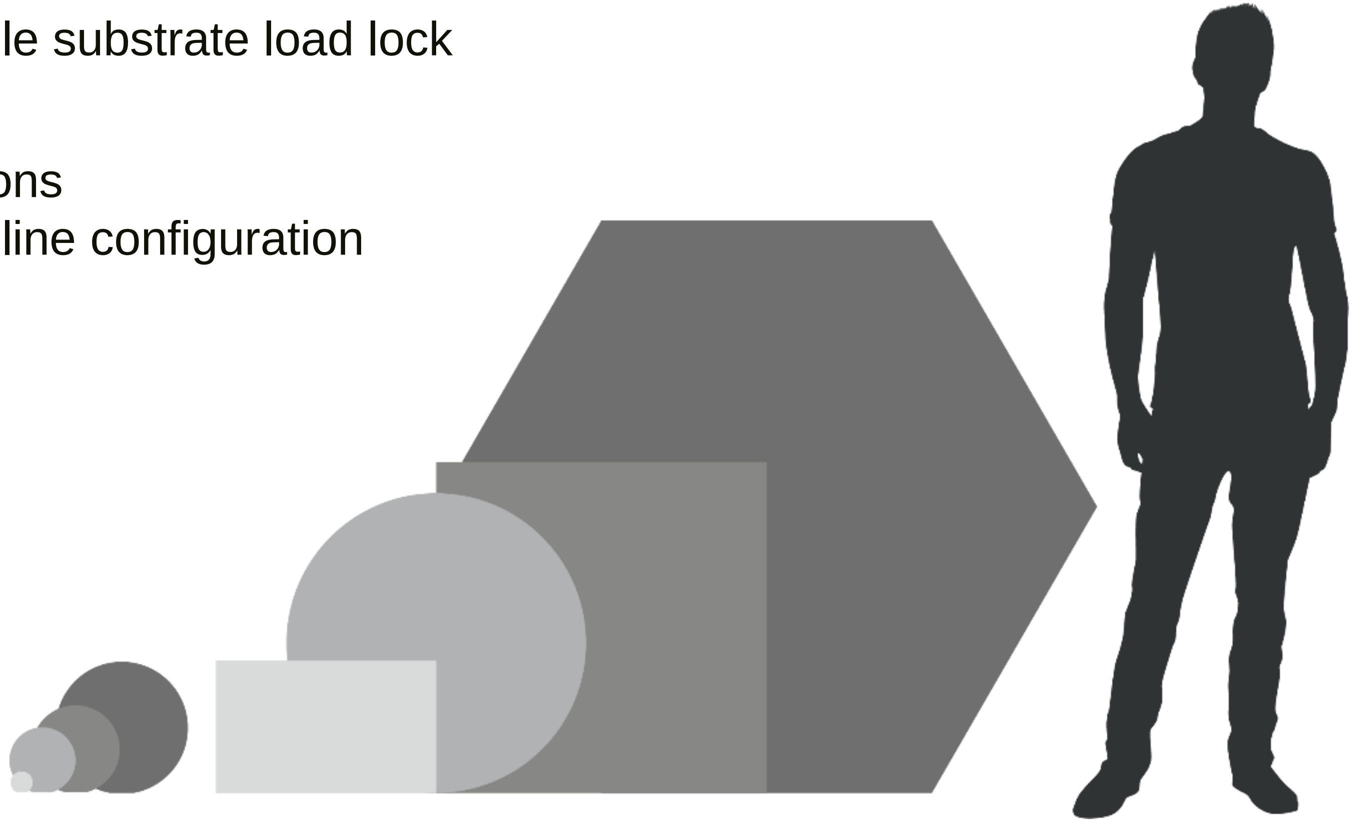
CS International
April 16, 2024

Who we are

company facts

Flexible Ion Beam and Plasma Processing Equipment

- Carrier-based processing of small sample sizes or individual loading of large substrates up to 3 m in diameter
- Direct wafer handling from 100 mm up to 300 mm wafer size
- Several loading options from direct handling, single substrate load lock or handling robots for up to two cassettes
- System designs from small R&D optimized solutions to high-volume production facilities in cluster or inline configuration



