Properties and applications of pulsed laser deposited thin films

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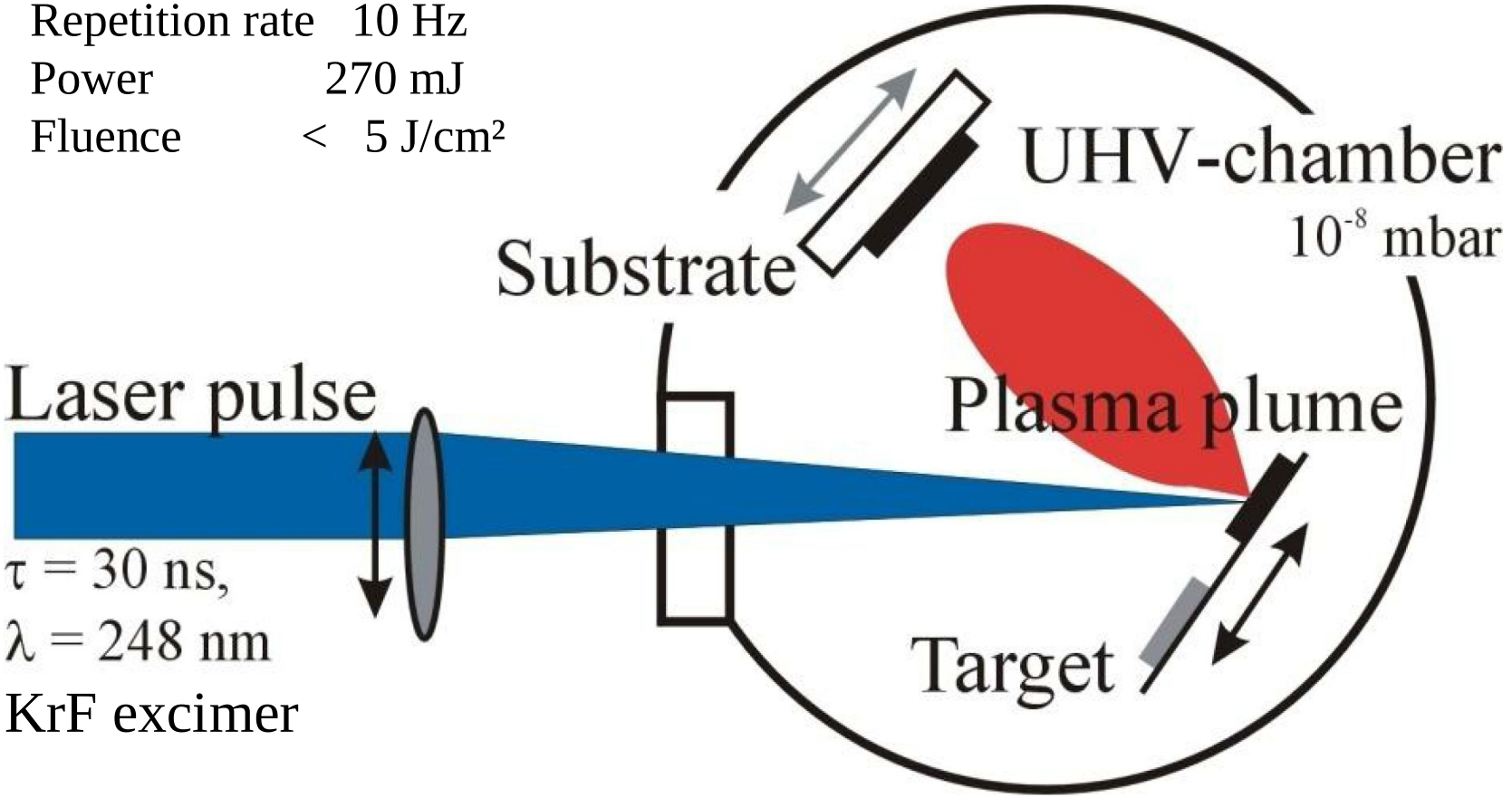
PLD Symposium - 21.07.2017

Setup for pulsed laser deposition

Repetition rate 10 Hz
Power 270 mJ
Fluence < 5 J/cm²



deposition independent from laser

Outline

Materials for PLD and physical principles

Processes at target and substrate

Properties of PLD grown thin films

Growth mechanisms and multilayers

Fabrication of X-ray optics

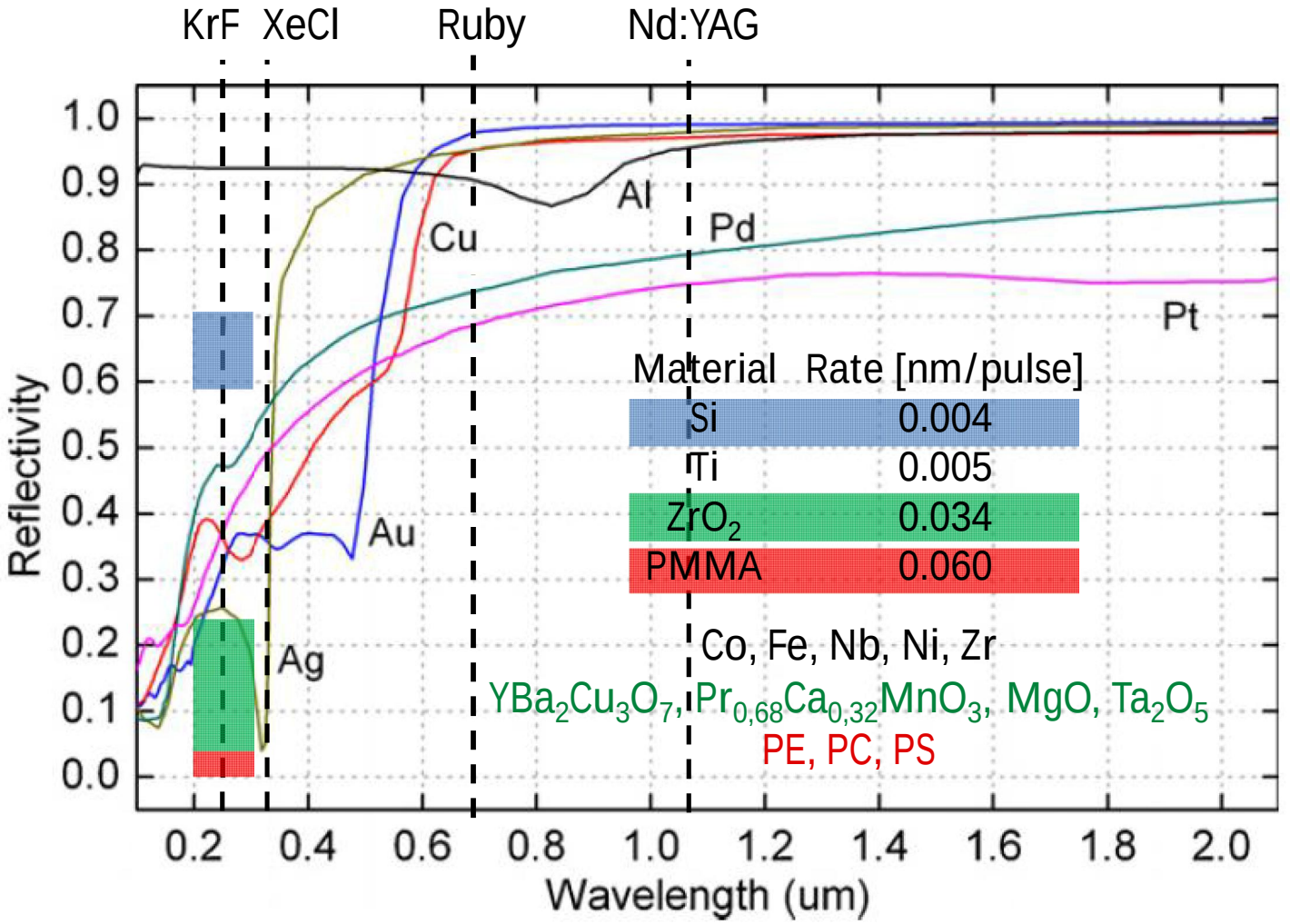
Thermally treated multilayers and Multilayer Zone Plates

