Insitu stress measurement of thin film and multilayer growth

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Introduction

- Thin film growth is often accompanied by a strain induced surface stress depending on material, growth mode, deposition conditions, etc.
- Macroscopic deformation of EUV optics occurs due to thin film growth stress, including interface formation stress

→In-situ stress measurements can give more insight in the physics of layer growth

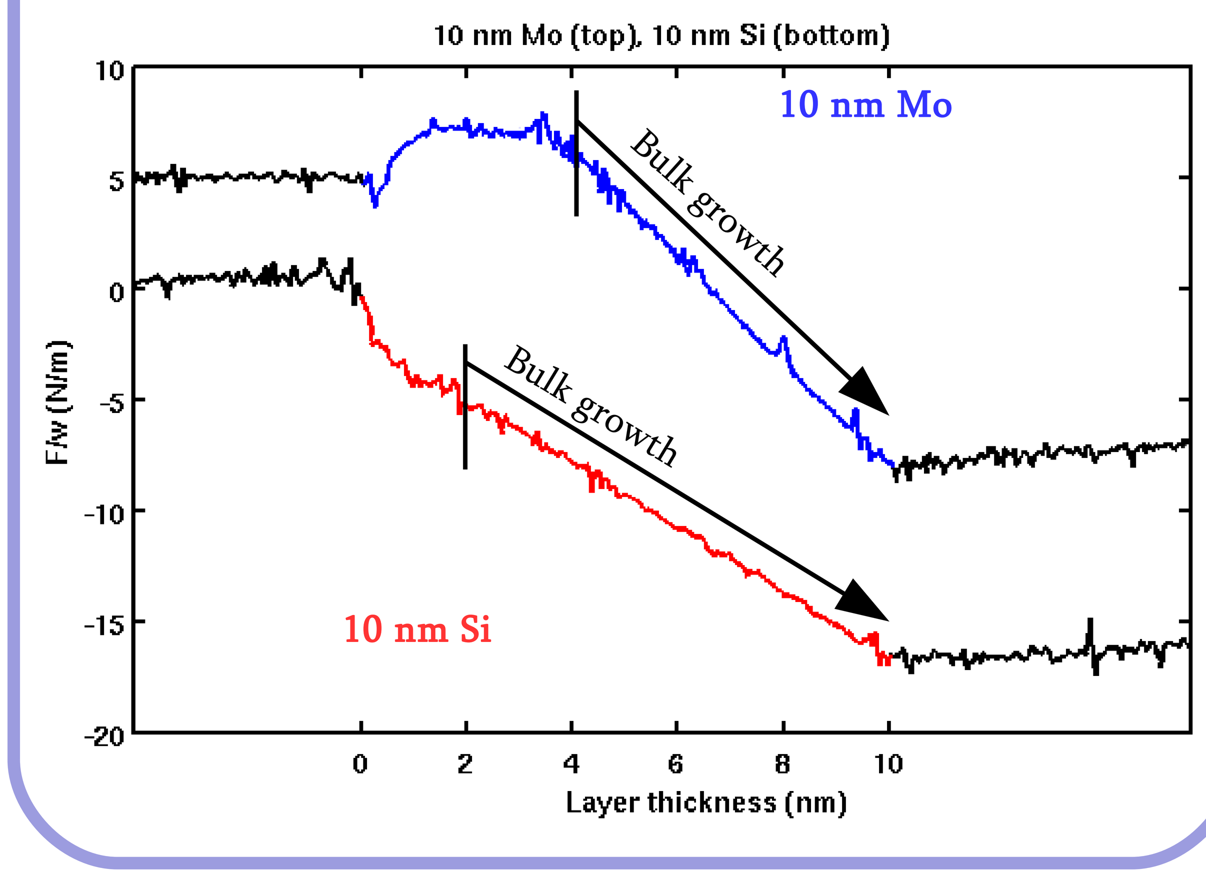
Stoney's equation relates substrate curvature 1/R to stress σ (N/m²). More convenient is the force per unit width F/w = σh (N/m), which is independent of layer thickness h.

$$\sigma h = \frac{E_s h_s^2}{6(1-\nu_s)}\left(\frac{1}{R}-\frac{1}{R_0}\right)$$

E_s: Young's modulus
h_s: substrate thickness
ν_s: Poisson ratio

Bulk Growth

After initial thin film effects the bulk growth sets in. Particles arrive at the substrate with high energy due to the magnetron sputtering process, causing implantation resulting in compressive stress. Stress development is comparable to literature[1].

