
Thin film fabrication technologies

MSE-465

Lecturer:

Johann Michler, Empa



WELCOME

Prof. Dr Johann Michler
Empa, Materials Science and Technology, Thun, Switzerland



CV

Prof. Dr. Johann Michler

Education:

1999 **Ph.D.** thesis at the Department of Materials Science, Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland

1995 **Dipl.-Ing.** (Engineering Diploma), in **Materials Science** at the Technical University of Erlangen-Nürnberg, Germany



Positions:

since 2007 Head of „Laboratory for Mechanics of Materials and Nanostructures“ at Empa, Thun

Entrepreneur:

2020 Co-founder of spin-off, **SwissCluster AG** (thin film deposition equipment)

2010 Co-founder of spin-off, **Eleoss GmbH** (watch components via UV-LIGA and electroplating)

2007 Co-founder of spin-off, **Alemnis AG** (micromechanical test equipment)

Laboratory for Mechanics of Materials and Nanostructures



Lab head – J. Michler

3 Scientists – I. Utke, X. Maeder, J. Schwiedrzik

2 Technical staff

21 non-permanents post-docs and scientists

7 PhD students

4 Thun site administration

~40 FTE

TT

Start-ups (~100 FTE, >50 PhDs)

Mostly active in the academic market for scientific instruments & deposition equipment

TOFWERK

Time-of-Flight Mass Spectrometry

alemiss

engineering your ideas

Swiss Cluster

Amanuensis

Mate Expert

ELEFOSS

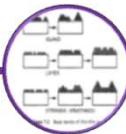
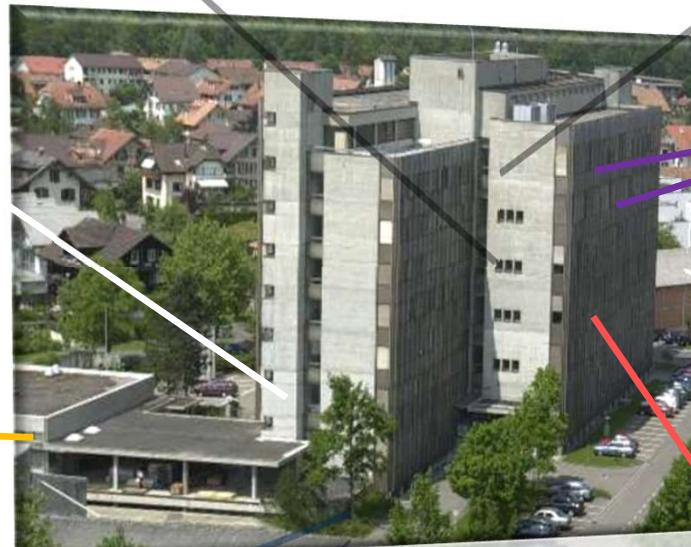
serving your science

infrastructure



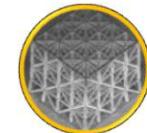
Nanomechanics labs

Nanoindenter, -in-situ SEM tester, HT mechanics
HT Tribom., Env. Tribom, industrial Tribom



Thin film deposition labs

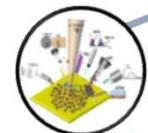
Galvano, PVD, ALD



Clean rooms

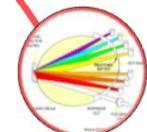
Class 10000/ Iso 7, +/-0.5°

2 Photon lithography, Laser litho, UV lithography



Microscopy labs

Cs-cor. TEM, SEMs, FIBs with EBSD, EDS, EDX, Tof-Sims, XRF, μ -Raman, AFM's



Chemical & Microstructure analysis labs

GDOES, XRD, XRF, TOFSIMS, Raman, FTIR, DTA, Metallography, optical spectroscopy
RBS, LA-ICMPS (Empa central, start-ups etc.)

Course roadmap

Statistical physics?

Components of deposition equipment?

What happens at the surface, in the plasma?

Interactions with substrate and between sublayers?

Plasmas

How does a film grow?

Tools we need to analyse and understand our films?

Sputtering

Ion bombardment

Interdiffusion and surface reactions & plasma etching and microfabrication

Vacuum Science

Nucleation & Dewetting
Epitaxy
Film Structure

Characterisation methods (optical, X-ray, ion beam,....)