Company Figures in Brief

Founded in **2013** as an independent technology company

250
Employees

96.3 Mio. €
Total Performance in 2023

17
Sales and service partners worldwide

> 100
Customers in the field of MEMS and optics

> 450
Systems in 24/7 production and R&D

Our Markets

scia systems

Wafer Processing

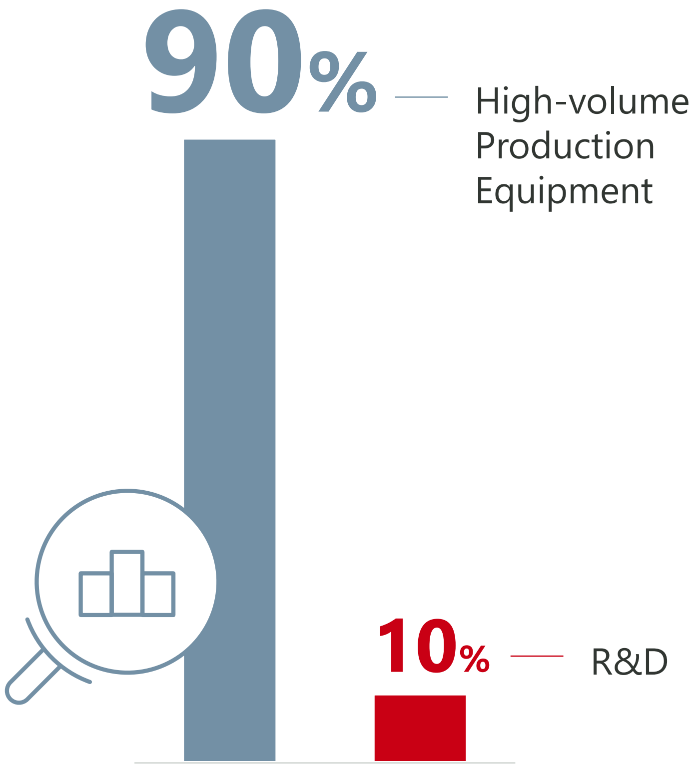
Mobile communication, sensors, magnetic storage, optoelectronics

Optics Manufacturing

Lithography optics, micro- and binary optics, astronomy applications

Customization and Product Development

Diversified (bio)medical applications, R&D



Production Facilities & Capabilities

scia systems

Company headquarters in Chemnitz, Germany

- In-house technology and process development capabilities
- Own equipment in 1,800 m^2 ISO 7 clean room
    - Metrology and tool capabilities for own and customer development work