Reflectivity of different classes of materials

Semi-conductors

Oxides

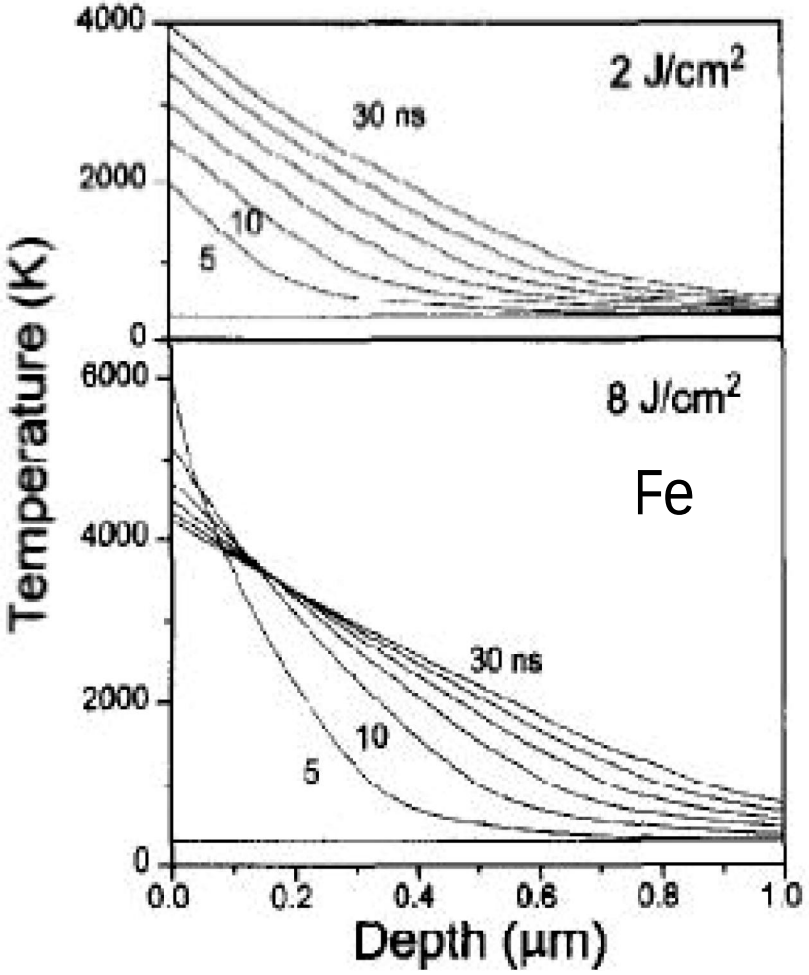
Polymers

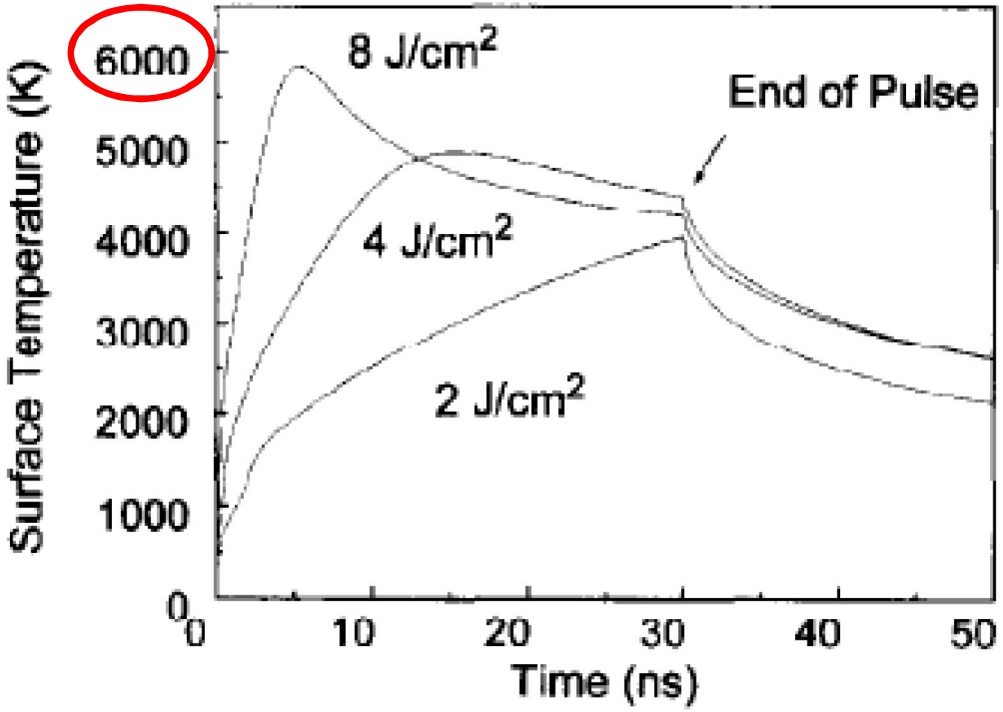


HTSC, oxides, nitrides, carbides, semiconductors, metals, polymers, fullerenes,...

Fabian *et al. Meas. Sci. Technol.* 21, 094034 (2010)

Processes at the target



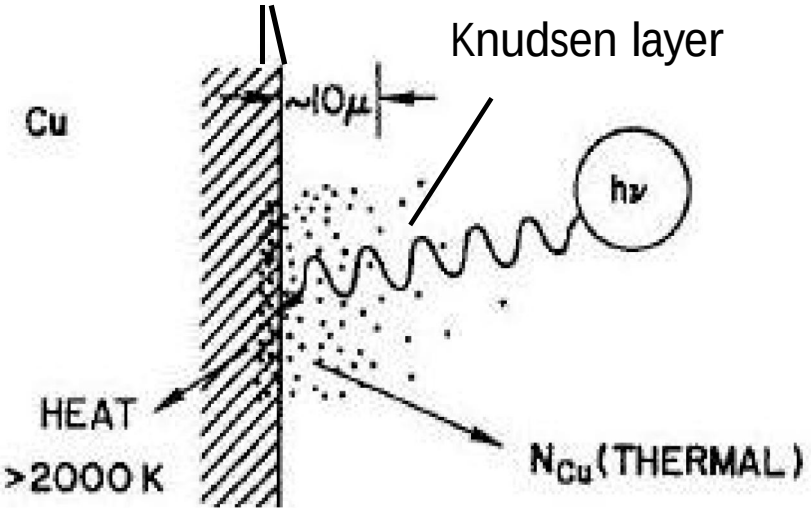


energy deposition at surface
heat transfer into volume

Fähler & Krebs *Appl. Surf. Sci.* 96-98, 61-65 (1996)

Ablation process

Skin depth 5 - 20nm

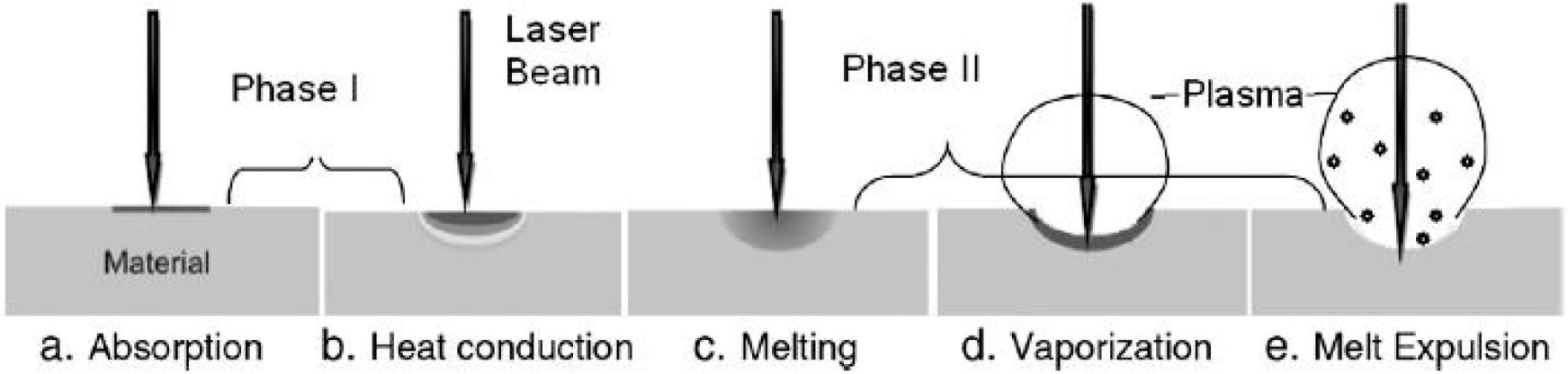


Eggert-Saha equation

$$\frac{{n_i}^2}{n_n} = \left(\frac{2\pi m_e kT}{h^2}\right)^{\frac{3}{2}} \cdot e^{-E_i/kT}$$

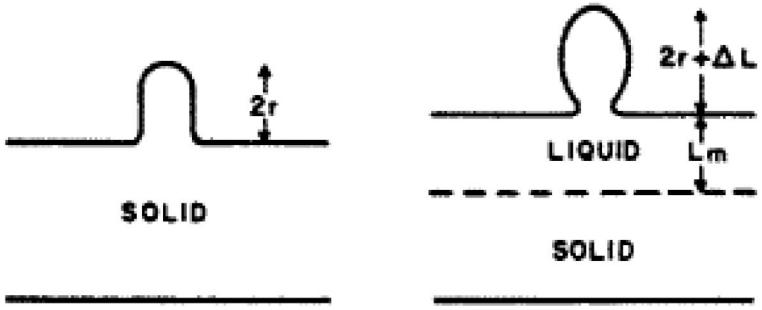
ionisation level 90 %

changes in surface morphology

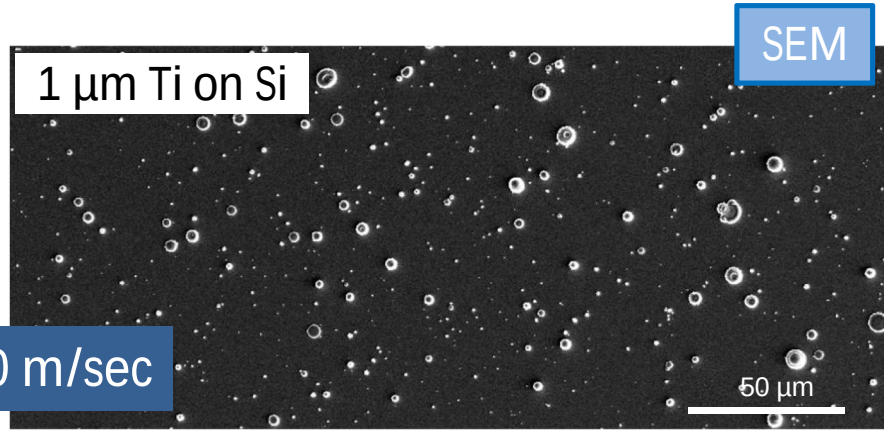


Vasantgadkar *et al. Thin Solid Films* 519, 1421–1430 (2010)
Kelly & Dreyfus *Surface Science* 198, 263-276 (1988)

