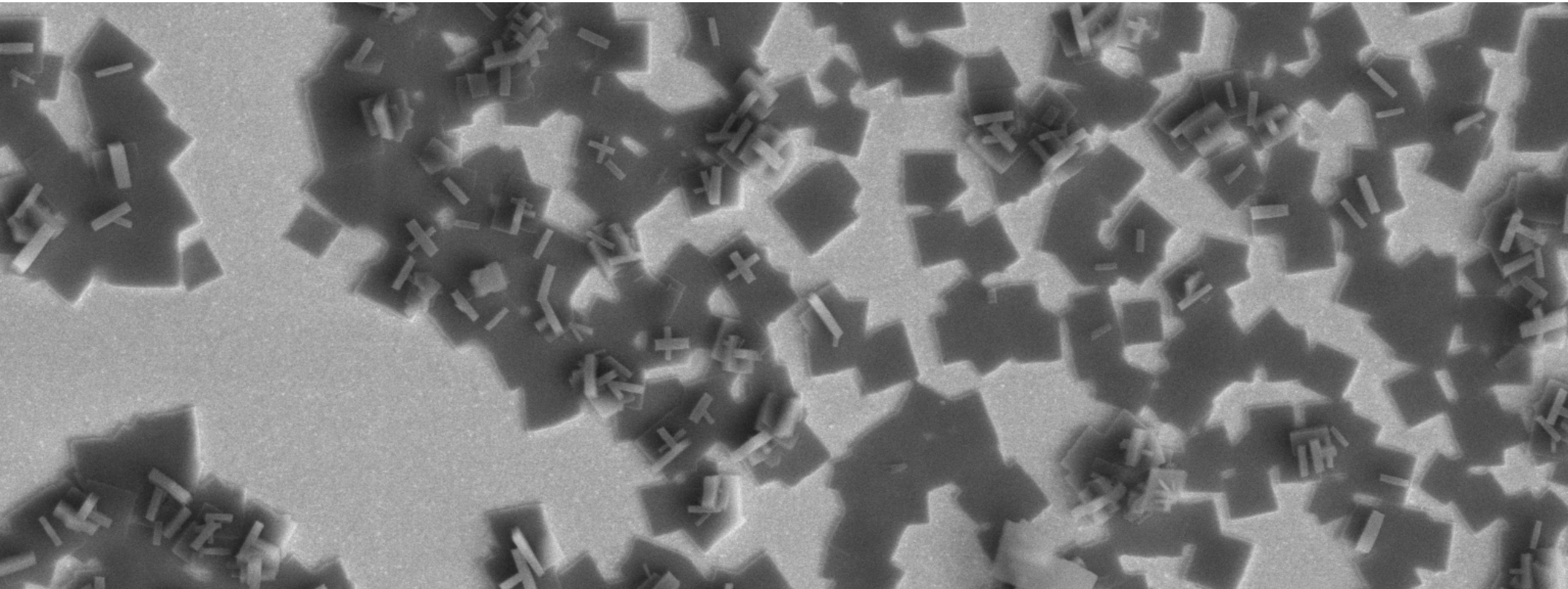

Materials department: superficial research in depth

S. Castellanos, R. Bliem, B. Weber, J. Frenken

2019 Source Workshop, Amsterdam, 4th Nov

ARCNL

Nanolayers

Joost Frenken

pellicle optics

Contact dynamics

Bart Weber

wafer/wafer table

Materials department

EUV Photoresists

Sonia Castellanos

resists

Materials & Surface Science for EUVL

Roland Bliem

pellicle optics wafer/WT resists

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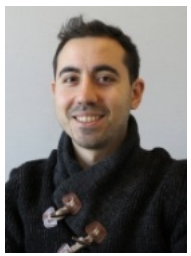
pellicle optics wafer/WT resists

Nanolayers: team and scope

ARCNL

PhD students

Cristina Sfiligoj



Görsel Yetik

Victor Vollema

Senior staff

Joost Frenken

Jan Verhoeven

Technician

Arend-Jan van Calcar

TOPICS & TECHNIQUES

Thin-film deposition

- Structure, texture, roughness, …
- Relation to deposition method (e.g. sputtering…)

Thin-film evolution

- Thermal effects
- Influence of H_2 and H, …

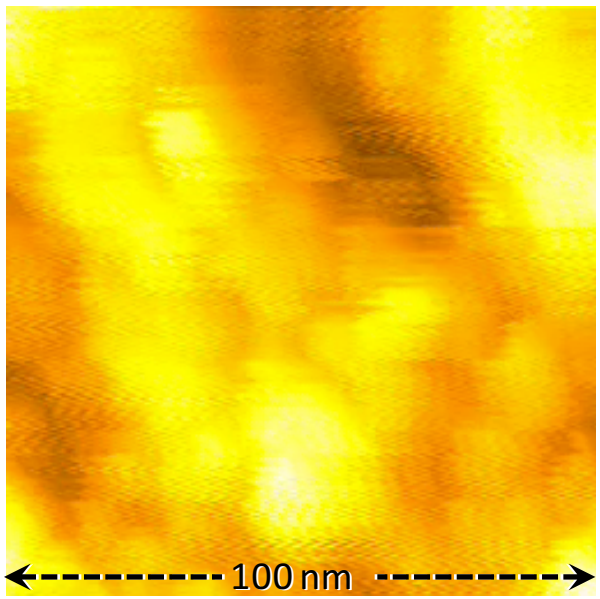
Techniques

- Various deposition techniques (e-beam, sputter)
- STM (in situ), AFM, SEM, Surface stress (in situ)
- XPS

Nanolayers: Ru films - deposition, structure, dewetting

ARCNL

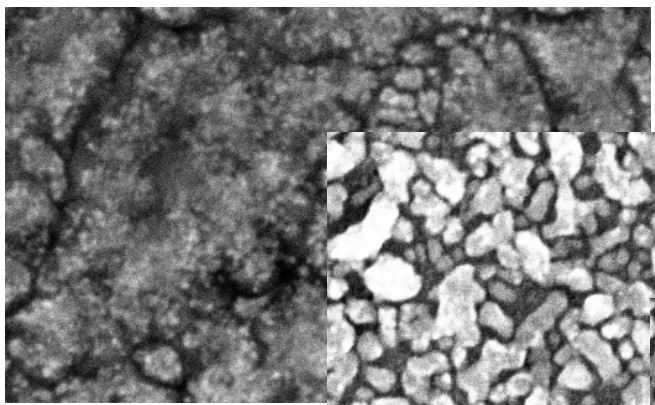
People: Cristina Sfiligoj (PhD stud.), Victor Vollema (PhD stud.)
Goals: (i) deposition-STM operational, (ii) observe polycrystallinity and dewetting