What we offer

Technology & product range

Standard Products & Technologies

Ion Beam Trimming / Figuring

scia Trim 200

scia Trim 300

scia Finish 1500

Magnetron Sputtering

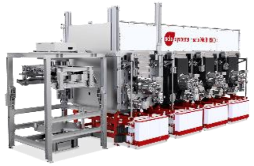
scia Magna 200

scia Magna 200 Inline

scia Multi 300

scia Multi 680

scia Multi 1500



Ion Beam Etching

scia Mill 150

scia Mill 200

scia Mill 300

Dry Cleaning

scia Clean 800

scia Clean 1000

scia Clean 1500

scia Clean 3000

Evaporation

scia Eva 200

Ion Beam Deposition

scia Coat 200

scia Coat 500

scia Opto 300

Physical Enhanced CVD

scia Batch 350

scia Cube 300

scia Cube 750

Reactive Ion Etching

scia Etch 200

scia Etch 400

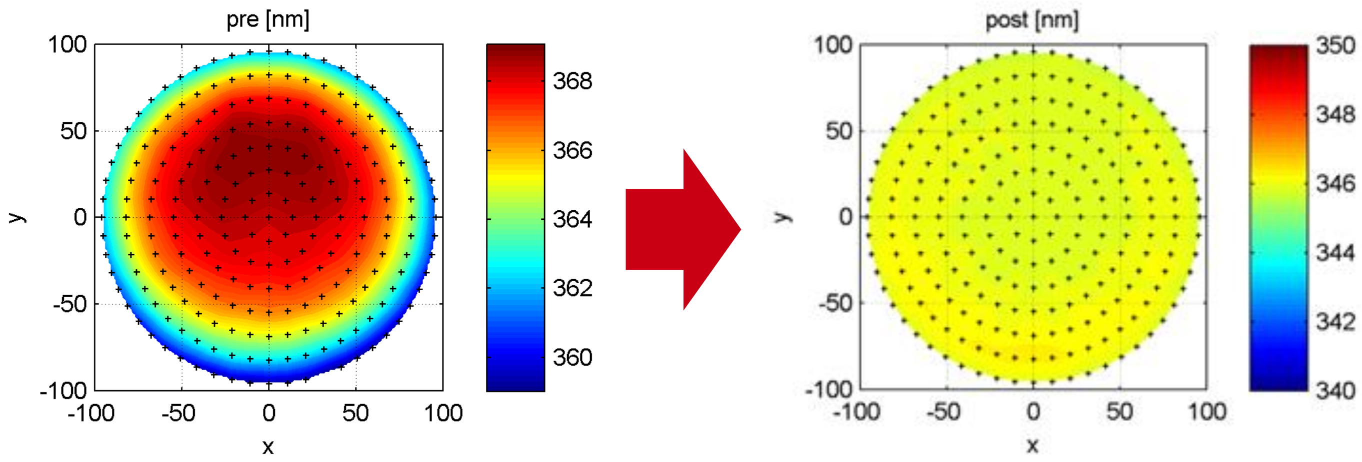
SiC Manufacturing Part I

TTV improvement

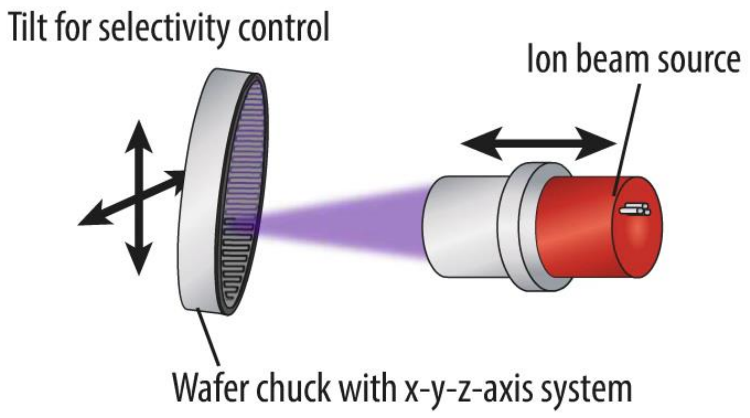
by Ion Beam Trimming

Basic Principle of Ion Beam Trimming (IBT)

- TTV improvement by localized thickness correction via focused broad ion beam
  - Can be applied to CMP-based long wavelength non-uniformities
- Contactless high vacuum process with depth resolution close to single atom layers
- Removal controlled by local dwell time of the ion beam at certain wafer positions
- Dwell time adjustment handled by pre-calculated velocity map in raster scan pattern
- Better thickness uniformity leads for many applications to higher yield



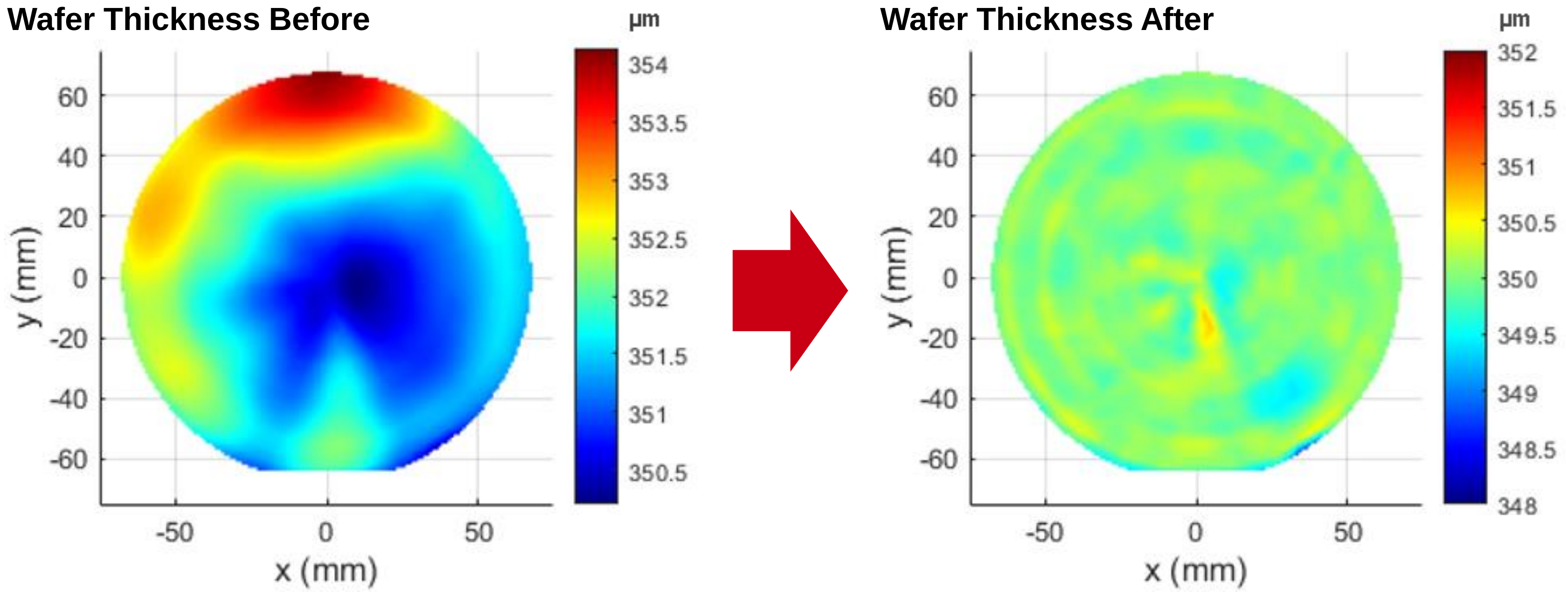
Left: thickness data before and right: after ion beam trimming



Principle of ion beam trimming by scia Trim 200

Improving the Total Thickness Variation (TTV)