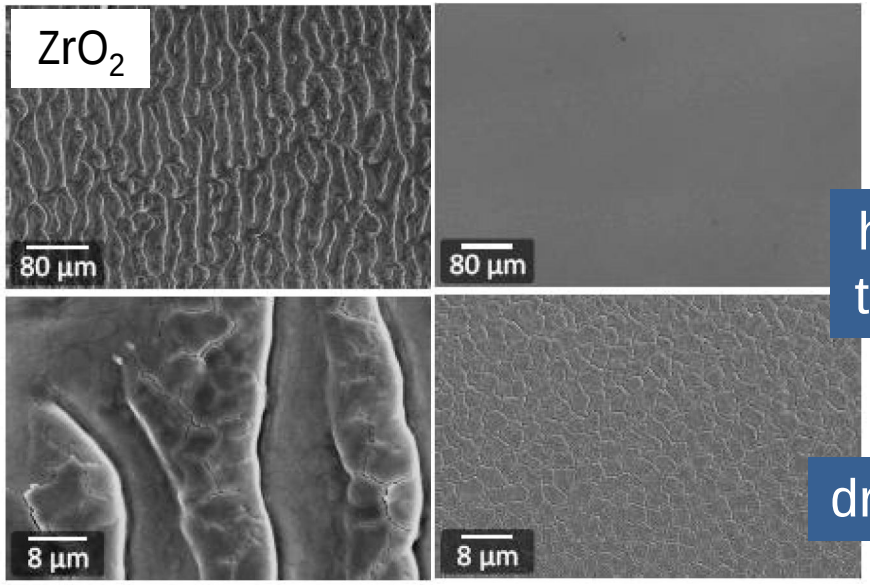
Droplet formation



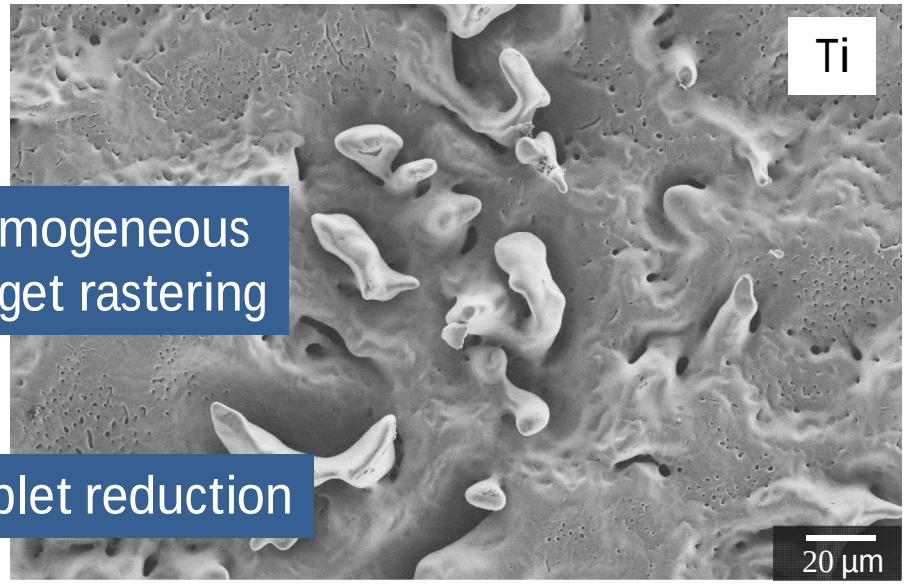
hydrodynamic sputtering



100 m/sec



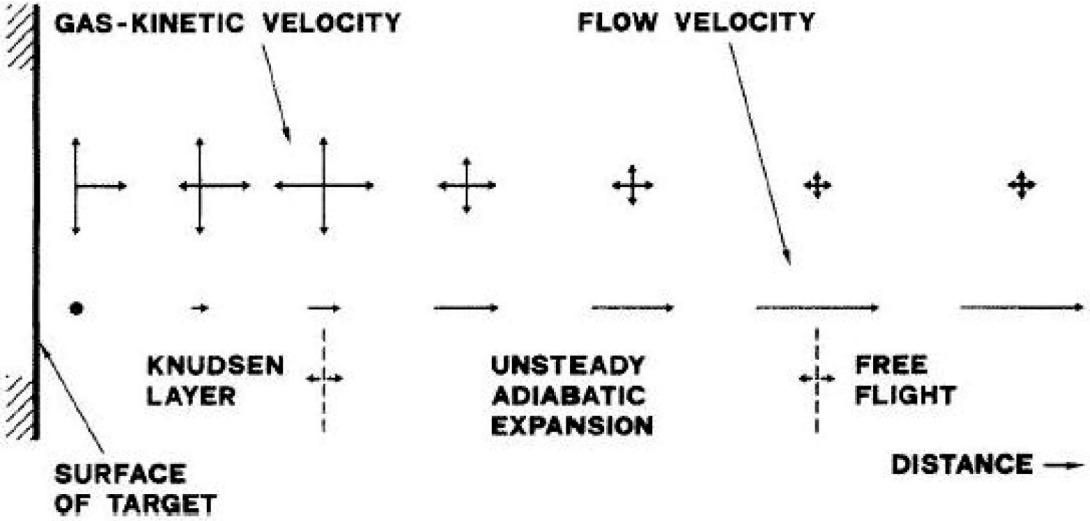
homogeneous target rastering

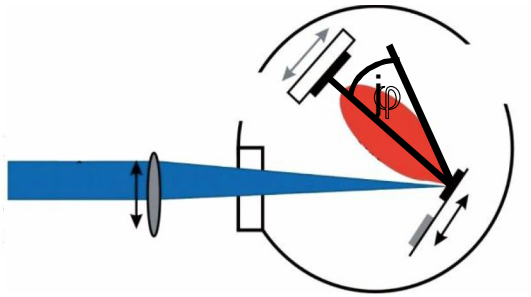


droplet reduction

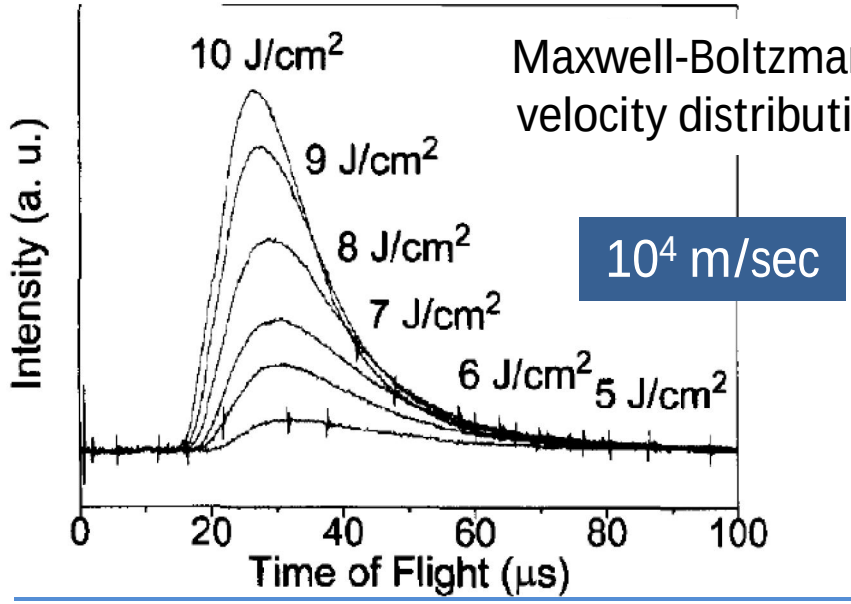
Chrisey & Hubler *Pulsed laser deposition of thin films* (1994)
Liese *Dissertation* (2012)

Shape of the plasma plume





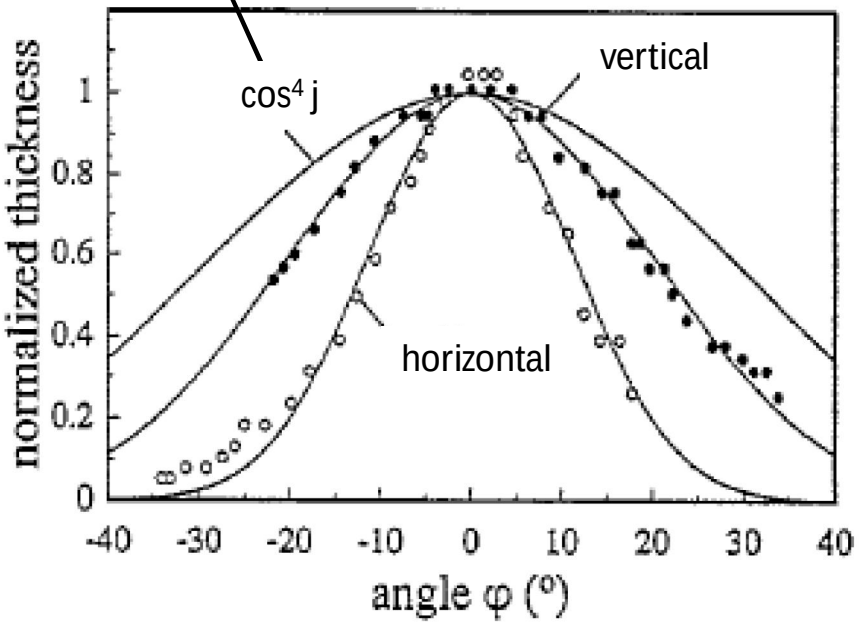
collisions lead to concentration of plume