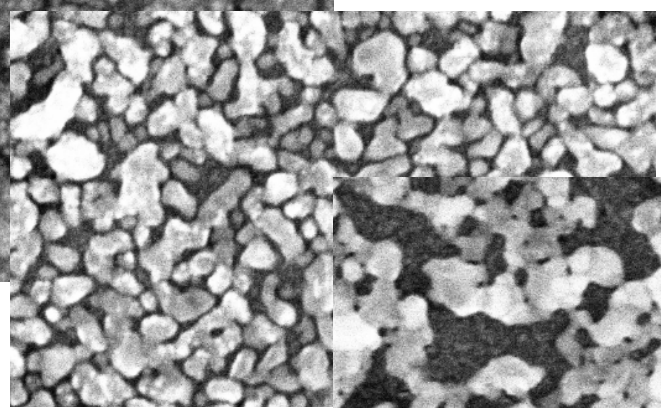
Live STM: 6 nm Ru deposition (e-beam) on Si, 122 min, room temp, 5×10^{-9} mbar

- Depo-STM operational
- Ru forms grains from the start

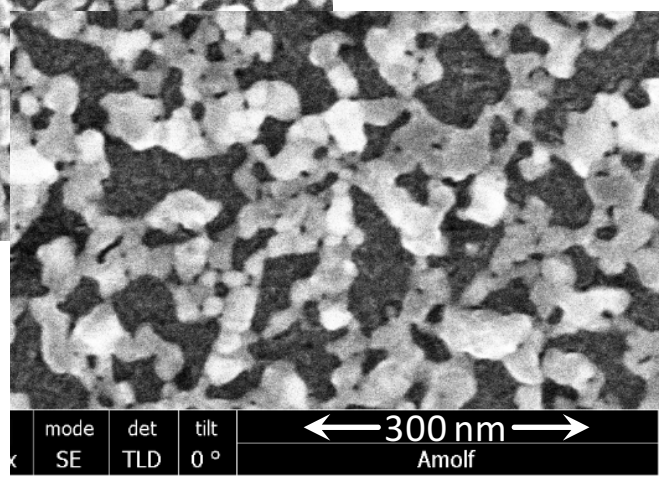
SEM-images: sputter-deposited Ru on SiO_2 after annealing



5 nm high-density Ru, after 800°C



5 nm low-density Ru, after 800°C



2 nm low-density + 3 nm high-density Ru, after 800°C

- Severe Ru dewetting at high T
- Film density has influence

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resists

Materials & Surface Science for EUVL

Roland Bliem

pellicle optics wafer/WT resists

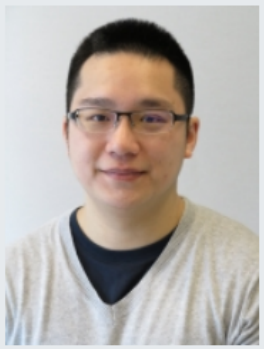
Contact Dynamics Group

Group Members

prof.dr. Steve Franklin
Group leader

dr. Bart Weber
Group leader

dr. Fiona Elam
Postdoc



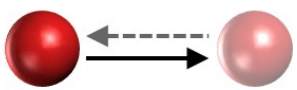
Feng-Chun Hsia
PhD student

Cyrian Leriche
Intern

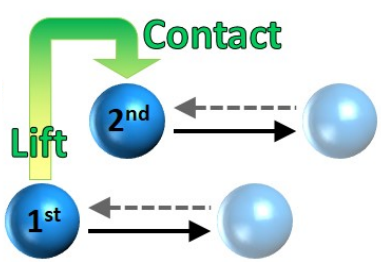
+PhD +PD

Repeated and non-repeated sliding:

Repeated

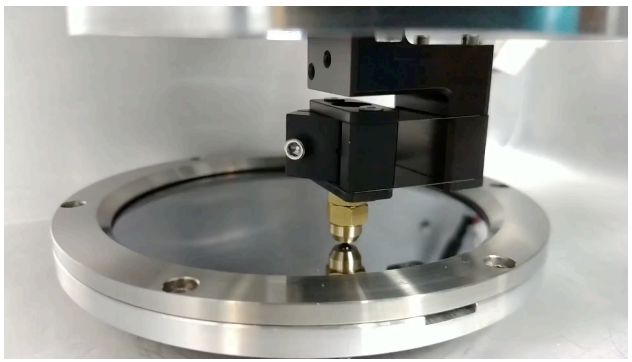


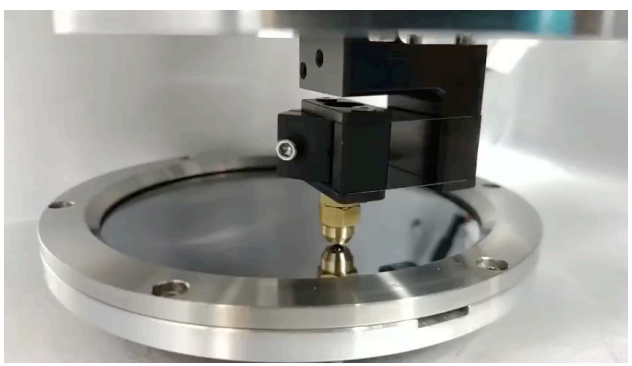
Non-repeated

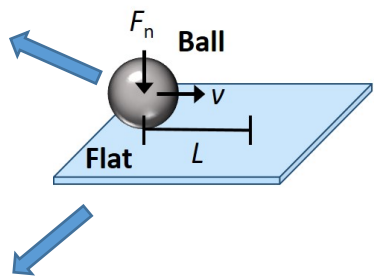


Example

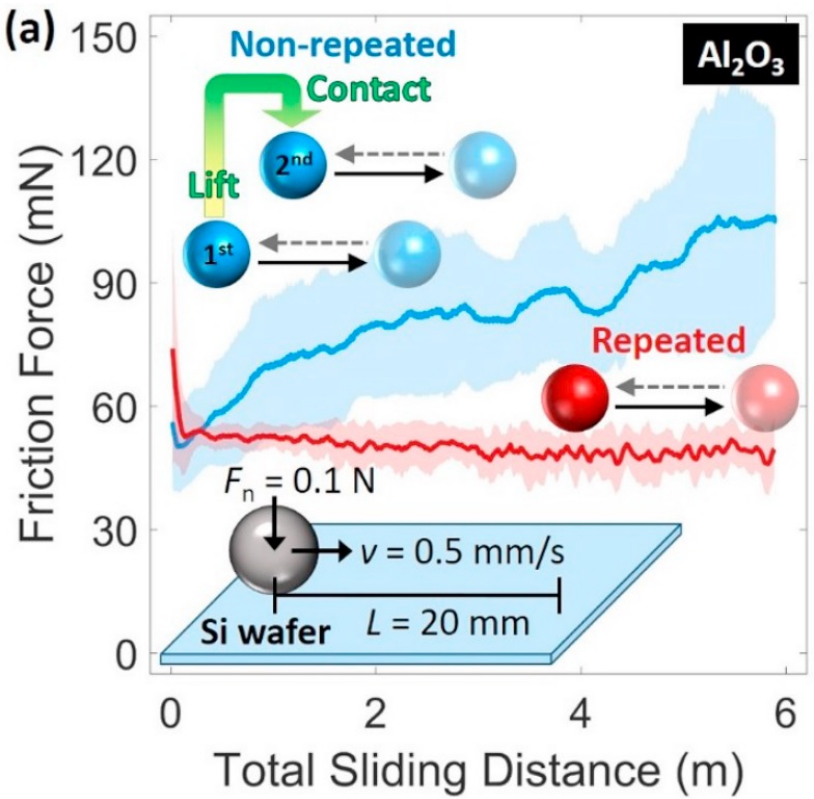
ARCNL Experiment



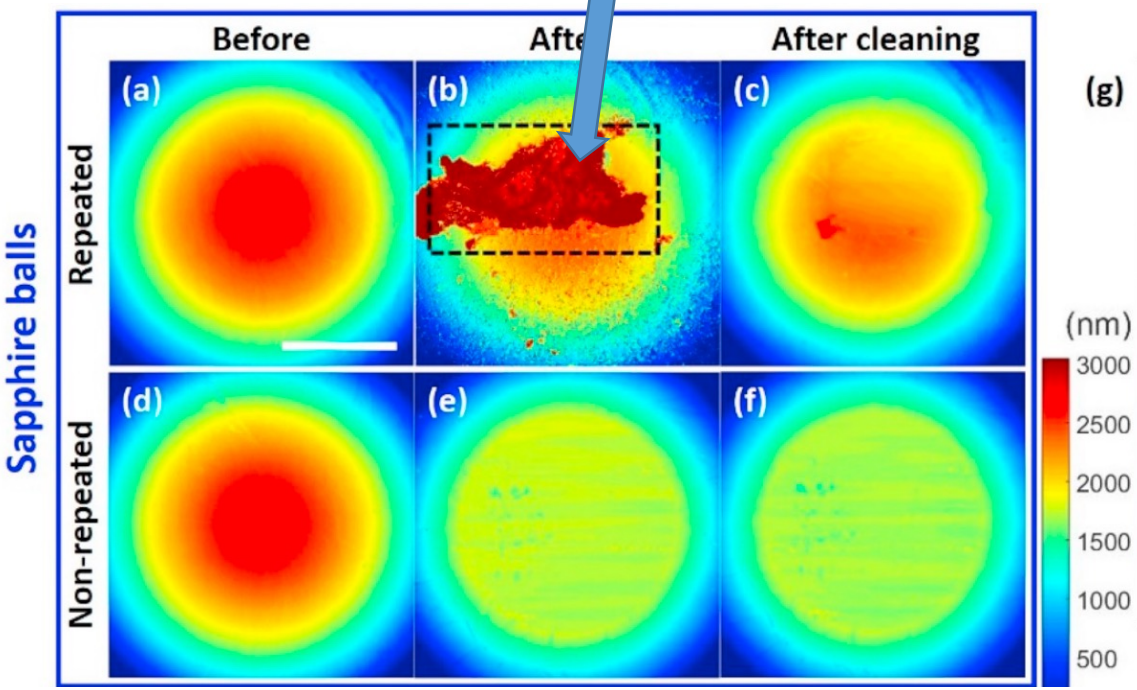




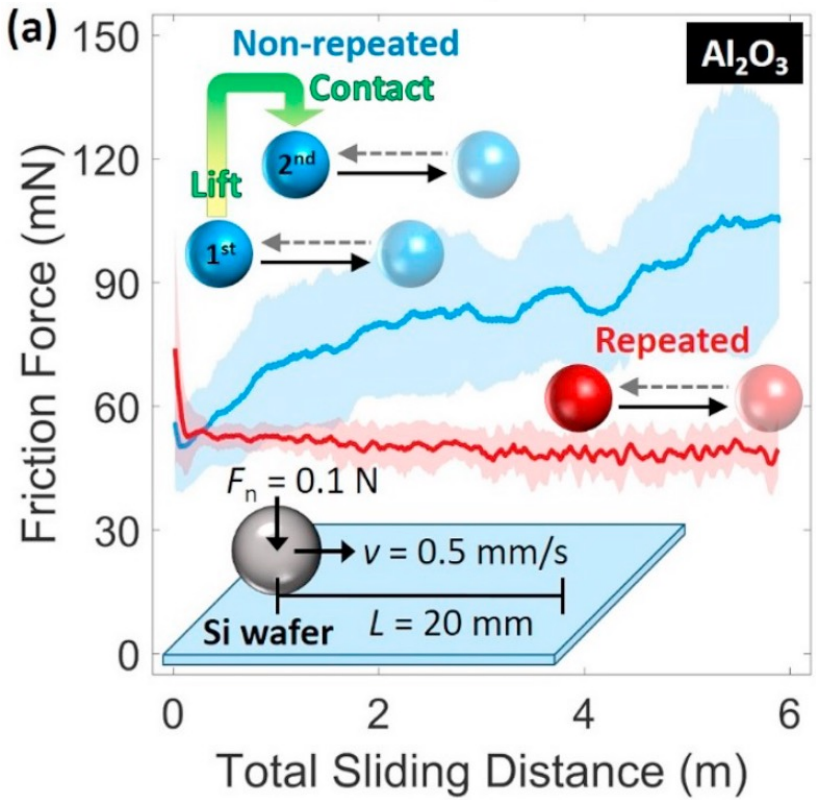
Non-repeated: 2x more friction, 6x wear



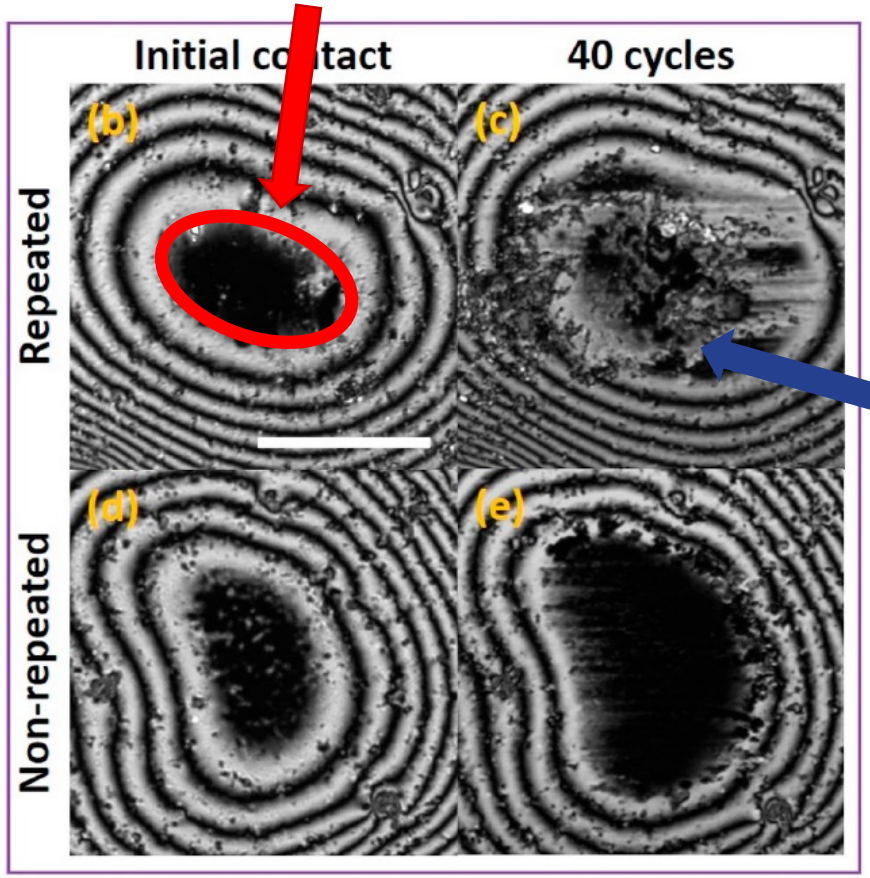
Third body that can be washed off



Third body = compressed debris



Ball-on-flat contact within central interference fringe



Compressed wear debris

Hsia, F.-C., Elam, F. M. Bonn, D. Weber, B. Franklin, S. *Tribol. Int.* **142**, 105983 (2019)