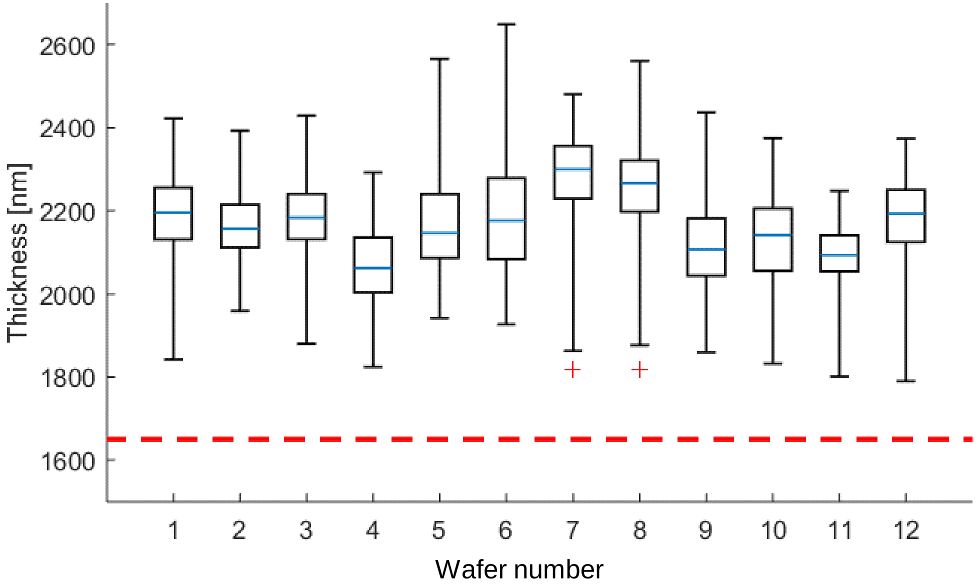
- Target SiC thickness: 350 µm
- Improvement
  - TTV 3.9 µm to 2.4 µm factor of 1.7
  - LTV 318 nm to 270 nm factor of 1.2
  - standard deviation: 837 nm to 193 nm factor of **4.4**
- Process time of ~ 50 min required from load lock to load lock to remove 1.8 µm SiC in average.



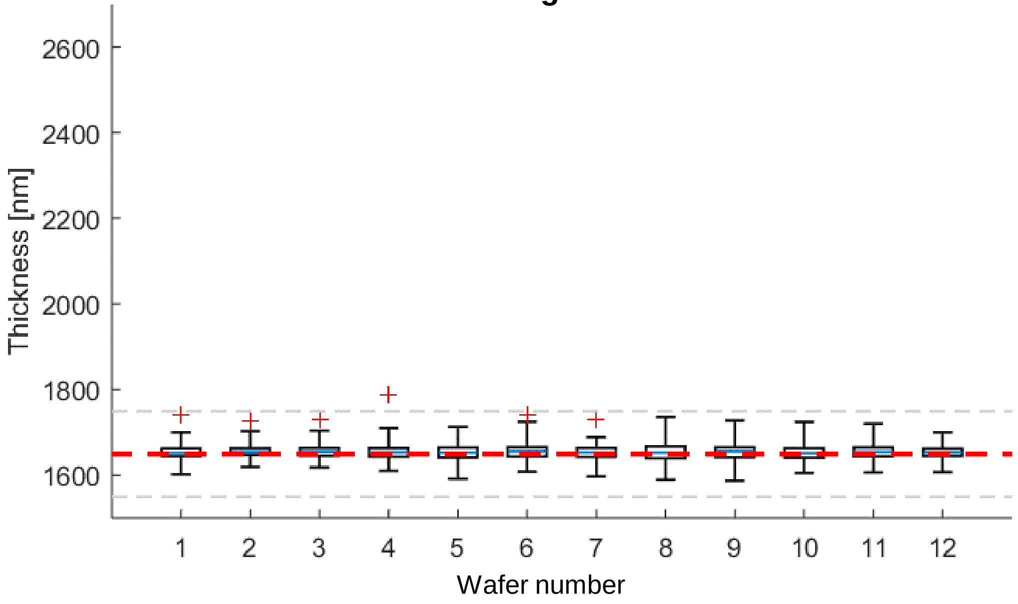
Improving the W2W Variation

- Processes reliable and stable, introduced into volume production for various wafer materials
- Reduction of wafer-to-wafer-variation (WtW) and within-wafer-variation (WiW)
- High throughput trimming process with fully automated wafer processing based on individual measurement data for each wafer