Maxwell-Boltzmann velocity distribution

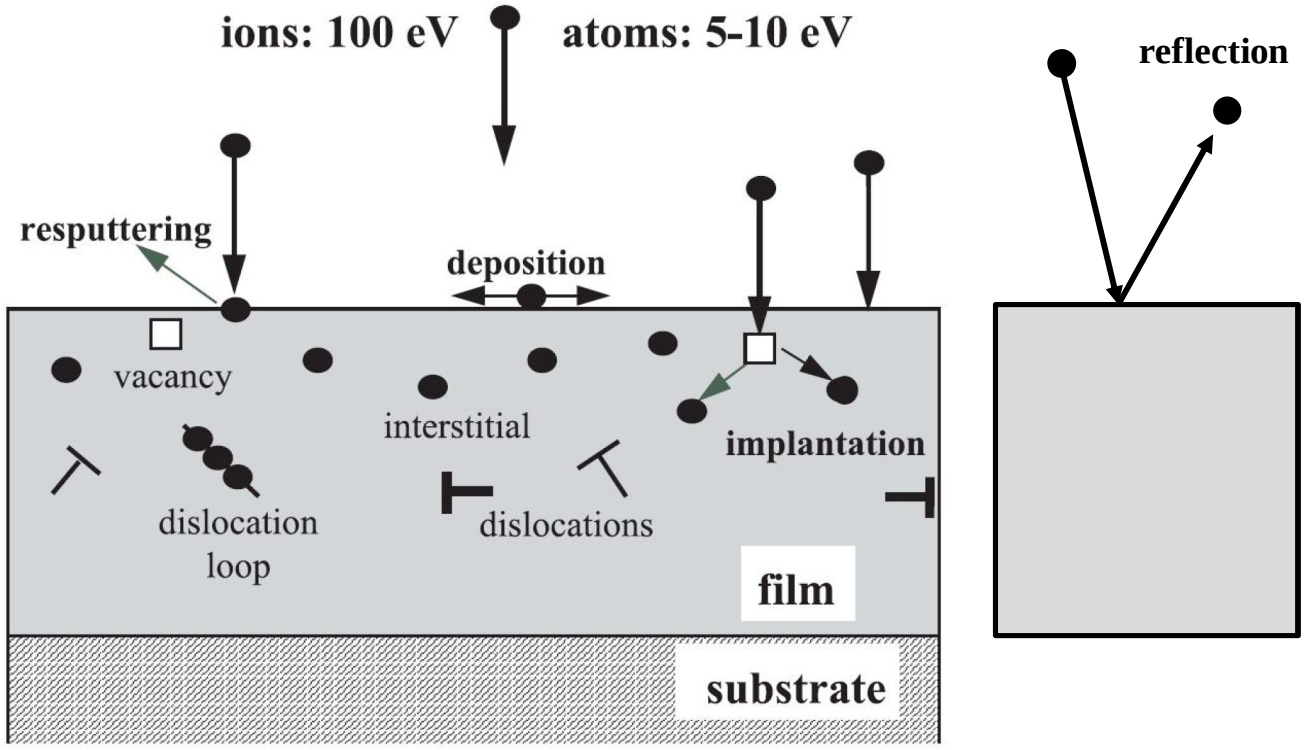
10^4 m/sec

thermal evaporation



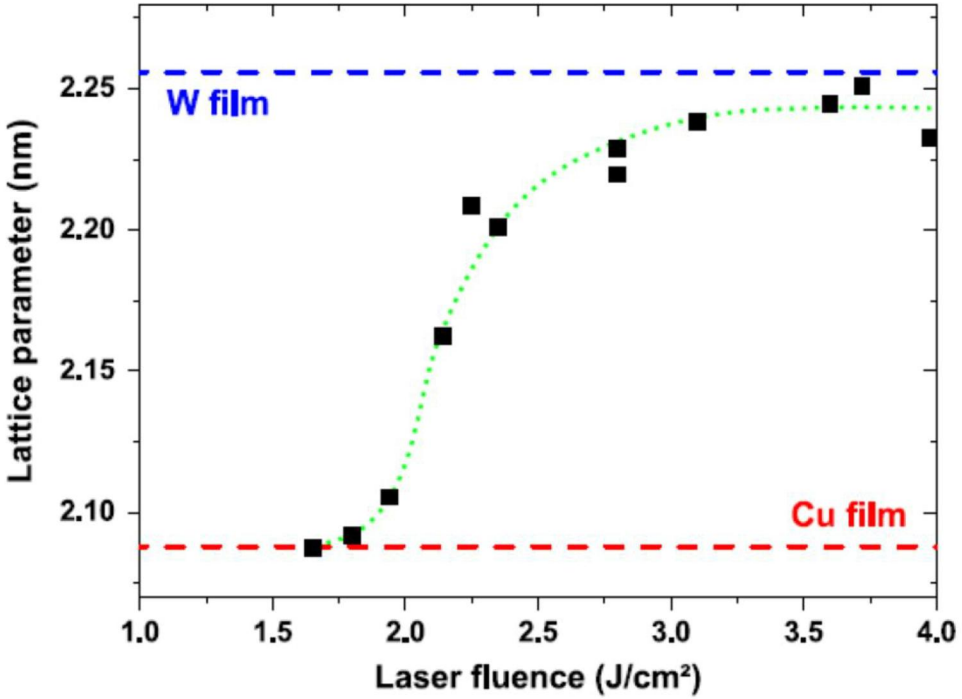
Kelly *et al. Nucl. Instr. Methods Phys Res* B65 187-199 (1992)
Krebs *et al. Appl. Surf. Sci.* 96-98, 61-65 (1996)
Krebs *et al. Appl. Surf. Sci.* 86, 86-89 (1995)

Processes at the substrate



Störmer *et al. Appl. Phys. A* 69 [Suppl.], S455–S457 (1999)

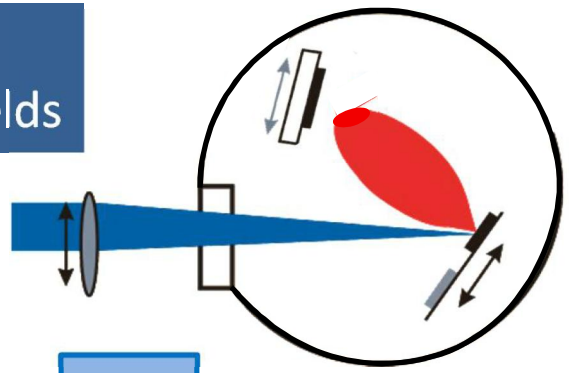
Variable stoichiometry



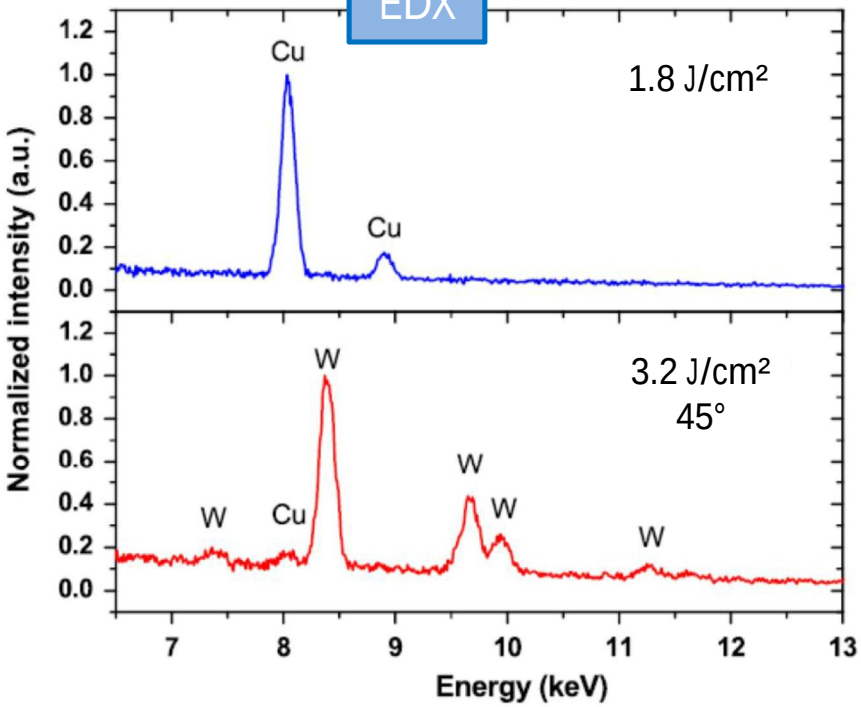
0–97 wt% W from a $W_{0.8}Cu_{0.2}$ target