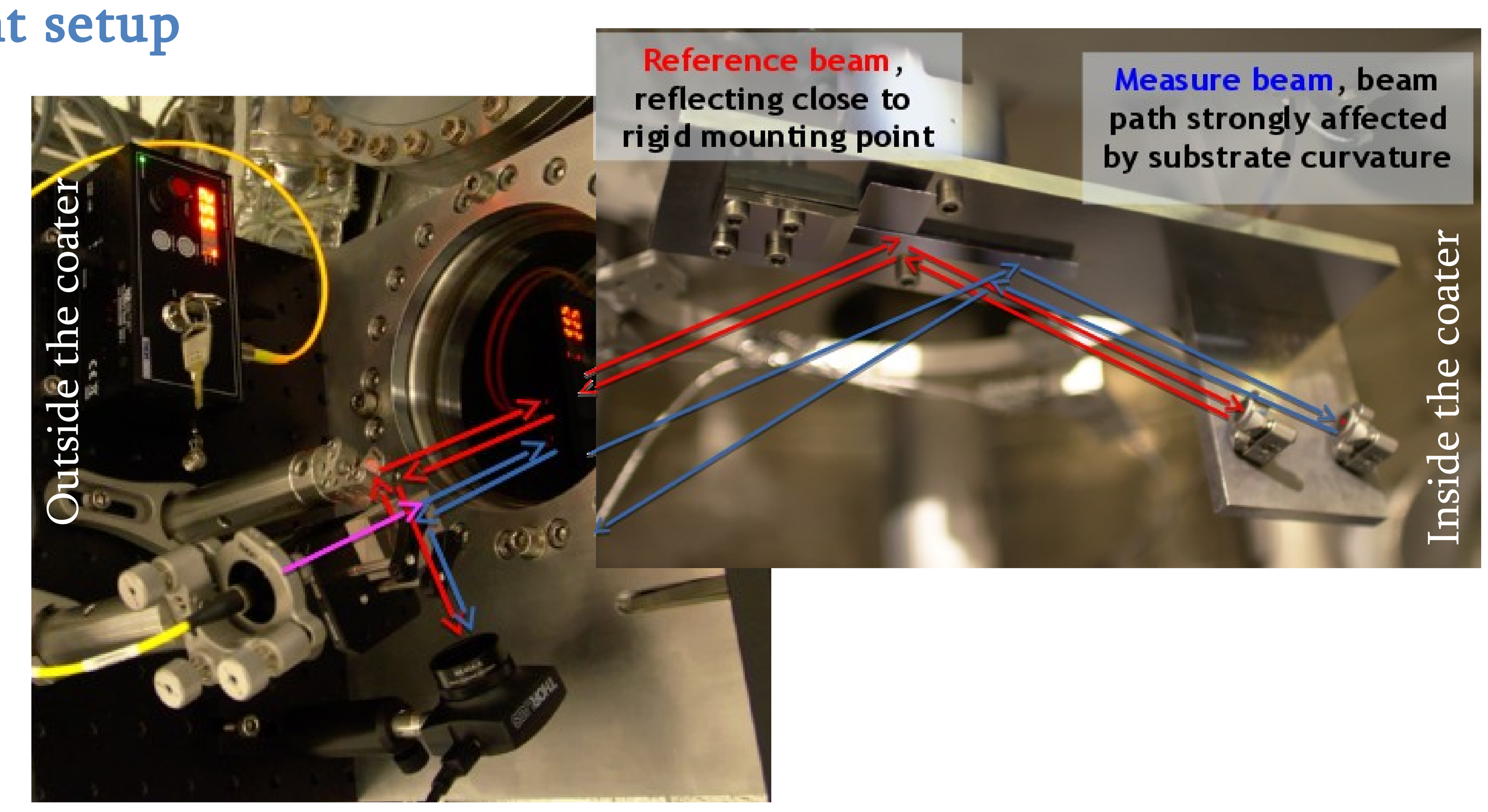


In-situ measurement setup

Dual beam laser deflectometer: beam separation on camera is proportional to curvature of cantilever

Optical measurement not disturbed by magnetron sputter deposition process, enabling in-situ measurement

Ex-situ white-light interferometry (WLI) used for calibration.