Thickness variation before trimming



Thickness variation after trimming



Exemplary results for SOI production grade wafers

Related Systems - scia Trim 200/300

- Fully automatic processing of any film and wafer materials
- Throughput optimized design with up to 2 process chambers and single or double cassette load lock
- Processing of wafer sizes up to 300 mm
- Film thickness correction down to 0.5 nm RMS at typical process times of a few minutes
- Significant yield improvement
- No edge exclusion with electrostatic chuck
- Sub-nanometer removal with zero base etch function

scia Trim 200 with Brooks MX 400 robot and cassette load lock

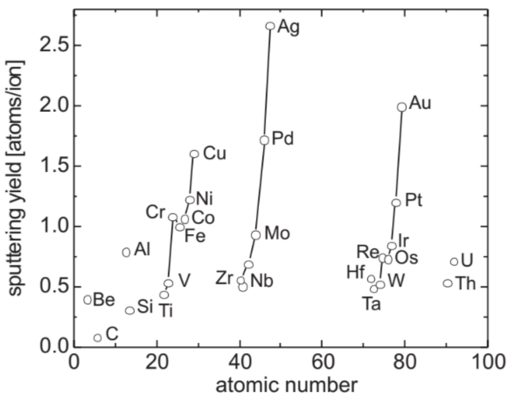
SiC Manufacturing Part II

Roughness improvement

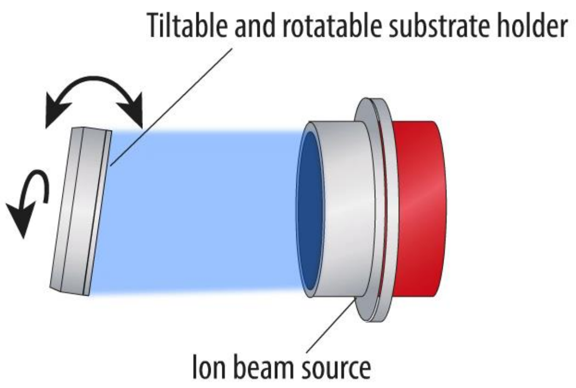
by Ion Beam Etching

Basic Principle – Ion Beam Etching (IBE)

- Generation of ion beam by broad ion beam source
- Atoms of material are ejected by bombardment of high energetic ions
- Any material with a sufficient high melting point can be etched
  as well as multilayer stacks containing films with different chemical etch rates
- Ion Beam Milling (IBM) / Ion Beam Etching (IBE)
  by (mostly) noble gases and resulting physical sputter process
- Reactive Ion Beam Etching (RIBE)
  where reactive gas is directly supplied to ion beam source
  and combined physical and chemical process
- Chemically Assisted Ion Beam Etching (CAIBE)
  the reactive gas is injected as background gas and reactions
  driven by ions activating absorbed reactive gas species



Periodic dependency of the sputter yield for fixed ion energy (Ar^{+}, 400 eV)



Process arrangement of scia Mill 200

Ion Beam Direct Smoothing

scia systems

- Effect on very short length scale of 10 nm ... 1 µm
- Full wafer size process with combined inert / reactive broad ion beam
- Utilizing dependency of sputter rate on local curvature and surface diffusion effects
- Smoothing mechanism very complex, highly dependent on etched materials, ion type, ion energy and ion beam angle
- Depending on materials and beam parameters formation of microstructures like dots or ripples can also be induced

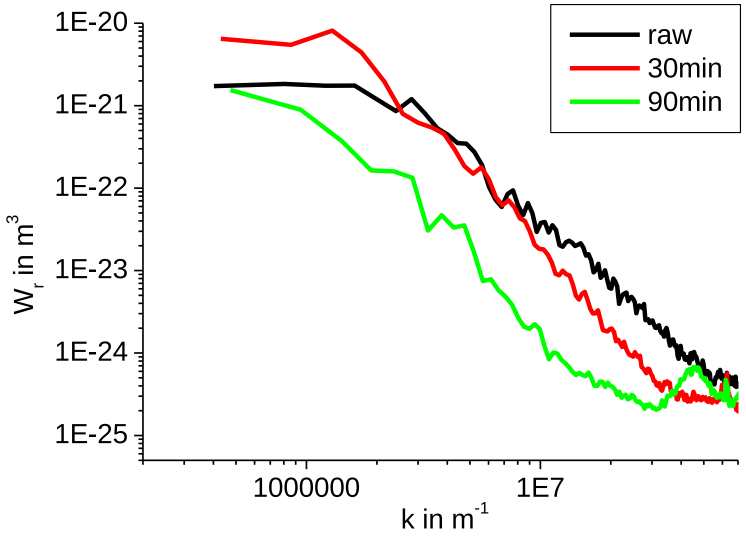
Bradley-Harper-Model with additional terms