different ablation thresholds

varying sputteryields

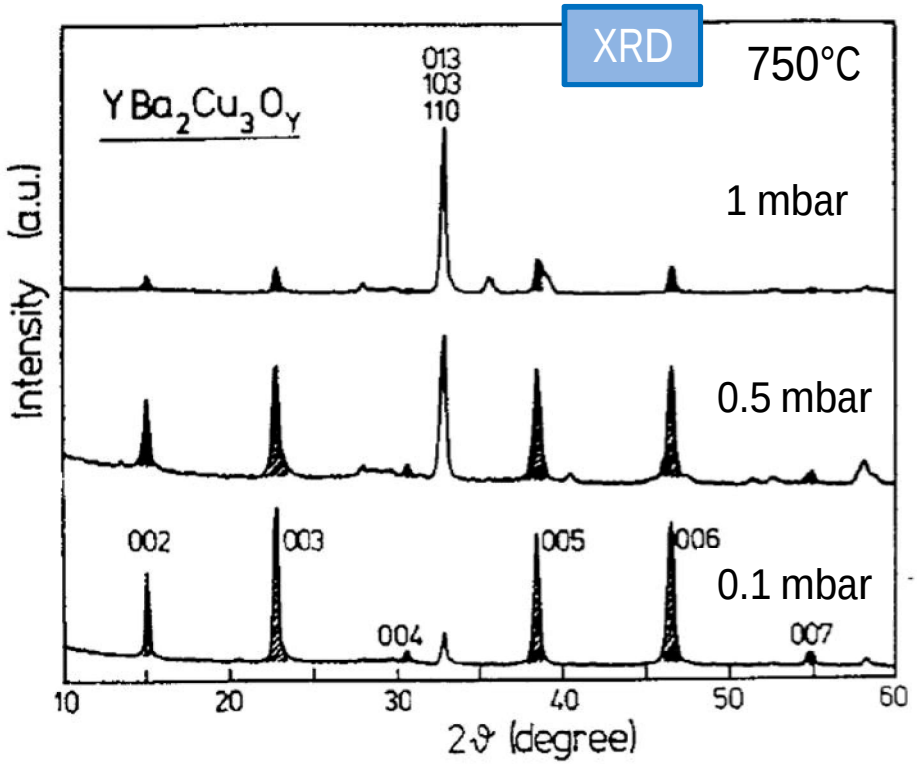


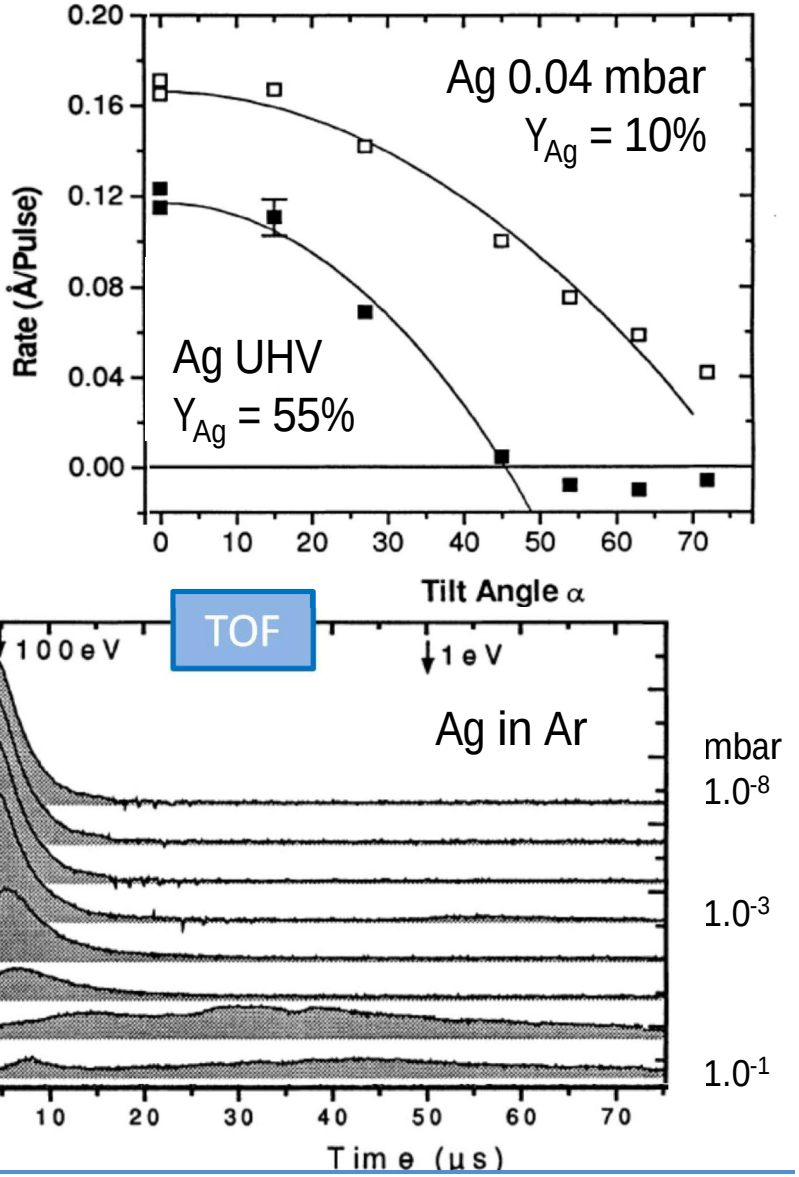
EDX



Klamt *et al. Appl. Phys. A* 122:701 (2016)

Effect of ambient pressure

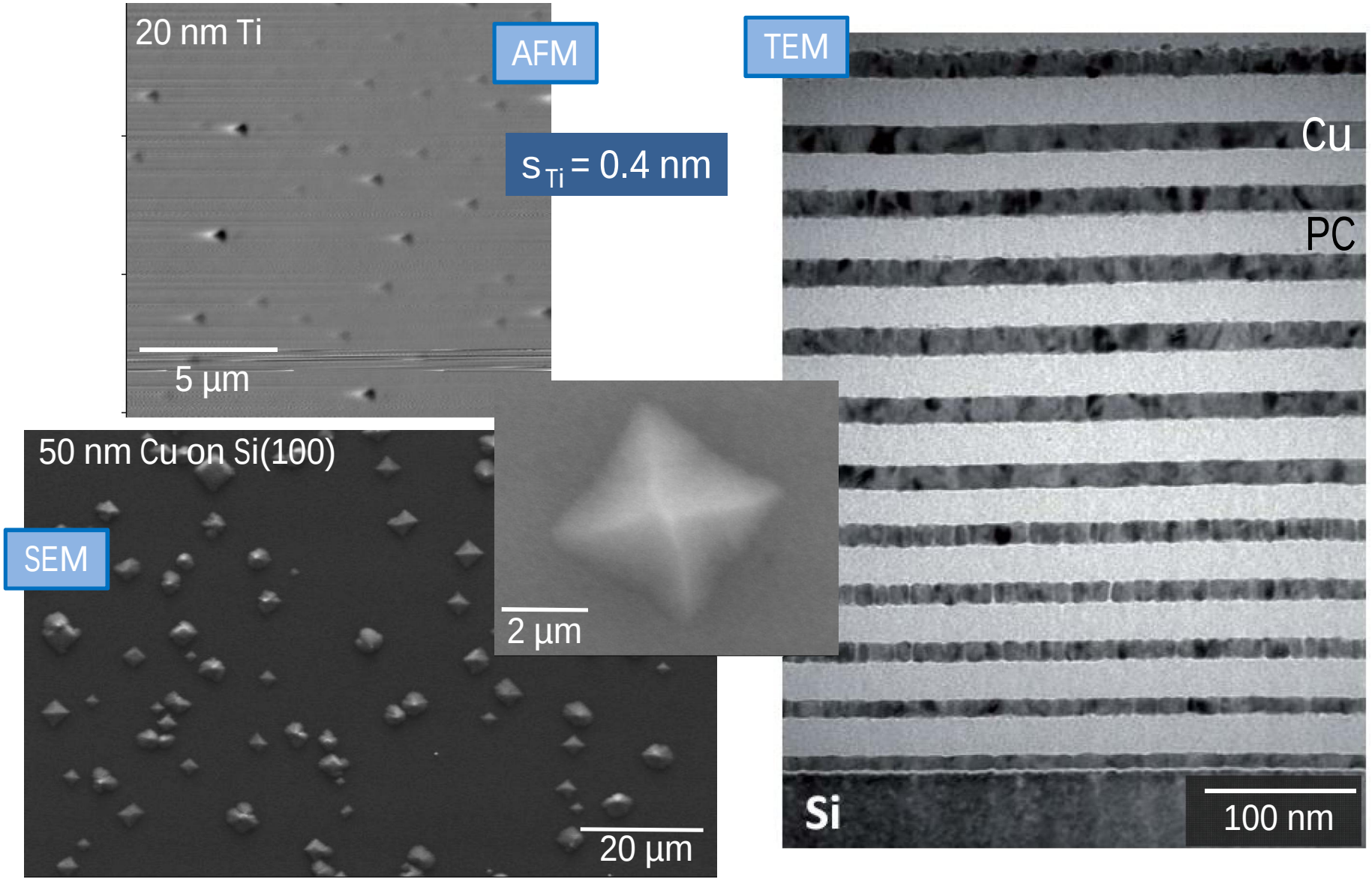




background pressure affects structure and rate

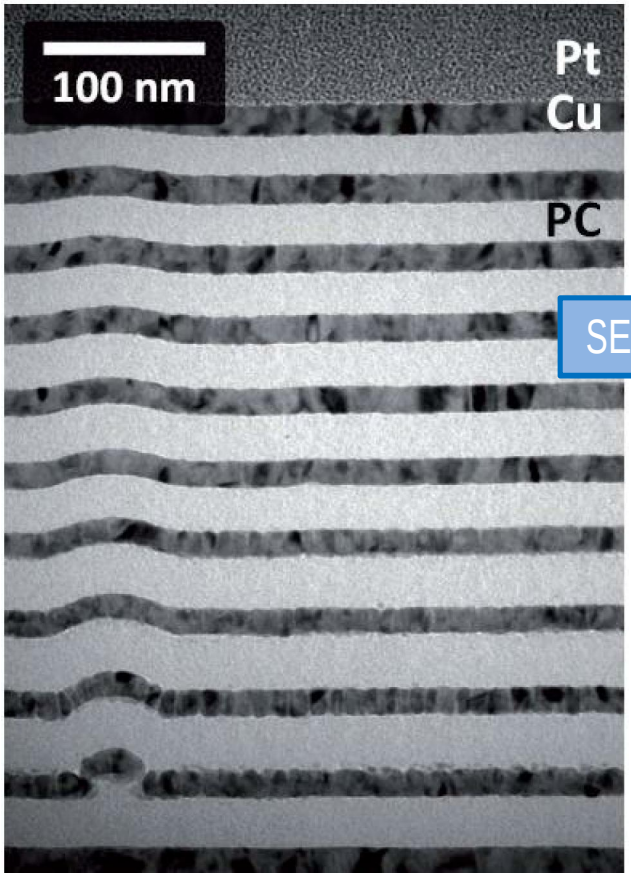
Krebs & Kehlenbeck *Physica C* 162-164, 119-120 (1989)
Sturm *et al. Applied Surface Science* 154–155, 462–466 (2000)

