Use of ion beam and RF sputter cleaning as a surface treatment for X-Ray optics

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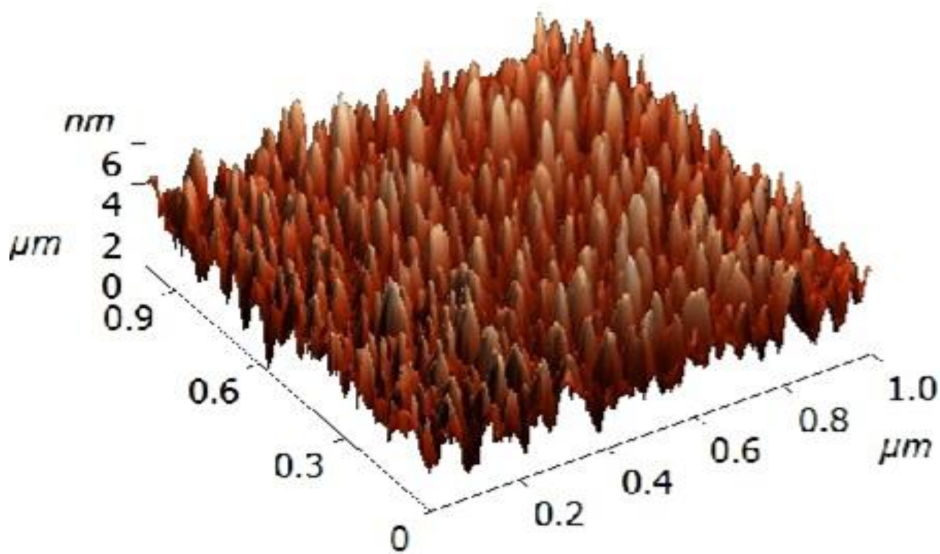
MICROROUGHNESS
- basic parameter for X-ray optics



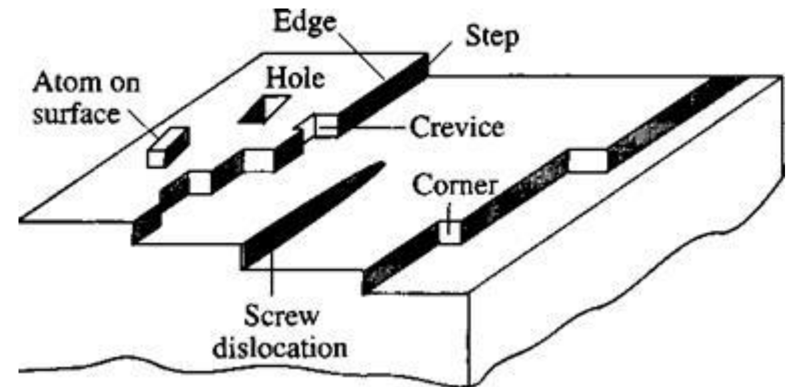
Illustrative AFM scan

(glass surface, RMS 1,0 nm)

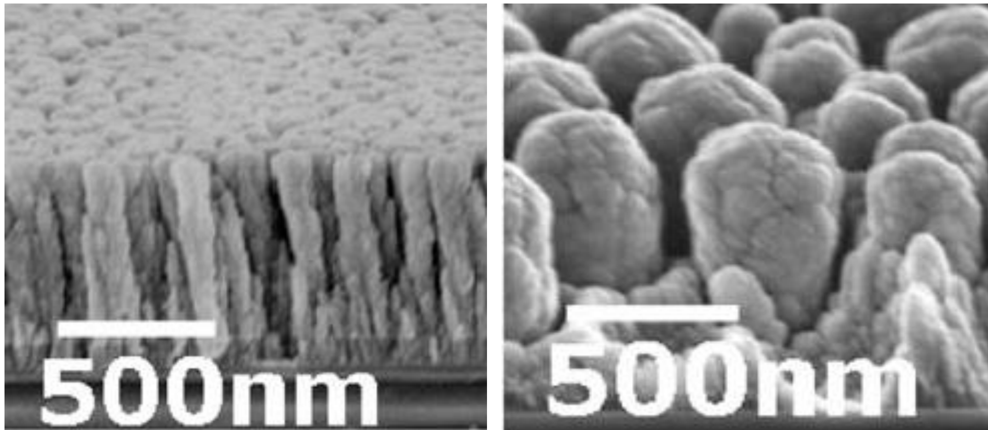
- Wavelenght in units of nm requires similarly (or better) smooth surface for good reflectivity
- Requirements for microroughness < 1 nm energies above 1 keV

MICROROUGHNESS – structural limits

- Microroughness of subnanometer scale aproaches limits of atomic structure
- Typical atomic radii 0,11-0,18 nm
- Defects of several atoms can cause increase of microroughness



Atomic defects



Influence of grain size

- Influence of nano and microstructure (grain size)
- Polycrystalic materials – smaller grains = smaller microroughnes

MICROROUGHNESS – methods of achieving smooth surface

Materials for low microroughness

- Polycrystalic materials with small grainsize (metals, metalic layers)
- Amorphous materials (glass)
- Monocrystals (Silicon)

Methods of achieving a smooth surface

- Mechanical polishing
- (manual or computer assisted)
- Chemical polishing
- Electroforming
- Ion beam surface treatment
- ...