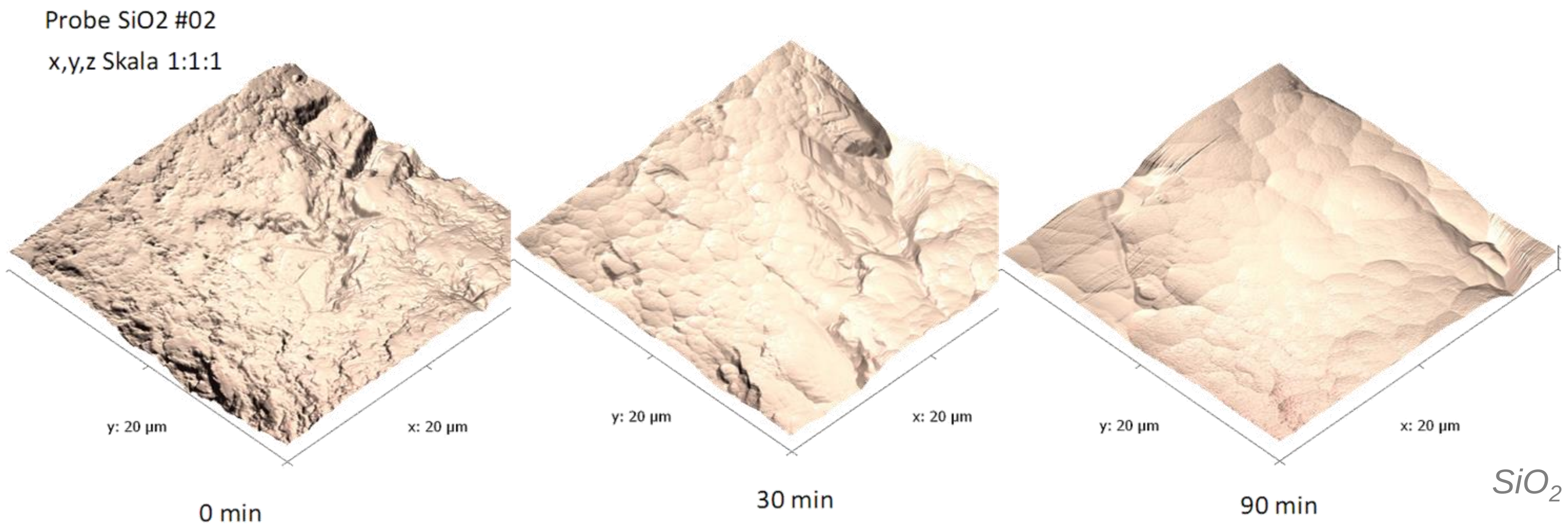
$$\frac{\partial h}{\partial t} = -v_0 + S_x \frac{\partial h^2}{\partial x^2} + S_y \frac{\partial h^2}{\partial x^2} + \frac{\lambda_x}{2}\left(\frac{\partial h}{\partial x}\right)^2 + \frac{\lambda_y}{2}\left(\frac{\partial h}{\partial y}\right)^2 - D_T \nabla^4 h - D_i \nabla^4 h + \eta$$

- Change of height profile
- Etch rate of flat surface
- curvature dependent etch rate = ion induced surface tension = negative surface tension
- Surface slope dependent etch rate
- Thermally induced diffusion
- Ion induced diffusion
- White noise

Ion Beam Direct Smoothing

- SiO_2 very rough before processing (up to μ-scale)
- Process smoothens micro-roughness very effectively
- Process limited at low spatial frequency → finer pre-polishing necessary