Initial state of growth

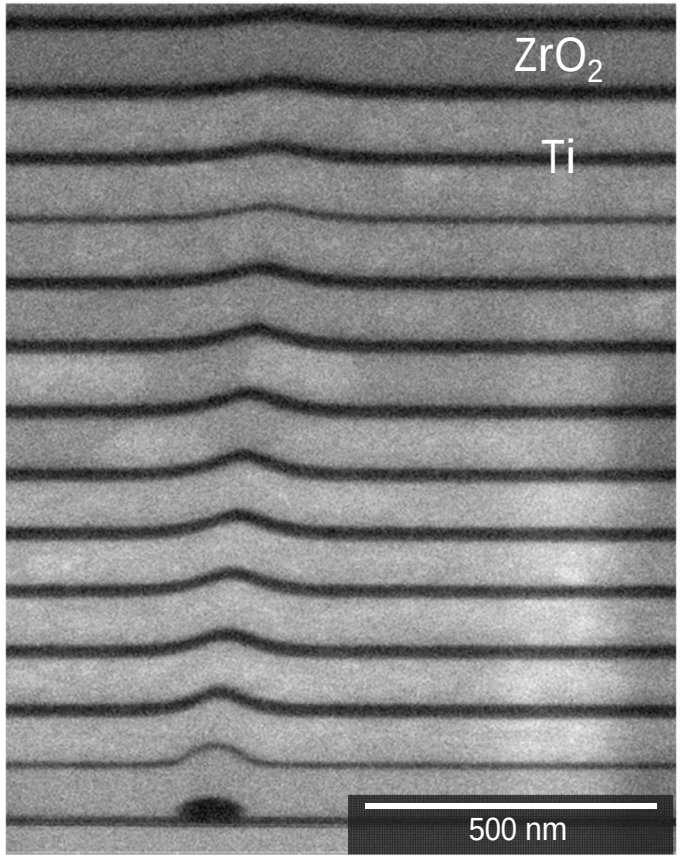


S. Schlenkrich *Dissertation* (2014)

Laser deposited multilayers



SEM

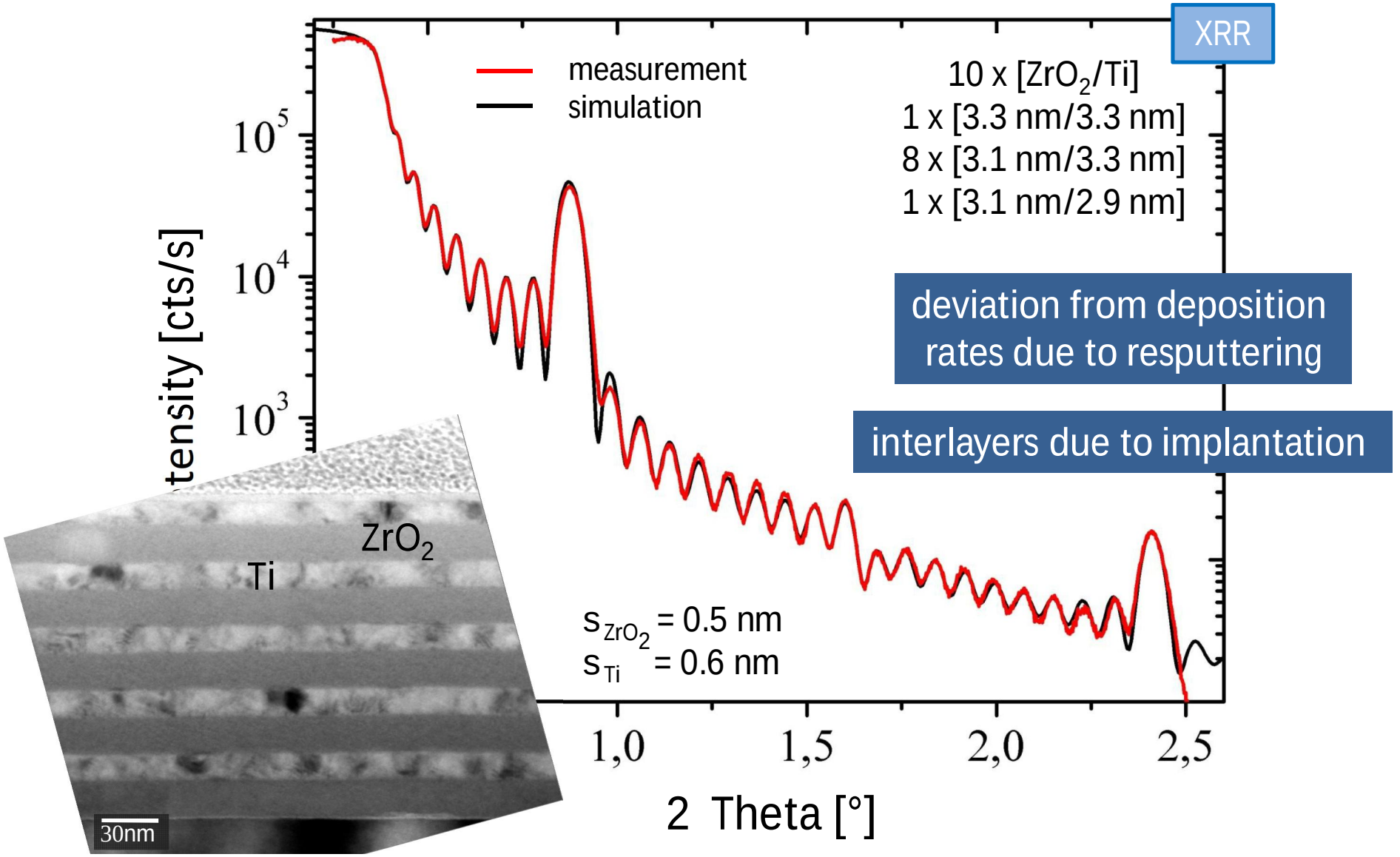


sputtererosion and ballistic transport

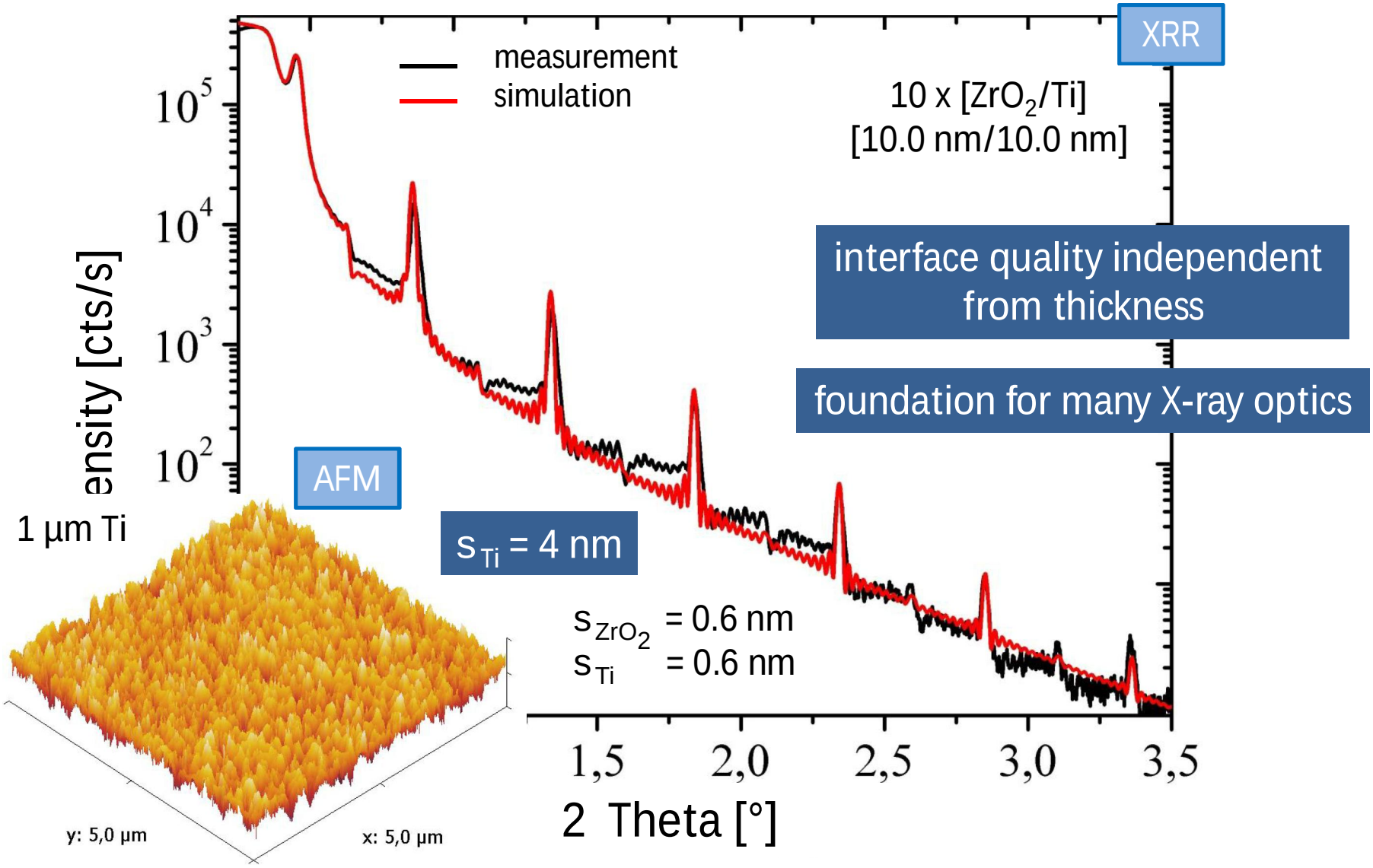
cumulative smoothing

Röder, Liese & Krebs *J. Appl. Phys*. 107, 103515 (2010)
S. Schlenkrich *Dissertation* (2014)