Materials Science Basics

PVD
ALD
CVD
Metal coatings
Hard ceramic and C-based coatings

Electrical, optical and magnetic properties
Other functional properties?

Evaporation

Major coating types and how are they deposited?

Accelerated materials discovery?

Do we all start from the same level?

Further major deposition technologies?

Mechanical Properties

Simples way to deposit a thin film?

Why coatings don't stick or fail under loading?

outline of the course

Wednesday I

Introduction & overview

Review of required elements of Materials Science

Vacuum Science

Evaporation

Wednesday II

Discharges and Plasmas

Sputtering and Ion bombardment

Plasma and Ion beam processing

Wednesday III

Chemical Vapor Deposition

Atomic Layer Deposition

Wednesday April IV

Diamond and amorphous carbon

Nucleation & Dewetting

Epitaxy

Every 2 weeks
4 x 45min

outline of the course

Wednesday May V

Film Structure

Residual Stresses in Thin Films

Wednesday May VI

Mechanical Properties & Tribology

Hard Coatings

Wednesday June VII

Outlook on selected topics:

- Combinatorial deposition & optical properties
- advanced (surface) analytical and techniques
- interdiffusion and surface reactions
- dry etching and deposition on 3D surfaces
- in-situ characterisation methods

(Virtual) laboratory tour @ Empa

Questions and Answers

Format of lectures

Lecture series numbering:



100 Introduction



110 Course roadmap and motivation



120 Review of Materials Science



130 Vacuum Science questions

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Lecture:

- all recorded mpeg format & pdf slide printout (length of videos are not 45min as the life lectures as they are compiled per topic and don't include breaks)
- table of content, lecture, summary, questions as support for exam preparation and solutions will be provided at the end of the course
- 1-2 slides virtual company visit or interview (if applicable; not exam relevant)

Exam: Oral exam

introductory books - references

Main reference:

Ohring 2002: Ohring Milton (2002) Materials Science of Thin Films, Deposition and Structure, 2nd edition, 2002, San Diego: Academic Press

Other references:

Smith 1995: Smith Donald L (1997) Thin-Film Deposition - Principles and Practice, New York: McGraw-Hill

Kääriäinen 2013, Tommi Kääriäinen, David Cameron, Marja-Leena Kääriäinen, and Arthur Sherman (2013) Atomic Layer Deposition - Principles, Characteristics, and Nanotechnology Applications, Wiley, Scrivener Publishing LLC

Pohl 2020, U.W.Pohl, Epitaxy of Semiconductors, Springer

Machlin 2005: Eugene Machlin (2005) Materials Science in Microelectronics I - The Relationships Between Thin Film Processing and Structure, 2nd edition., Morgan Kaufmann

Schultrich 2018: Bernt Schultrich (2018) Tetrahedrally Bonded Amorphous Carbon Films I - Basics, Structure and Preparation, Springer Series in Materials Science 263, Springer-Verlag GmbH Germany

Mitterer 2014: Christian Mitterer (2014) PVD and CVD Hard Coatings, in: Reference Module in Materials Science and Materials Engineering, Comprehensive Hard Materials Volume 2, 2014, Pages 449 - 467, Elsevier

introductory books - references

Rostislav 2013: Rostislav Daniel, Jindrich Musil (2013) Novel Nanocomposite Coatings - Advances and Industrial Applications, CRC Press, Taylor & Francis Group

Nix W.D. (2014) Metallic thin films: stresses and mechanical properties, in: Metallic Films for Electronic, Optical and Magnetic Applications: Structure, Processing and Properties, Woodhead Publishing Limited, p353-421

Madou M.J. (2012) Fundamentals of Microfabrication and Nanotechnology, Three-Volume Set, CRC Press Taylor & Francis Group, Boca Raton

Harsha K.S.S. (2005) Principles of Vapor Deposition of Thin Films, Elsevier Science, Amsterdam

Blasek G. (2010) Vakuum - Plasma - Technologien, Beschichtung und Modifizierung von Oberflächen, EUGEN G. LEUZE VERLAG KG , BAD SAULGAU

Mattox D.M. (2010) Handbook of Physical Vapor Deposition (PVD) Processing, William Andrew (Elsevier), Oxford

Jousten K (2016) Handbook of Vacuum Technology, Wiley-VCH Verlag GmbH & Co., Weinheim

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