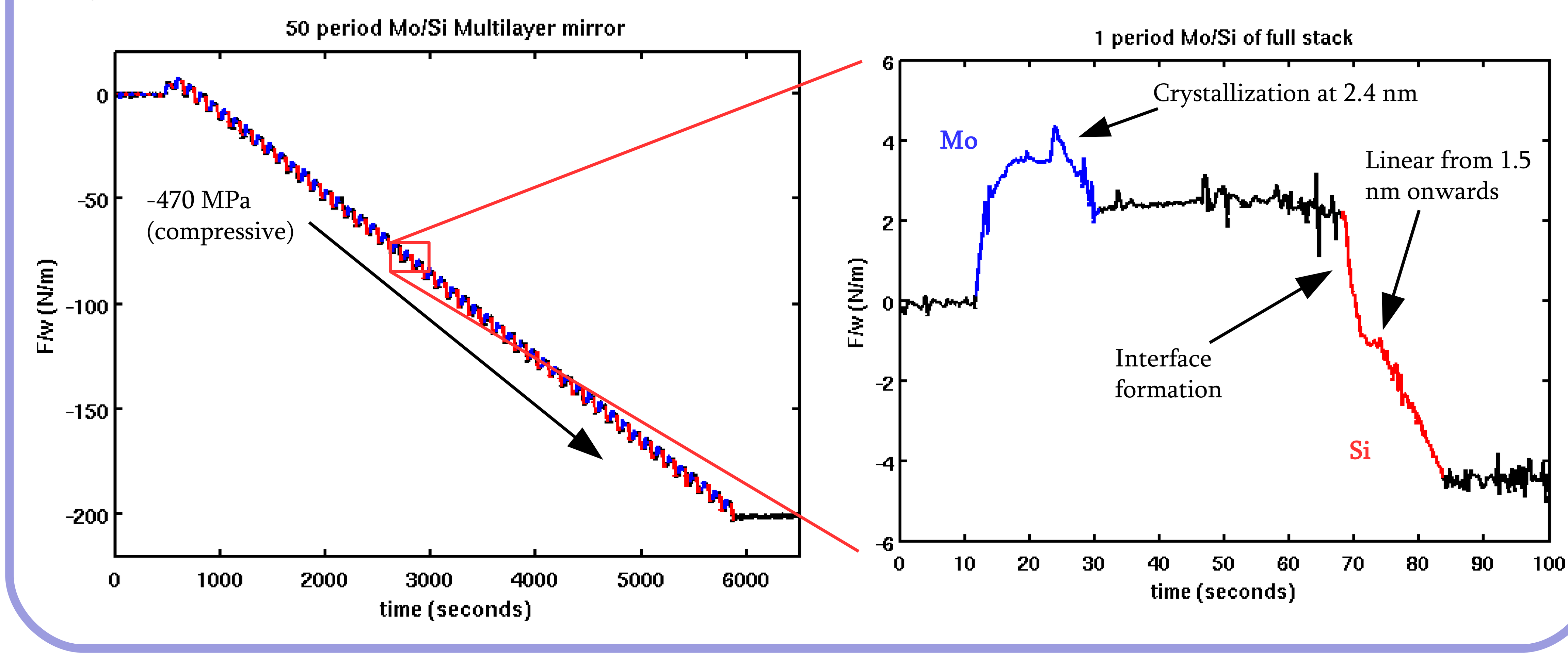


Mo/Si Multilayer system

Mo/Si multilayer (ML) mirrors are commonly used in EUV photolithography

- 7 nm period, 3nm Mo, 4nm Si. 50 bilayers, 350 nm total thickness
- Stress development linear for whole multilayer stack. Total stress (470 MPa) calibrated by WLI
- Mo crystallization allows atoms to assume efficient stacking, creating tensile stress
- Si on Mo interface compressive as MoSi2 formation on the Mo crystalline surface wants to expand.