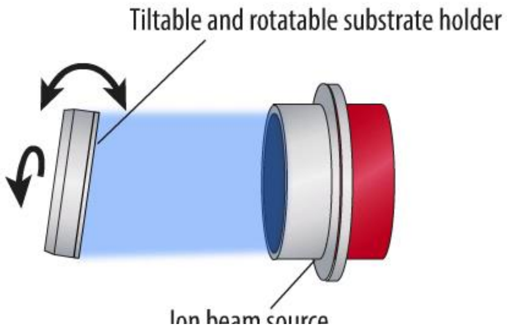


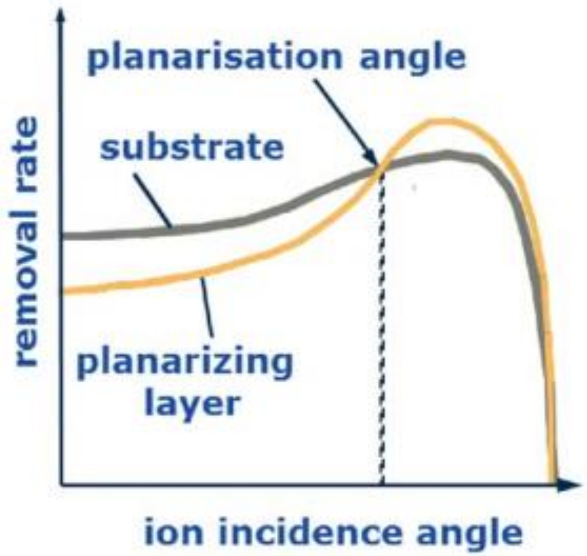


SiO_2 polishing results after Ion Beam Etching

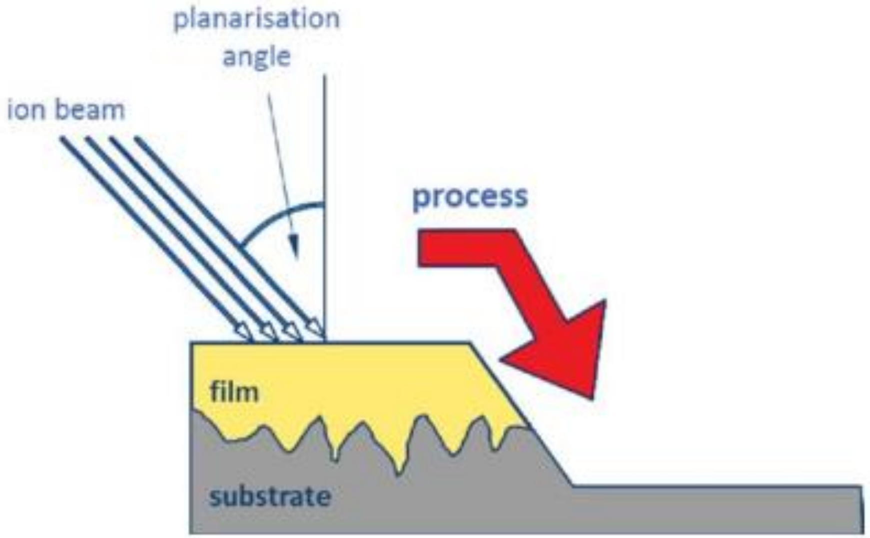
Planarization with Sacrificial Photo Resist

- Removal rate of substrate and photo resist vs. angle of incidence of ion beam
- Covering of rough surface with liquid-like film, e.g. photo resist
- Transformation of smooth resist into the substrate by ion beam etching
- Selection of planarization angle at selectivity of 1
- Possible on SiC, Si and other materials