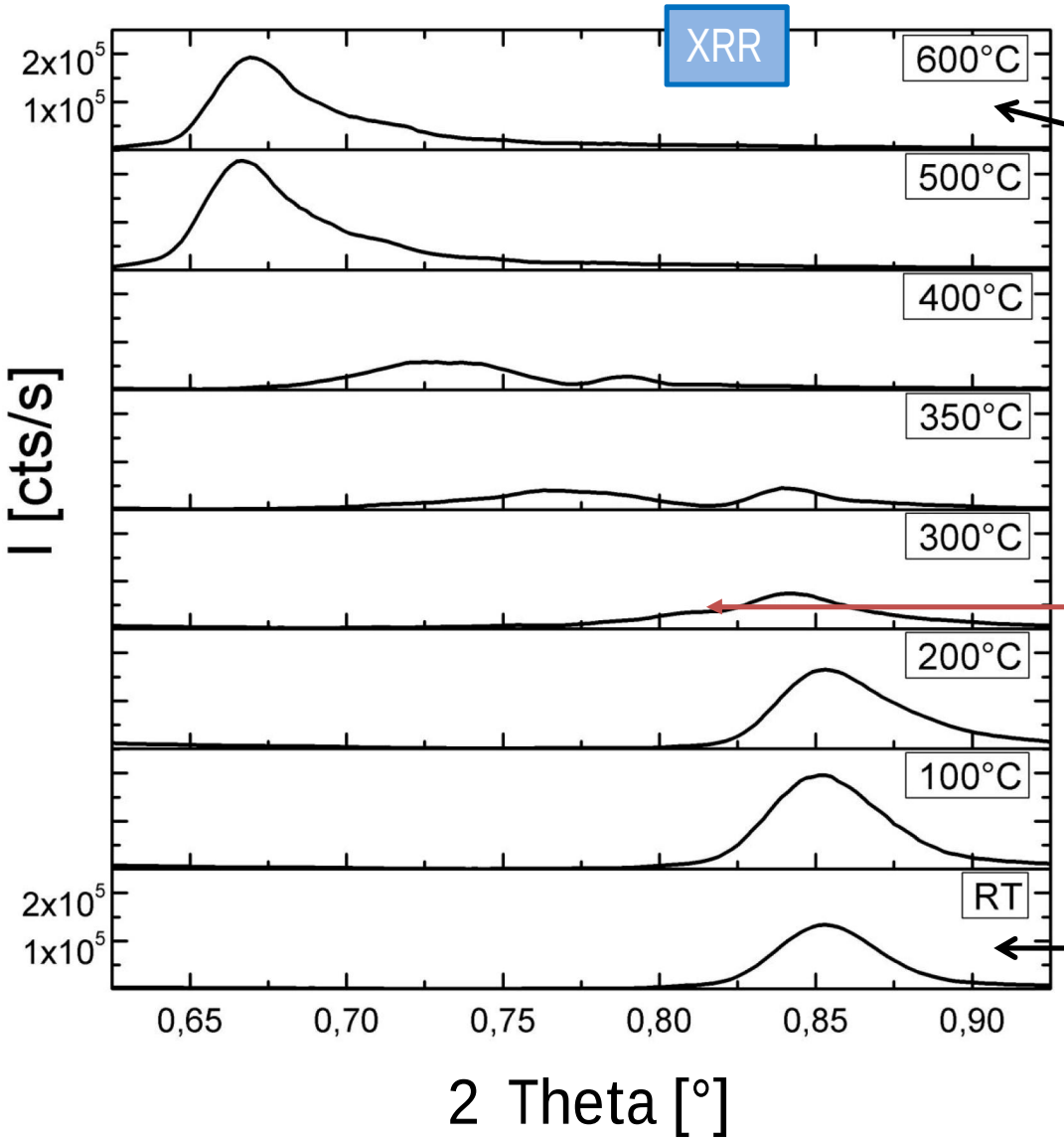
Precise characterization of multilayers

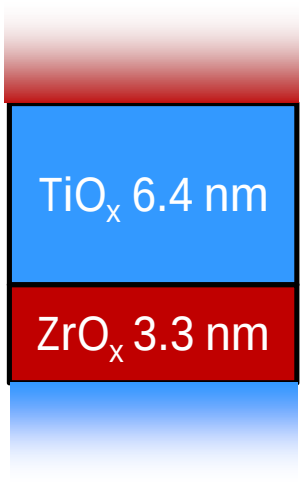


Perfect [ZrO_2/Ti] multilayer stack



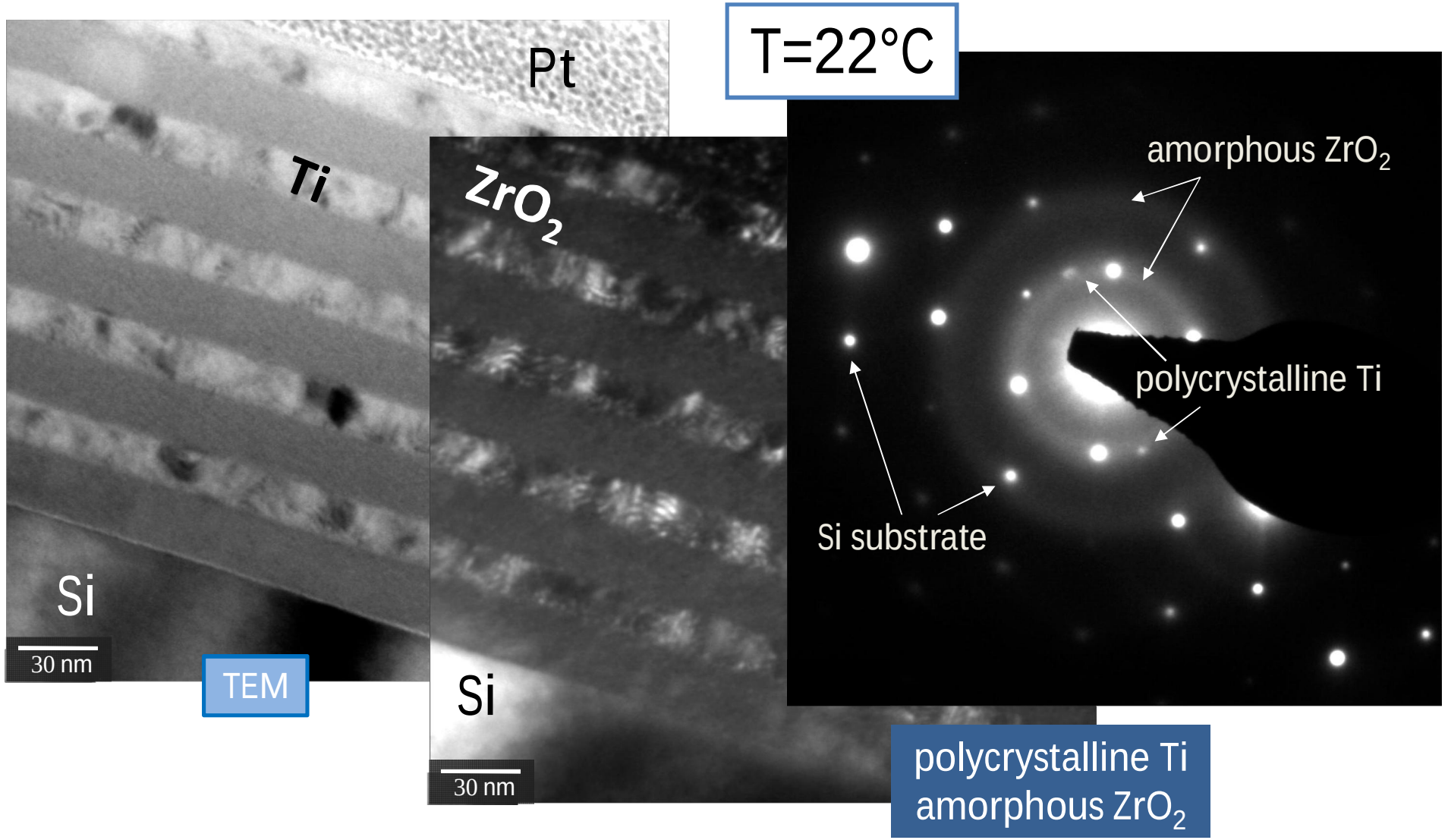
Thermal stability of 25 x [ZrO_2/Ti]