Sub-angstrom resolution measurement reveals growth details on interface formation and crystallization

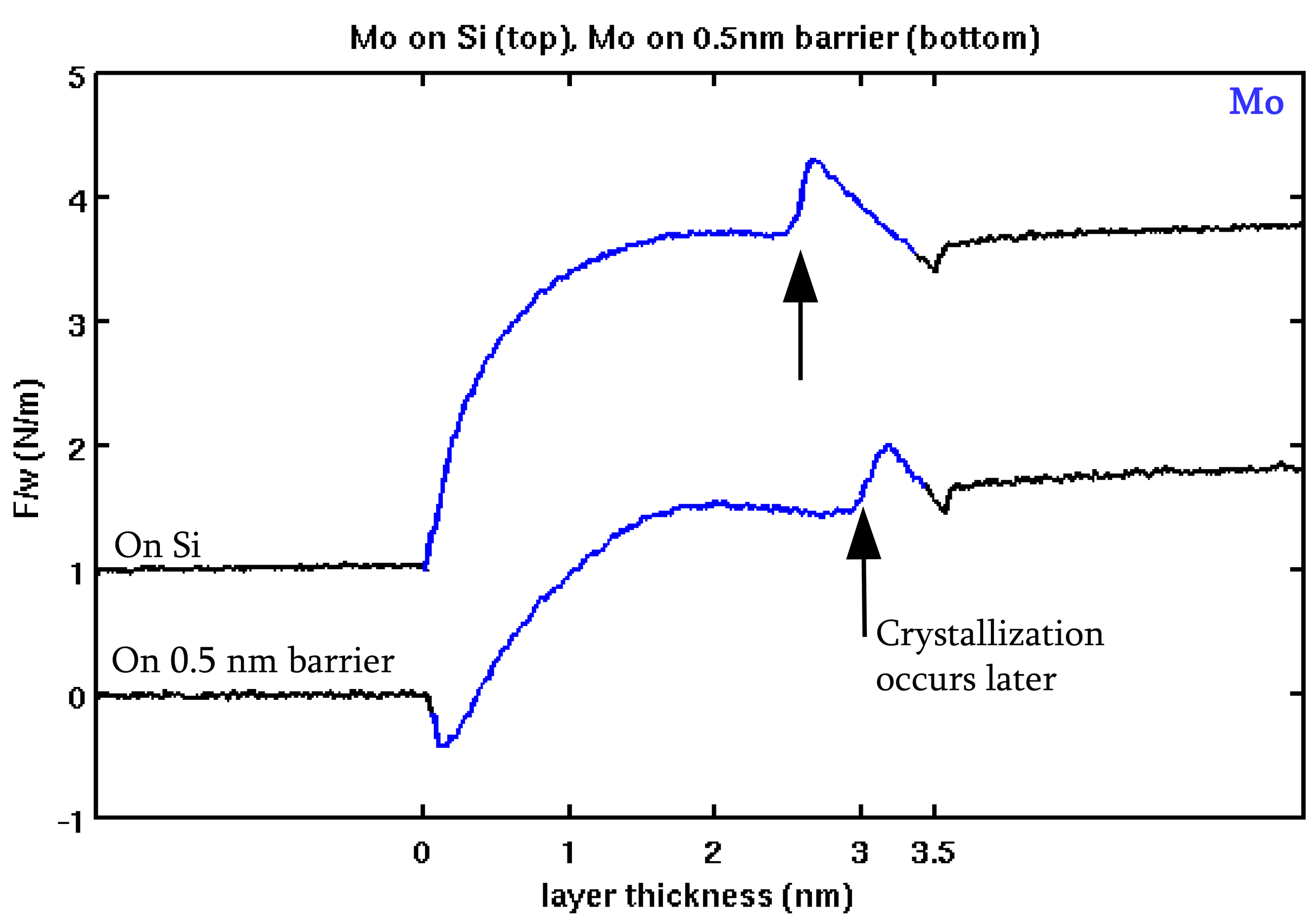


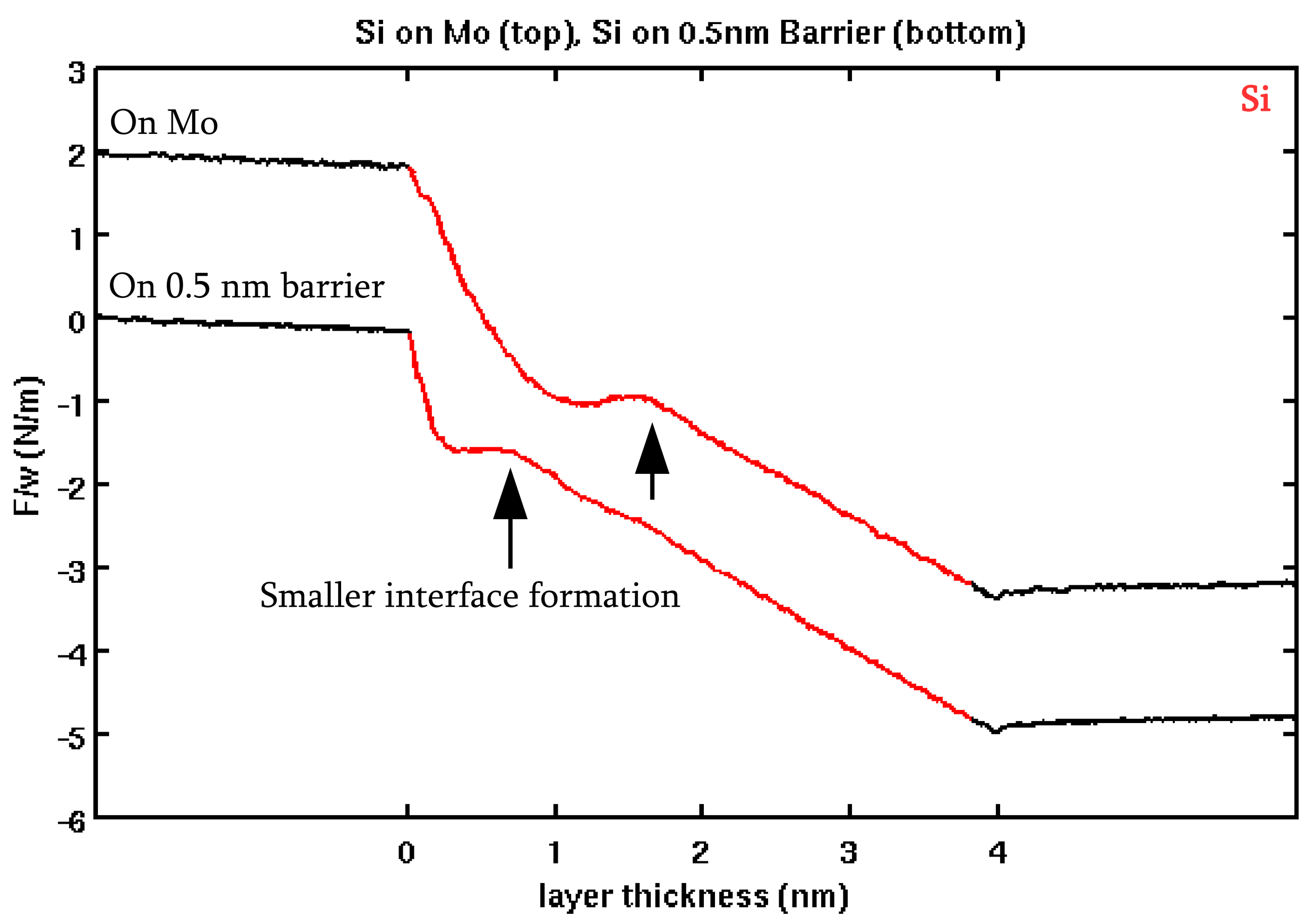
Interface engineering

0.5 nm Barrier layer deposited between depositing Mo and Si.

- Barrier layer atoms diffuse into Mo for Mo-on-barrier-on-si, delaying crystallization and changing stress (2.6 N/m to 1.7 N/m)
- Si-on-barrier-on-Mo layer shows smaller interface layer due to less MoSi2 formation, reducing layer intermixing.

→Effects of thin barrier layer measurable and identifiable





Conclusions

- Stress development can be measured with sub-angstrom precision:
- Interface formation stress reveals reduced interface formation on barrier layer
- Crystallization of Mo on barrier layer delayed due to barrier layers atoms diffusing into Mo

Acknowledgements

Industrial Focus Group XUV Optics at the MESA+ Institute at the University of Twente, industrial partners: ASML, Carl Zeiss SMT GmbH, PANalytical, SolMates, TNO, and Demcon, as well as the Province of Overijssel and the Foundation FOM.

Literature

1. J.M. Freitag, B.M. Clemens, Appl. Phys. Lett. 73, 1998, p.43