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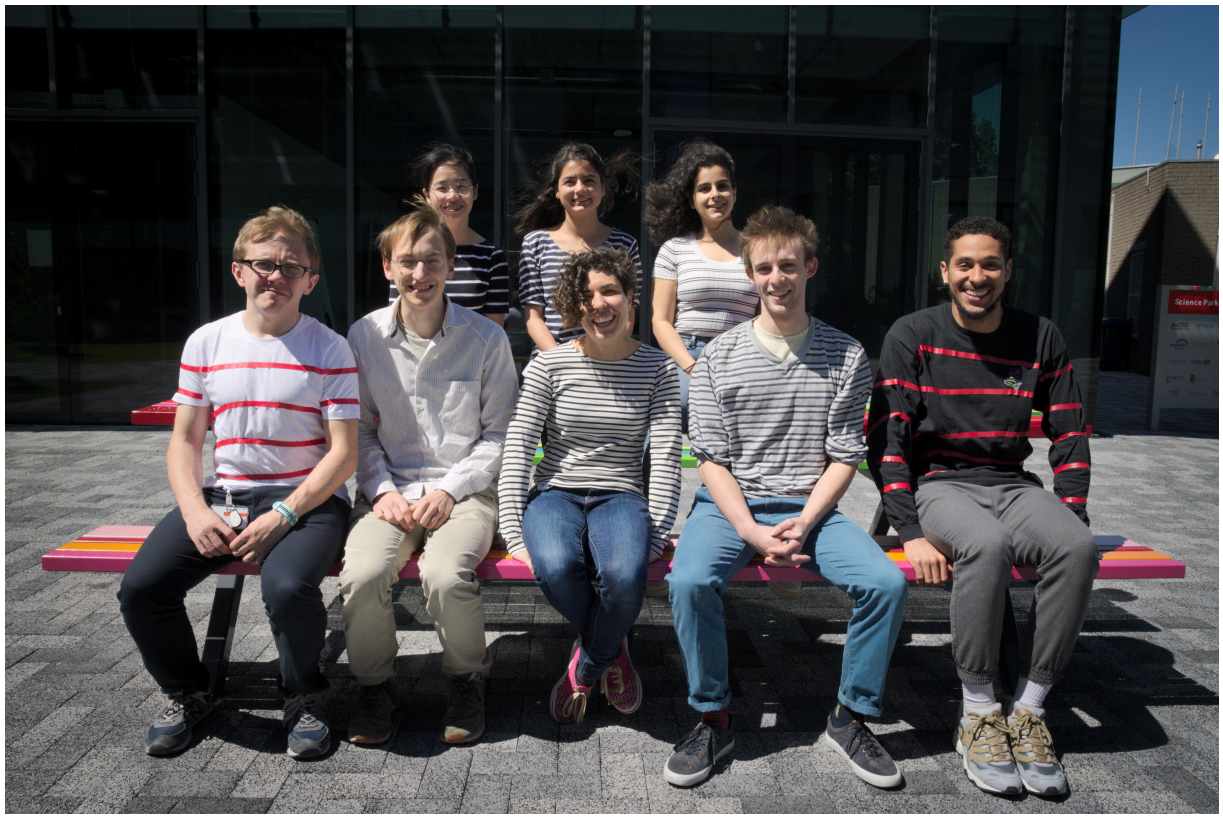
EUV Photoresists: team