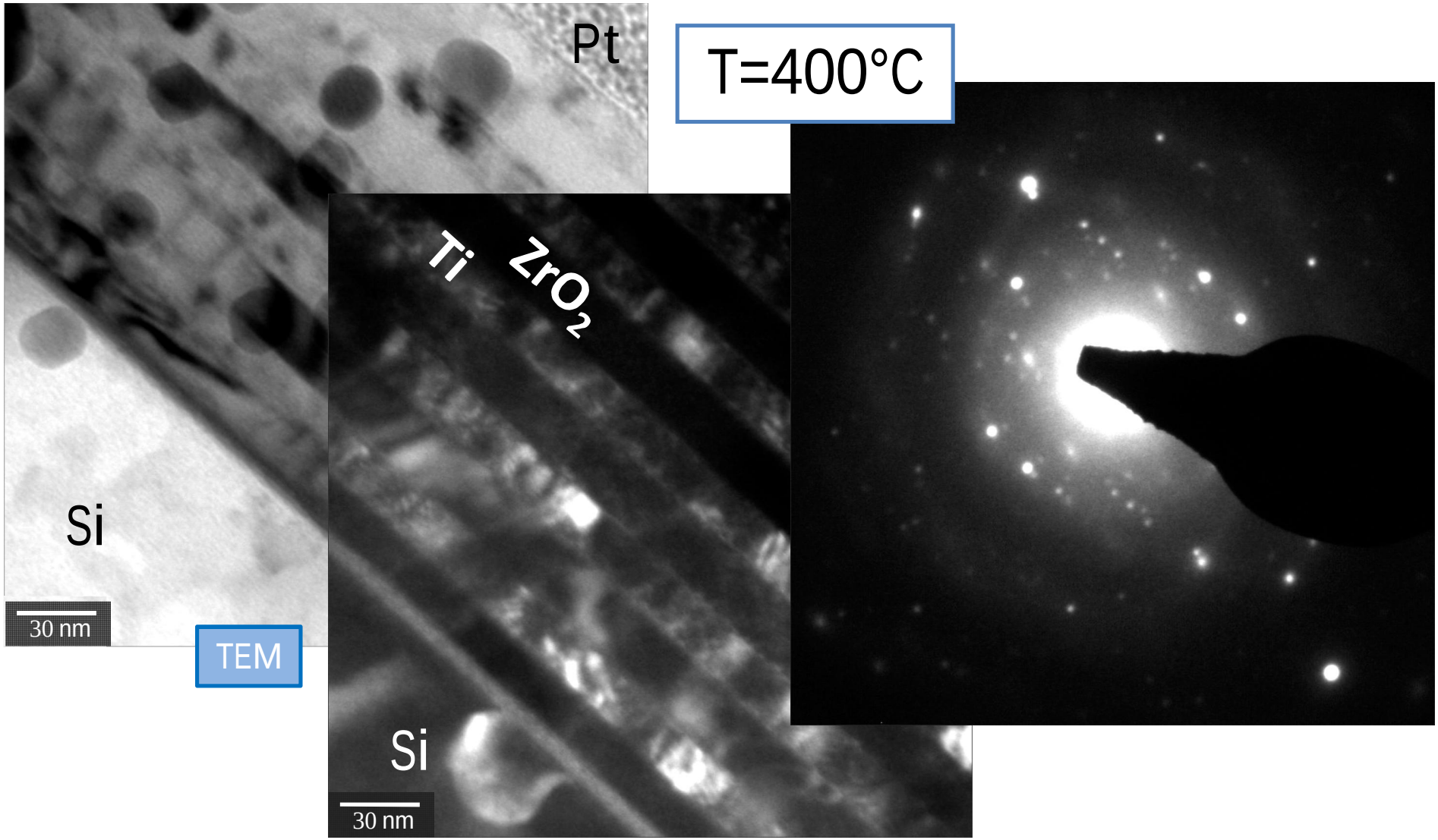


change of lattice periodicity
reduction of ZrO_2
oxidation of Ti

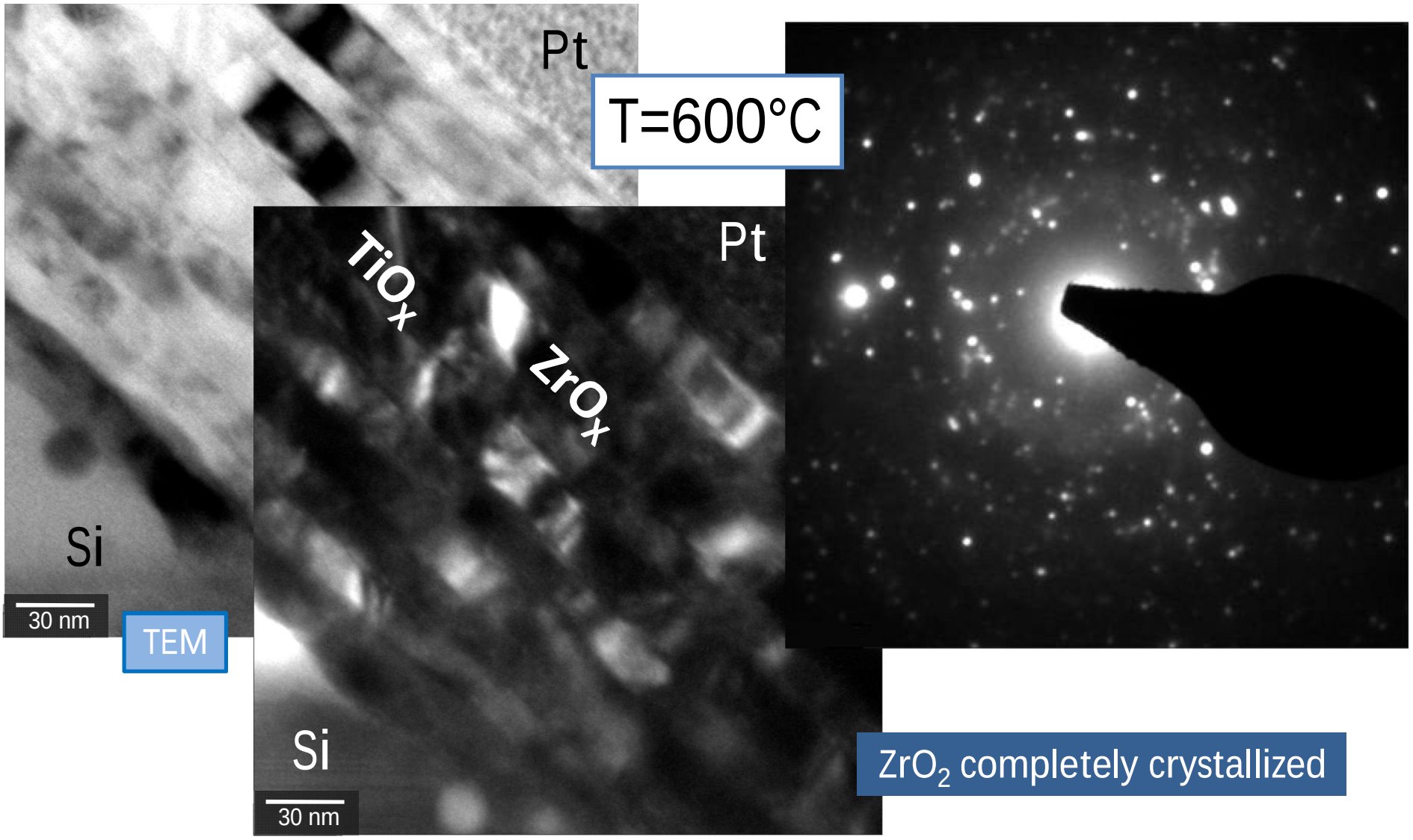
Heating of ZrO_2/Ti multilayers



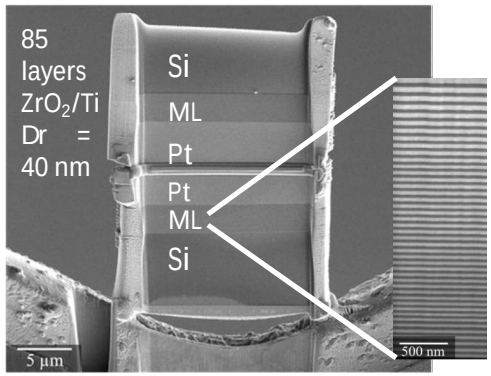
Changes during heating



Inner morphology after annealing



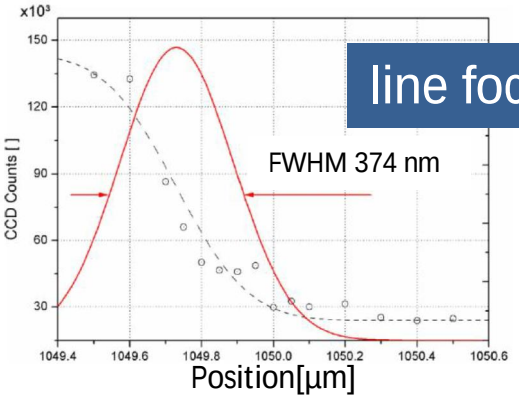
Multilayer Laue Lens

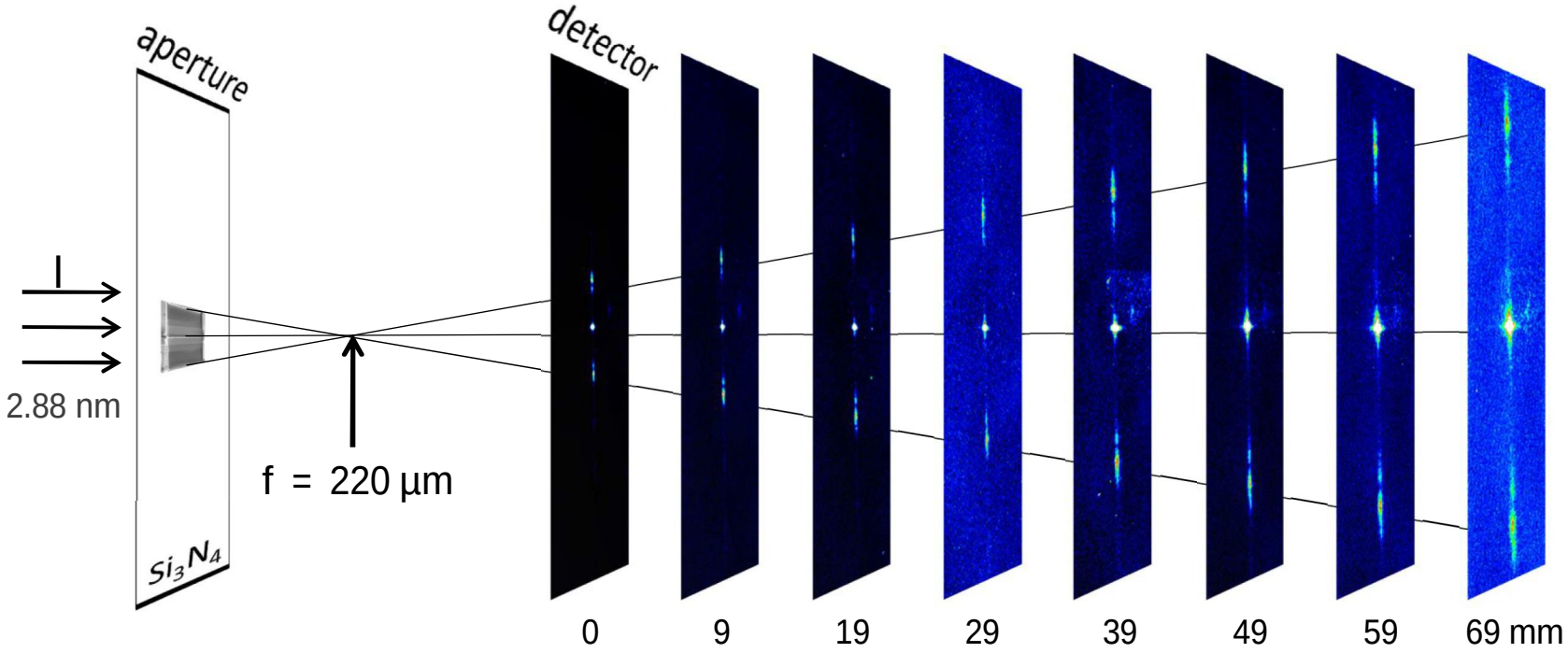


zone plate law

$$r_n = \sqrt{n\lambda f + \frac{n^2\lambda^2}{4}}$$

line focus





Liese, Radisch & Krebs *Rev. Sci. Instrum.* 81, 073710 (2010)
Reese *et al. Appl. Phys. A* 102, 85 (2011)

Multilayer Zone Plate (W/Si)