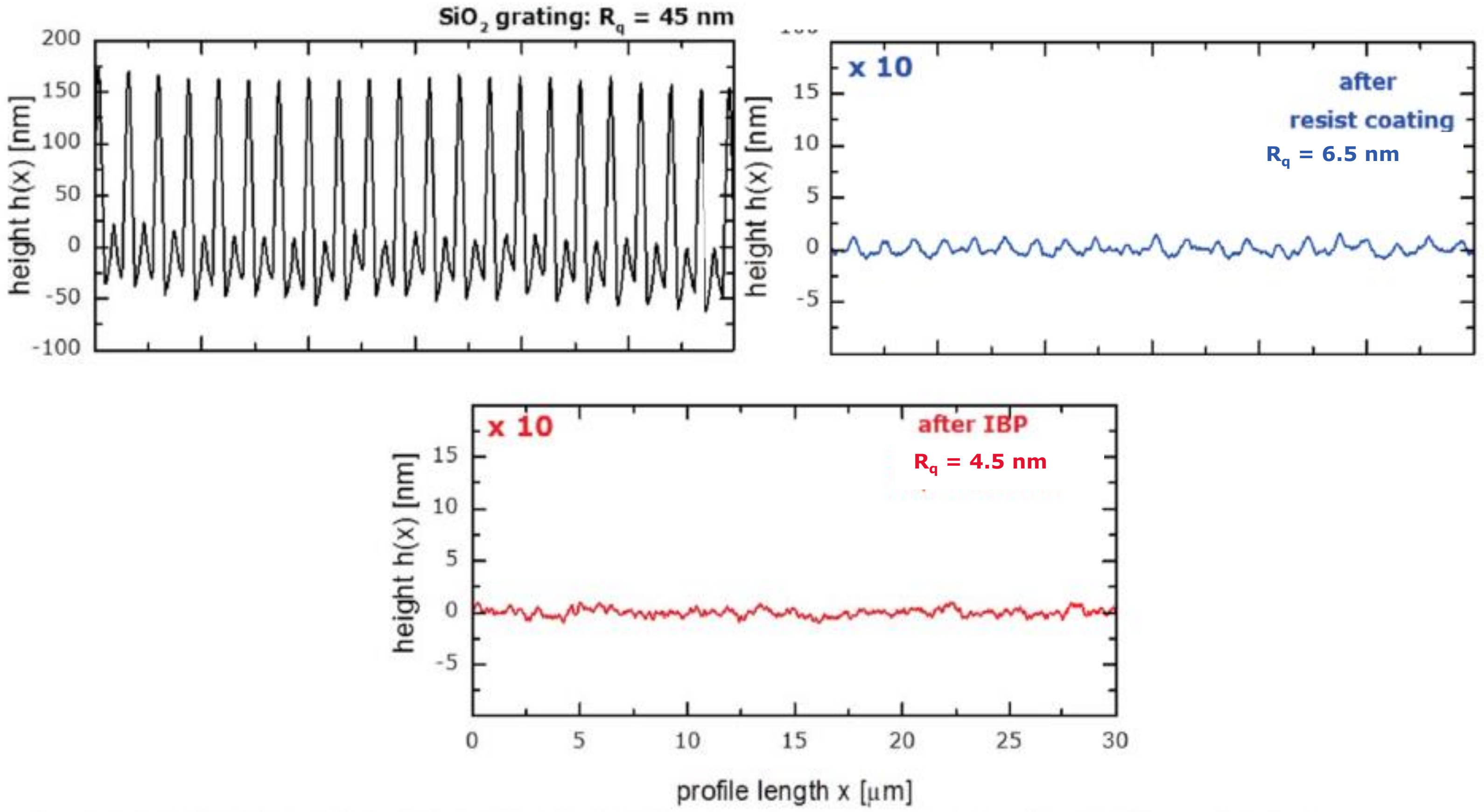
IOM



Principle of ion beam planarization

Planarization with Sacrificial Photo Resist

- SiO_2 layer roughness reduction



Planarization with Sacrificial Photo Resist

- SiC wafers roughness reduction
- Reduction of roughness R_a from 4.2 nm to 0.9 nm

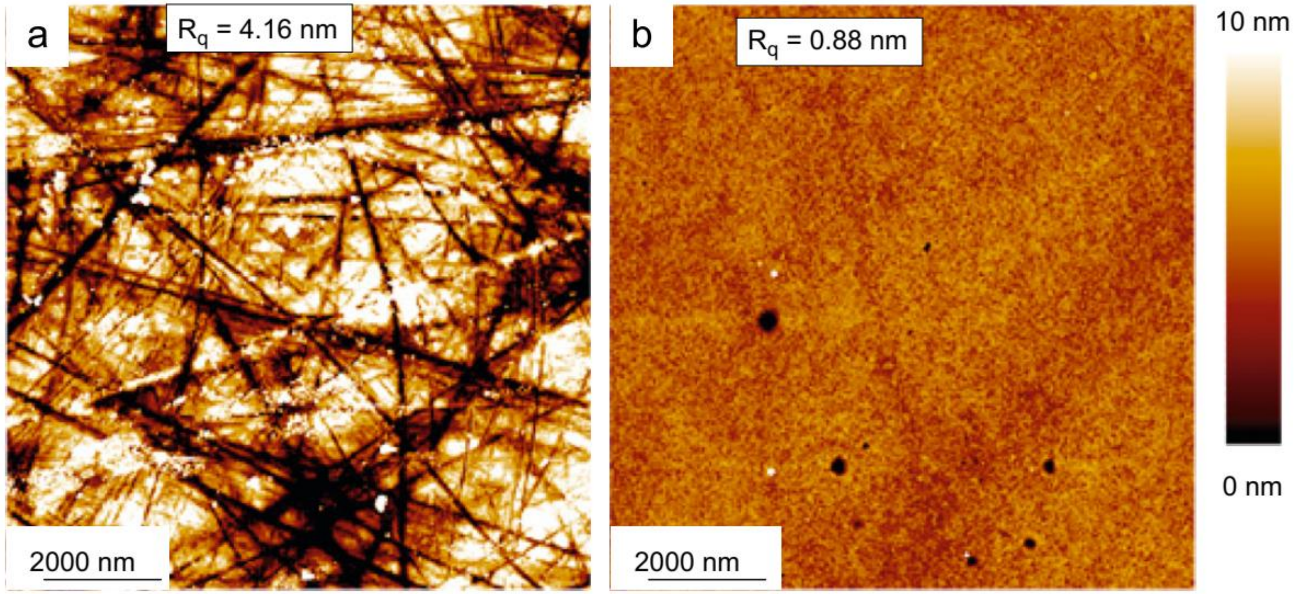


Fig. 5. Smoothing of a mechanically polished SiC surface by ion beam planarization. The 10 µm AFM images show the initial SiC surface with characteristic polishing scratches and a RMS surface roughness of ~4.2 nm (a) and after two ion beam planarization runs where the surface roughness has been reduced to 0.88 nm RMS (b). The small pores still visible in the AFM image of the planarized surface (b) are caused by imperfections in the photoresist. By an optimization of the photoresist the pores can be avoided.

Ultra-precision surface finishing by ion beam and plasma jet techniques – Status and Outlook, 2010, T. Arnold

Related Systems - scia Mill 150/200/300

- Etching angle adjustment with tiltable and rotatable substrate holder
- Process control with exact end point detection by secondary ion mass spectrometry or optical emission spectroscopy
- Processing of wafers with photoresist masks due to good wafer cooling
- Throughput-optimized production systems in variable cluster layouts including handling robots with single or double cassette load lock
- Flexible tool for R&D and small scale production with single substrate load lock

scia Mill 200 in cluster layout with 3 process chambers

Why scia Systems?

scia Systems is the technology leader in thin-film process equipment based on advanced ion beam and plasma technologies.

We supply our customers with:

Coating, etching, and cleaning systems based on advanced ion beam and plasma technologies

In-house technology and process development

Extensive project expertise

Global sales and service network

The key components are developed and manufactured by scia Systems itself

Thank you!

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