ARCNL



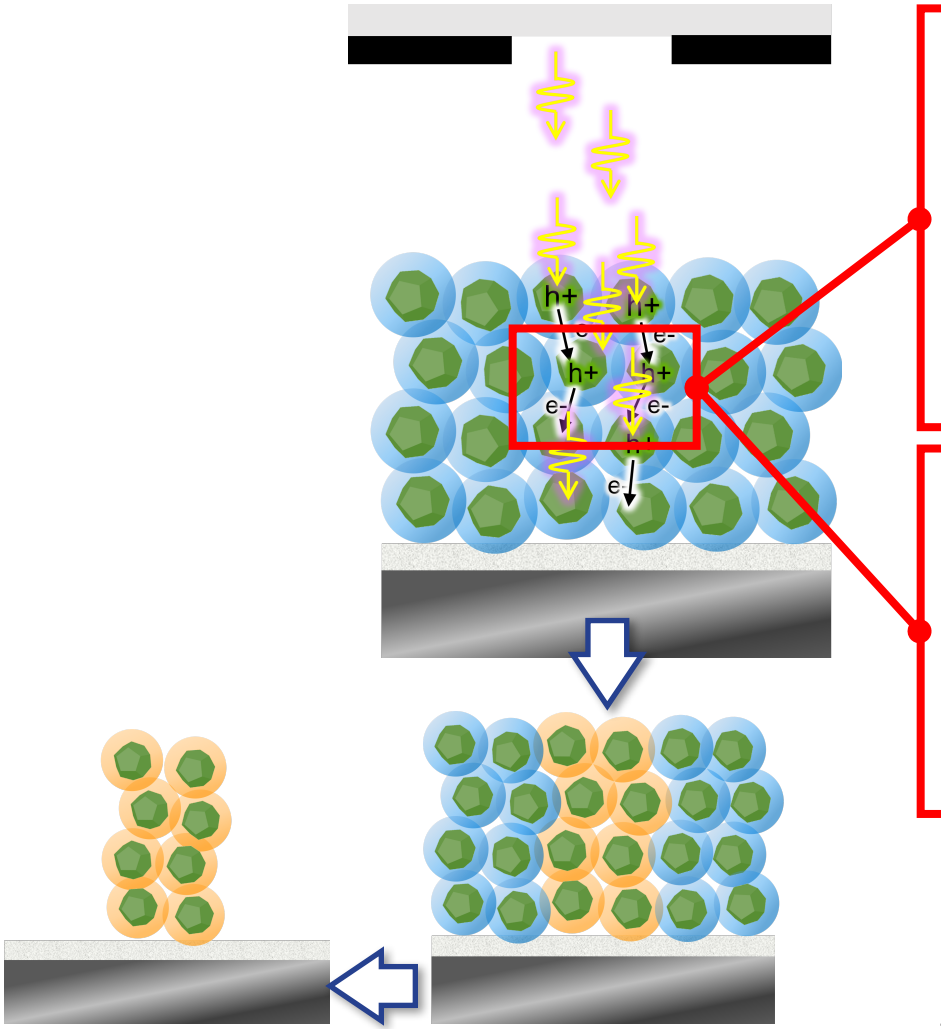
PAUL SCHERRER INSTITUT

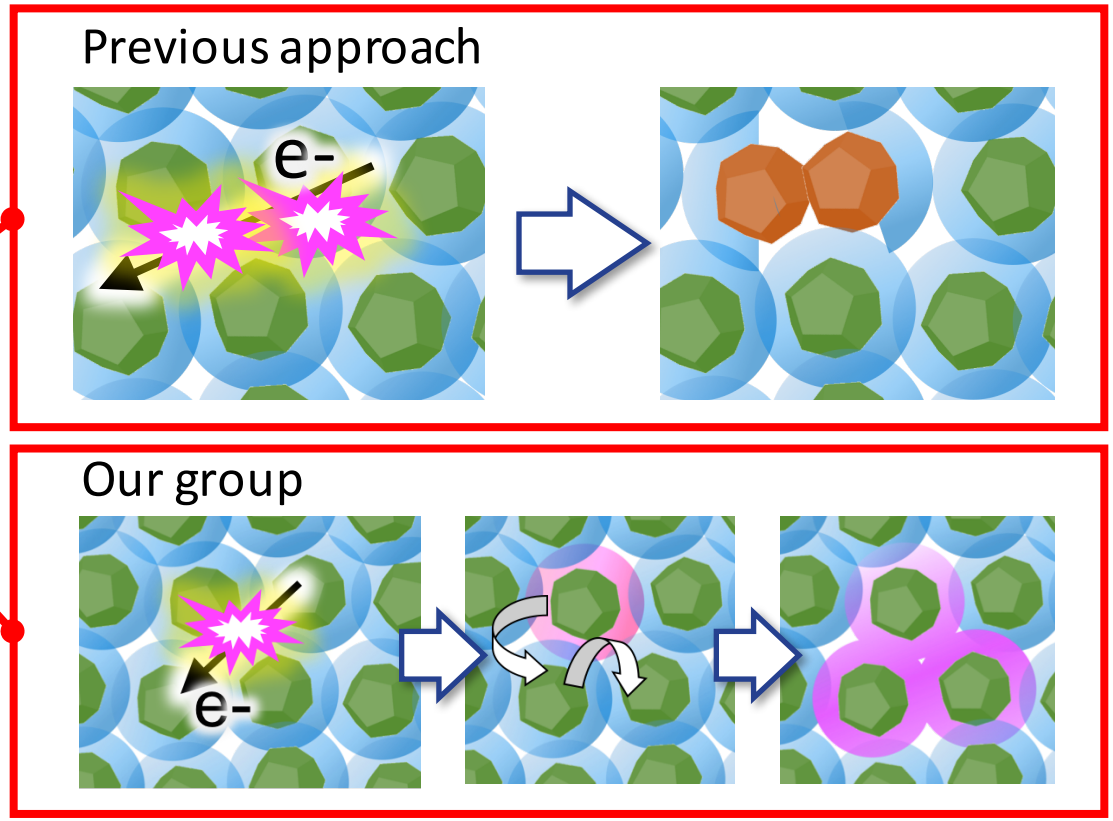
PSI

Elettra Sincrotrone Trieste

SOLEIL SYNCHROTRON

Mastering EUV photochemistry



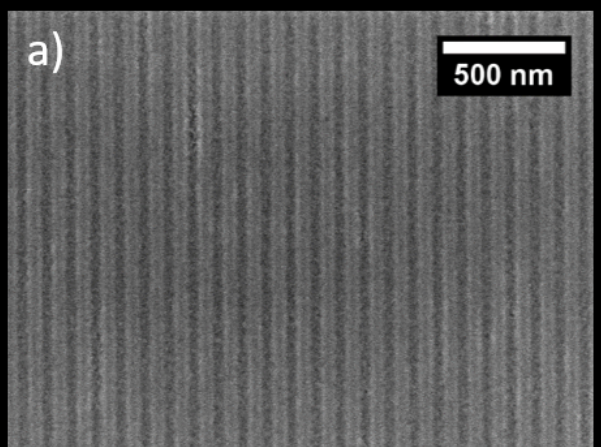


J. Micro/Nanolith. MEMS MOEMS 18(1), 013504, **2019**
J. Mater. Chem. C, 7, 33, **2019**
Eur. J. Inorg. Chem., 4136, **2019**
Proc. SPIE 10957, **2019**, 109570B
J. Nano/Microlitho. MEMS MOEMS (**in press**)