ION BEAM SURFACE TREATMENT

- Atomic method of surface treatment
- Beam of ions with energies of hundreds keV and uniform direction sputter surface atoms of the substrate
- Loosely bonded atoms on projection and defects are preferentially sputtered

Veeco 747 ion beam system

RF SPUTTER ETCHING

- „Reverted“ sputtering
- RF signal connected to the substrate
- Plasma as a source of bombarding ions
- Similar energies of bombarding ions to ion beam (peak to peak voltage hundreds V)
- Slightly worse uniformity of direction

EXPERIMENT

- Comparison of ion beam surface treatment (ion milling) with RF sputter cleaning
- For use in production of X-ray optics demanding mass production (scores of plates integrated into mirror modules)
- RF sputter cleaning easily combined with other vacuum processes (e.g. deposition of reflective layer)

PARAMETERS OF THE EXPERIMENT

Substrates

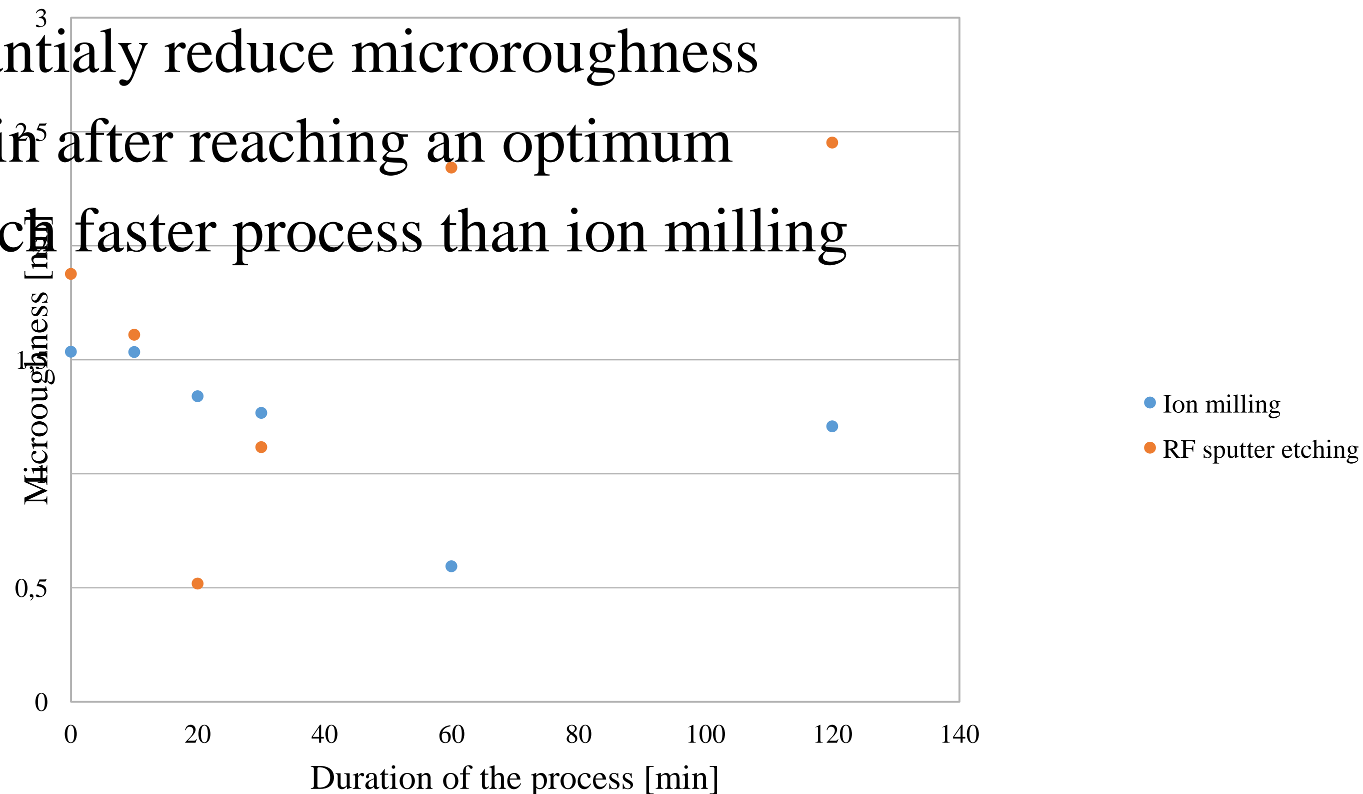
- Flat float glass (20x60 mm)
- **Vacuum processes**
- Neutralized Ar+ ions (IM) or Ar plasma (RF)
- Power 1000 W
- Background pressure >5,0 mPa