1st generation

HP 50 nm
57 mJ/cm^2

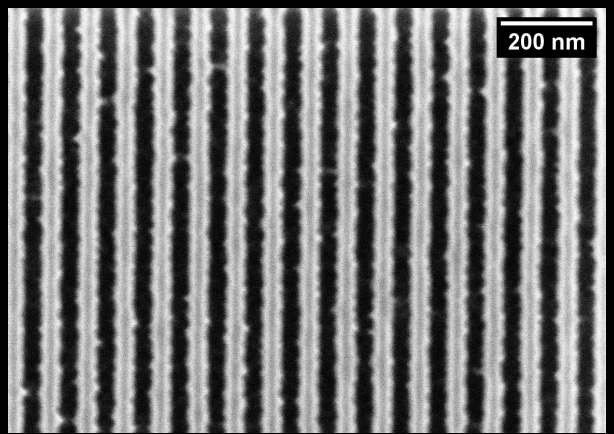
Zr-MOC



2nd generation

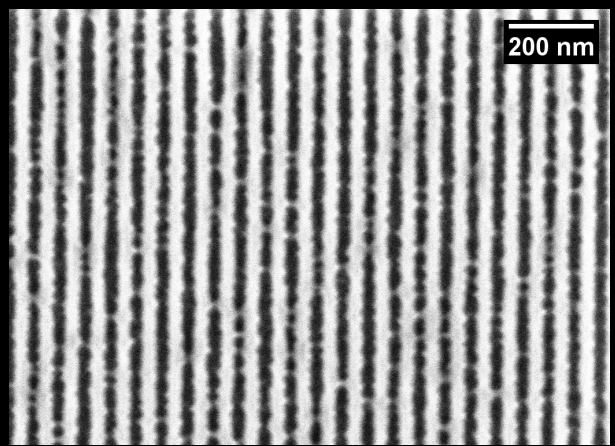
HP 40 nm
38 mJ/cm^2

Zr-MOC-F



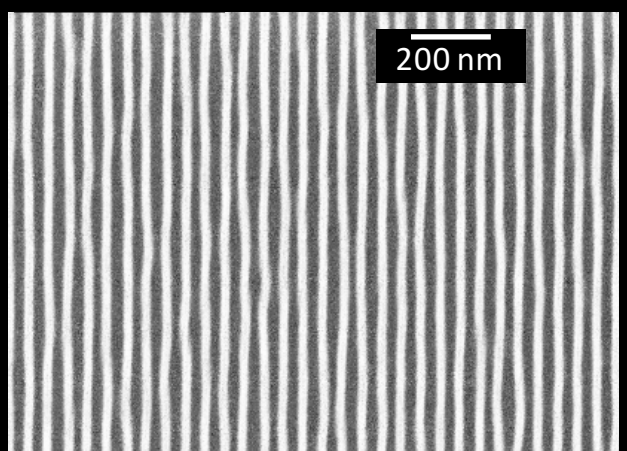
HP 30 nm
36 mJ/cm^2

Zr-MOC-F



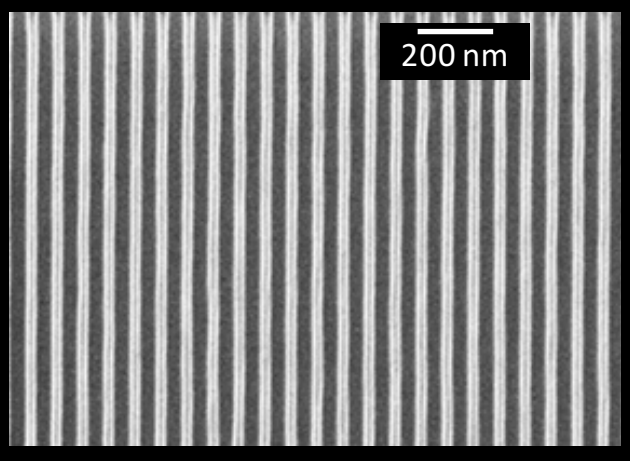
HP 22 nm
13 mJ/cm^2

Zn-MOC-F

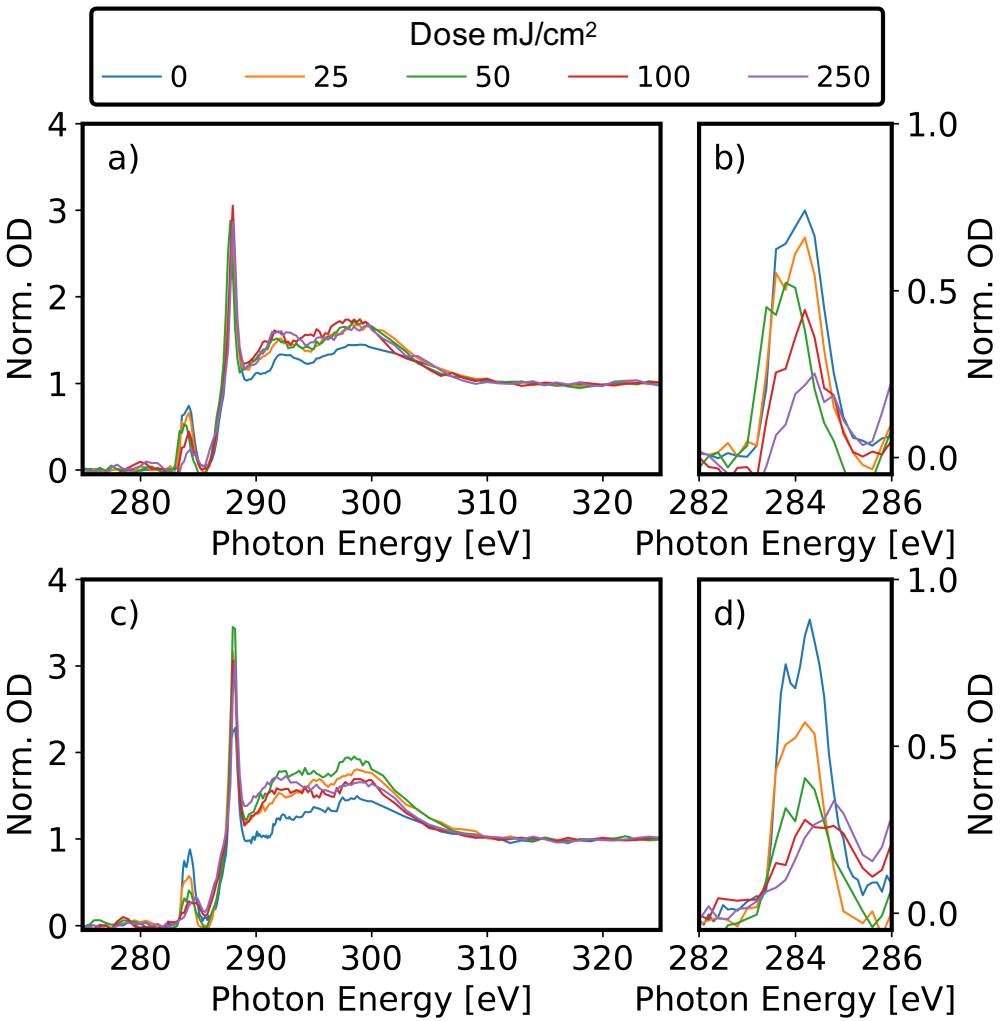


HP 30 nm
15 mJ/cm^2

Zn-MOC-F

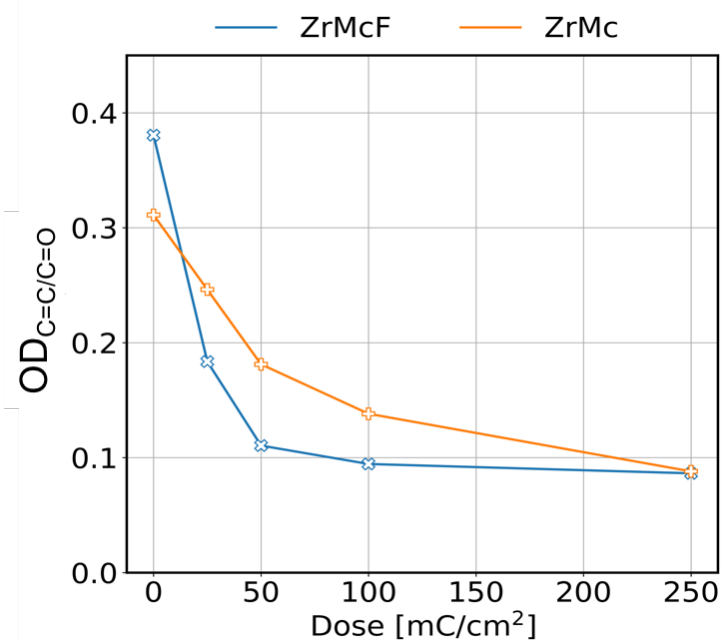


Mastering EUV photochemistry



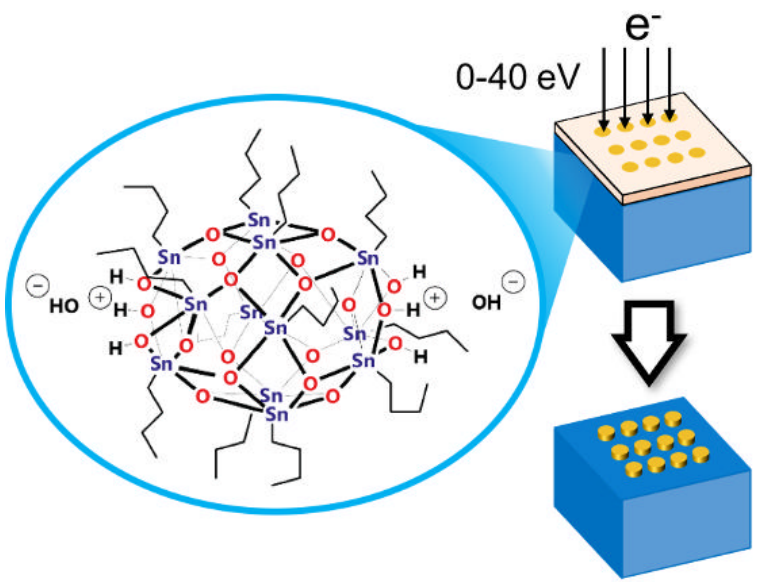
Spectroscopy research:

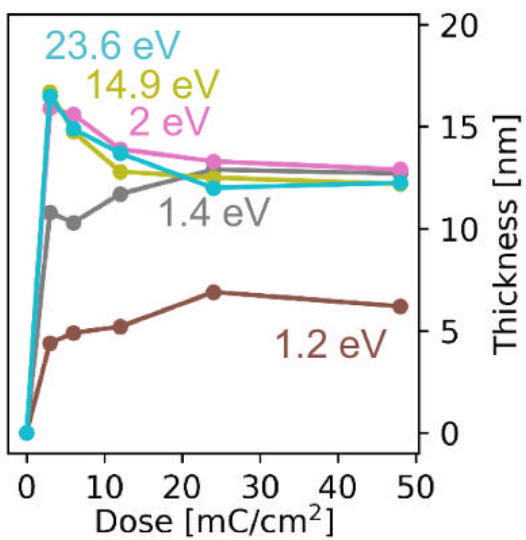
- new mechanisms vs litho performance
- Reaction kinetics vs sensitivity/contrast



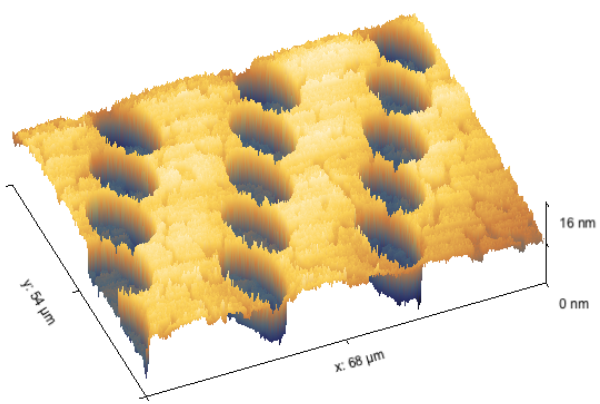
Mastering EUV photochemistry

Chemistry of low-energy electrons:
- <10 e-/molecule for patterning
- e < 2 eV do chemistry





AFM after LEE exposure



I. Bespalov, Y. Zhang, R. M. Tromp, S.J. van der Molen, A. M. Brouwer, J. Jobst*, S. Castellanos*, "The Key Role of Very Low-Energy Electrons in Tin-based Molecular Resists for Extreme Ultraviolet Nanolithography" (**submitted**)

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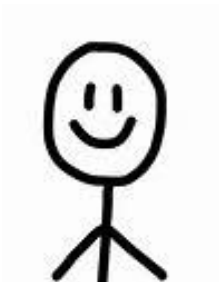
ARCNL

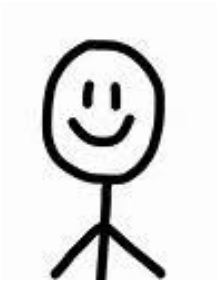
PhD students

Alessandro Troglia



Stefan van Vliet

Technician



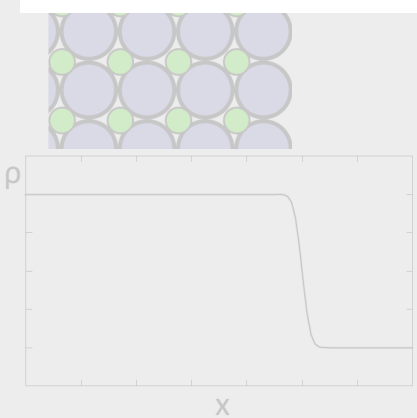
Bartjan Spaanderman

Senior staff

Roland Bliem

Surfaces & Interfaces: Locations of sharp gradients

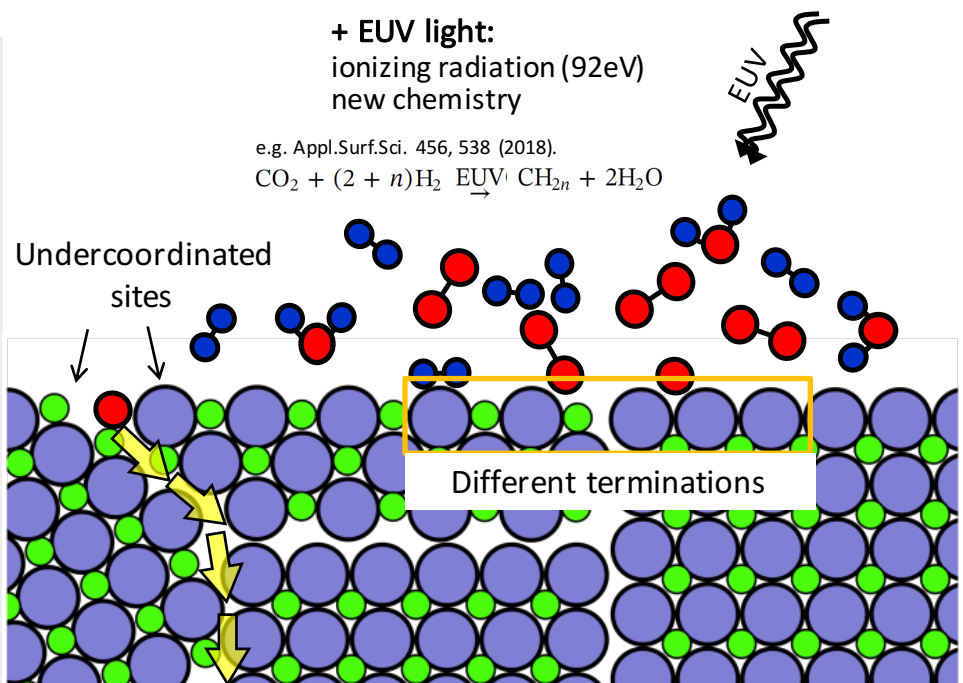
Real life:
not a border to vacuum
not a perfect crystal
not a static situation