Metrology

- X-ray reflectometry
  - Roughness
  - density
- AFM measurement
  - Microroughness (10 x 10 µm)
  - Confirmation of X-ray reflectometry results

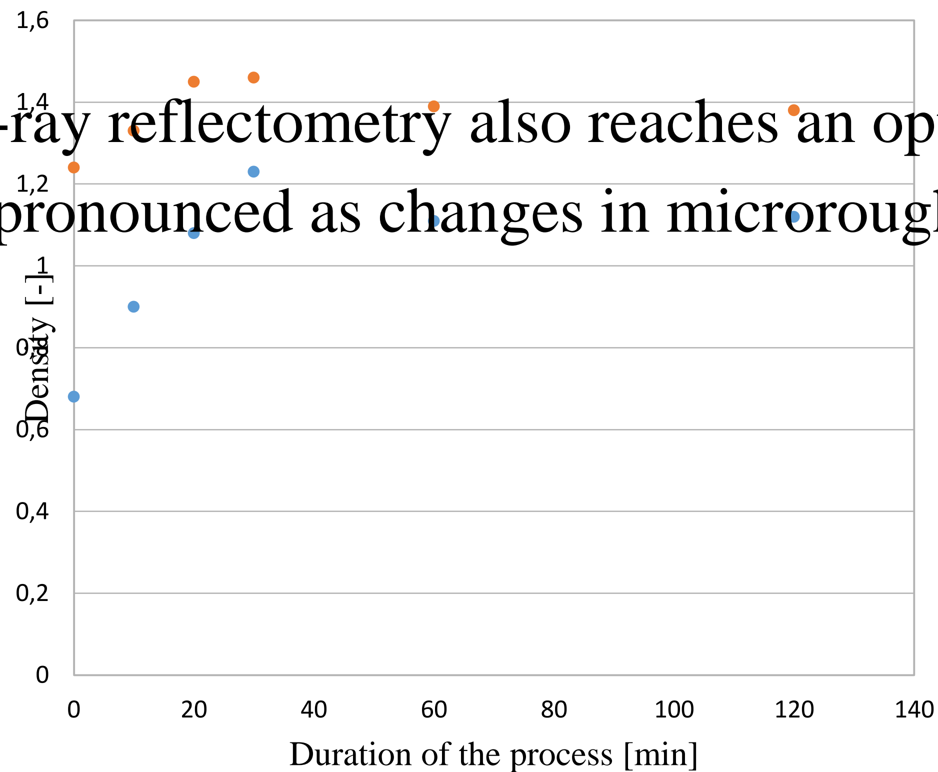
RESULTS
- microroughness

- Both processes can substantialy reduce microroughness
- Microroughness rises again after reaching an optimum
- RF sputtering of glass much faster process than ion milling



RESULTS
- density

- Density as measured by X-ray reflectometry also reaches an optimum (maximal
- Changes in density not so pronounced as changes in microroughness



RESULTS
- summary

0	1,535	1,876	0,68	1,24
10	1,533	1,609	0,9	1,33
20	1,339	0,518	1,08	1,45
30	1,266	1,116	1,23	1,46
60	0,563	2,343	1,11	1,39
120	1,207	2,452	1,12	1,38

EXPLANATION OF THE PROCESS

- RF sputter etching and ion beam surface treatment operate on similar princip

- **Three stages of the sputtering**

1) Sputtering of surface layer (impurities, loose atoms...)

- *decrease of microroughness, increase of density*

2) Optimum – smooth surface revealed

- *minimal microroughness, maximal density*

3) Further sputtering – underlying structure is revealed

- *increase of microroughness, slight decrease of density*

CONCLUSIONS

- Both processes can significantly improve microroughness of glass surface
- RF sputter etching can be used as an alternative to ion beam surface treatme
- RF sputter etching of glass is faster process than ion beam surface treatment
- It is necessary to find optimal time and parameters of for each material

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Thank you for your attention