+ EUV light:
ionizing radiation (92eV)
new chemistry

e.g. Appl.Surf.Sci. 456, 538 (2018).

$$CO_2 + (2+n)H_2 \xrightarrow{EUV} CH_{2n} + 2H_2O$$

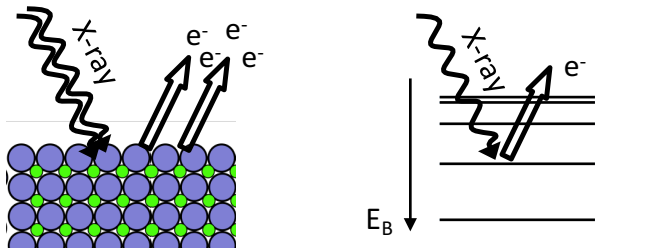


Grain boundaries = diffusion channels (+ reactive spots, breaking points, nucleation points …)

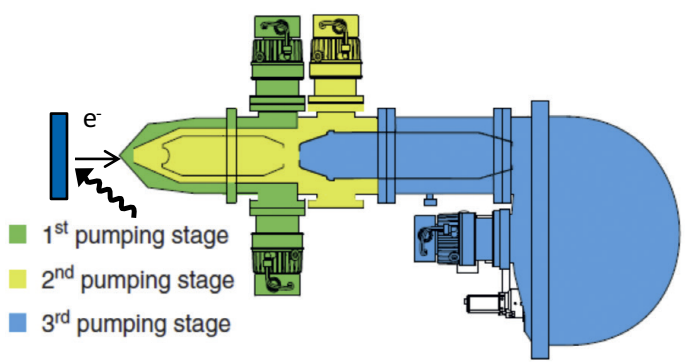
Photoelectron Spectroscopy

- Central aim: Understand fundamental interaction processes at surfaces <u>while they are happening</u>
  - Surface
    + gas environment
      + EUV radiation, + …
- Tool: (**N**ear-**a**mbient **p**ressure)
  X-ray **P**hotoelectron **S**pectroscopy (NAP)-XPS
  - <u>Surface-sensitive</u> & Quantitative
  - <u>Composition and chemical state</u>
  - Combined with extreme ultraviolet (EUV) light source (92 eV, 13.5 nm)
  - *In-situ* XPS at up to 20 mbar

→ at the relevant conditions



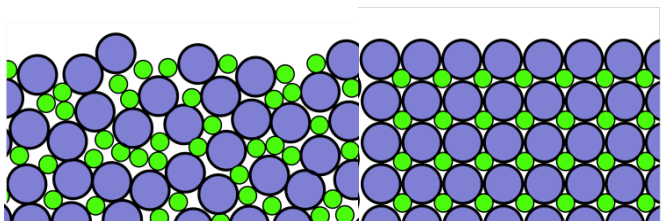
$E_{kin} = E_{ph} - E_B - \Phi$



Thin films for EUVL - Pathways to explore

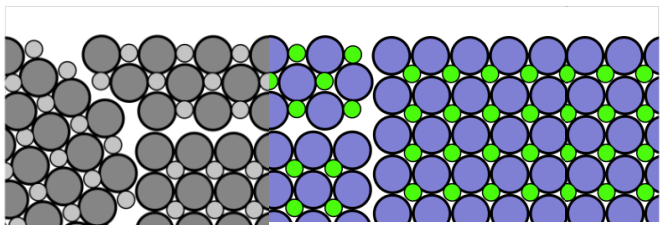
Composition

Alloying, Doping, New Materials



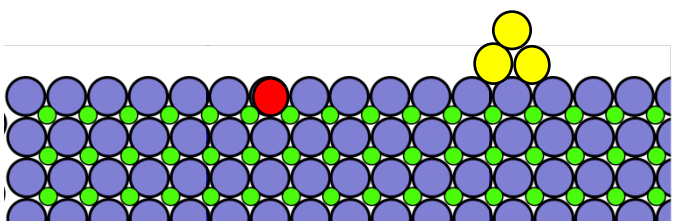
Structure

Perfect - polycrystalline - disordered



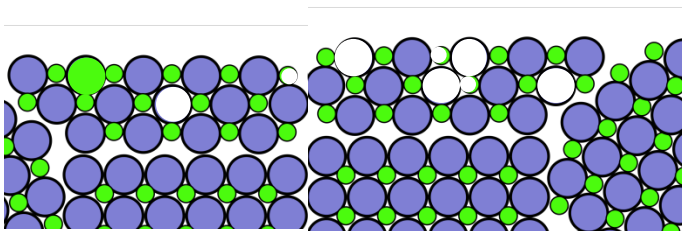
Defectiveness

Vacancies, Boundaries, Steps, Substitution



Contaminants

Minority species can dominate chemical processes at the surface (e.g. Ru+Sn)



Grow & compare amorphous layers

- Nature's preference: crystallization

  → (poly-)crystalline films for most deposition methods

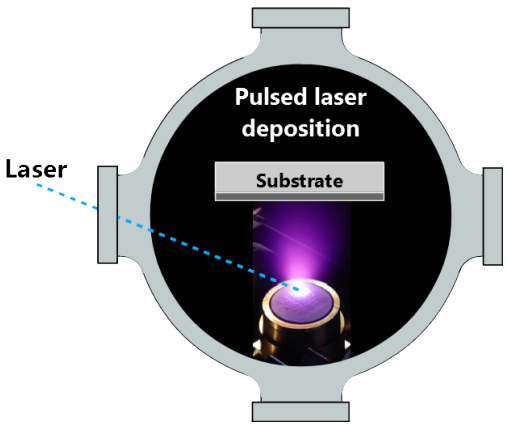
- Pulsed Laser Deposition (PLD)

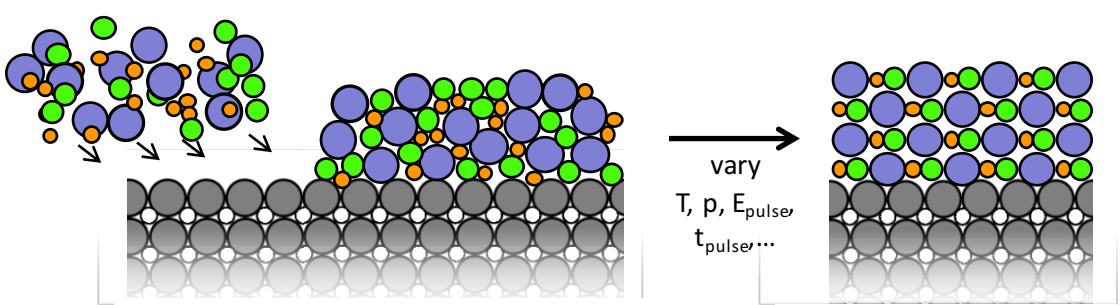
  Complex crystalline layers

  but also <u>off-equilibrium structures</u>

  → Saturating surface with material at every pulse

  → Flexible in composition





Pulsed laser deposition

→ extremely versatile