Master's Degree Program in Micro and Nanotechnology according to the Bologna Agreement

A collaborative International Network for Applied Research between Education and Industry in the Euregio Bodensee

Euregio Bodensee

Micro and
Nanotechnology Network (MNT)

Fachhochschule Vorarlberg

NTB
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FÜR TECHNIK BUCHS

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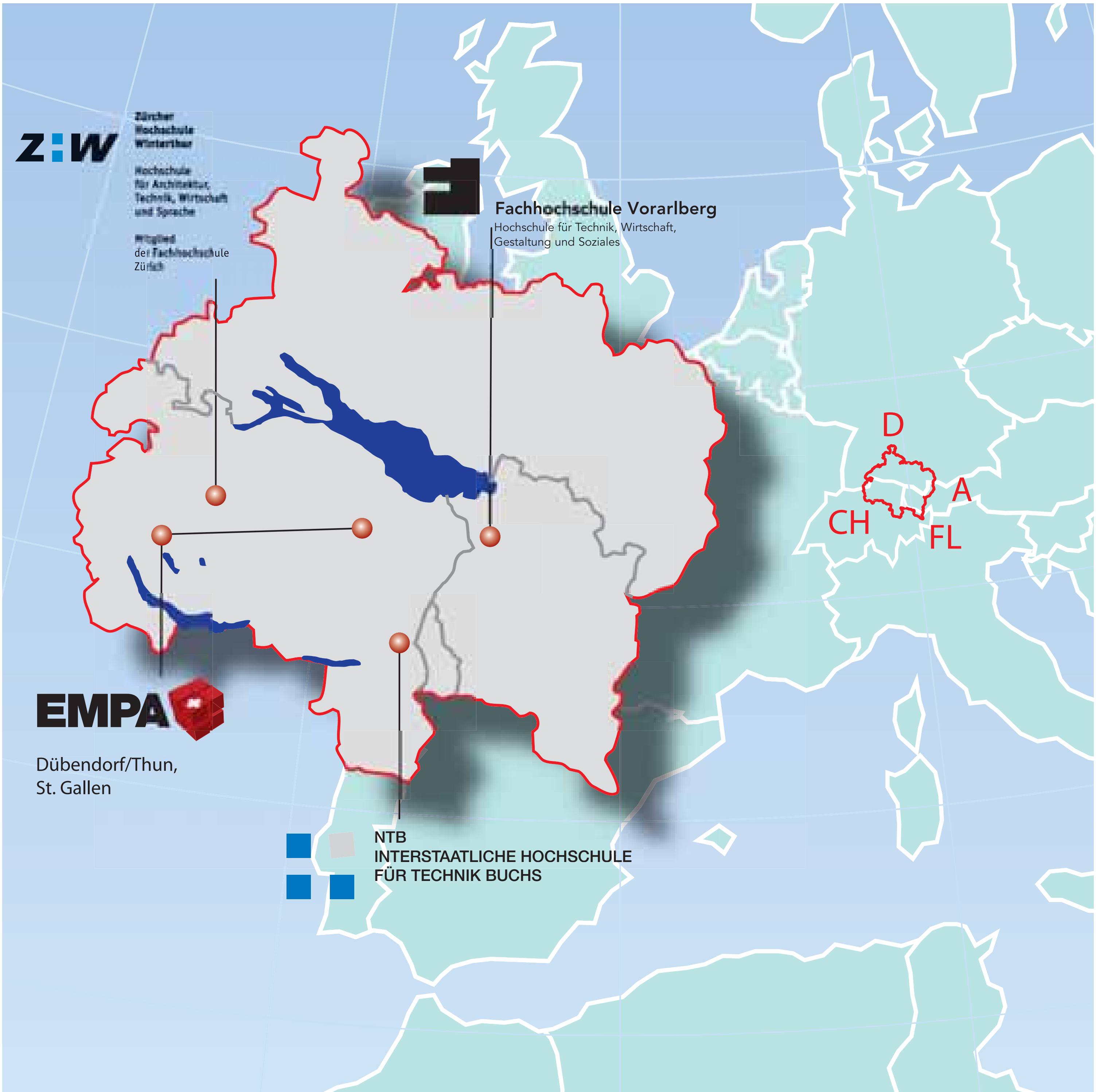
Technik, Wirtschaft
und Sprache

EMPA



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The international network for micro and nanotechnologies is a cooperative venture between four established Universities of Applied Sciences and research institutions in the Euregio Bodensee: Vorarlberg University of Applied Sciences (FHV), Interstate University of Applied Sciences of Technology Buchs (NTB), Zurich University of Applied Sciences Winterthur (ZHW), and the Swiss Federal Laboratories for Materials Testing and Research (EMPA), which is the ETH (Swiss Federal Institute of Technology Zurich) domain's institution for multidisciplinary research into sustainable materials and systems engineering.

The members of this network support open and international cooperation in a Europe of regions. Their aim is the sustainable development of future-oriented micro and nanotechnologies and their industrial use of such technologies. With partners in business and industry, they contribute their expertise and resources as well as their connections to joint research projects.

Being also aware of their responsibility to pass on new technologies to the people of the region and to future generations, these four institutions are planning to establish a joint continuing education program for engineers: an in-depth postgraduate master’s degree in micro and nanotechnology and its applications, which allows graduates to combine their traditional engineering knowledge and skills with new technologies.

By encouraging and enabling their engineers to participate in this master’s degree program, companies profit in many ways. For example, degree program students and graduates contribute to the renewal of a company’s current product portfolio, which improves a company’s long-term market position. Companies benefit from the synergy between study and research and business and industry. In their master’s theses, students investigate an applied research problem at their companies.

For a region in which reliable precision work is not only seen as part of that region’s tradition but also its future, this combination of traditional engineering and new technologies ensures an almost unbeatable advantage for the region.

This folder provides a brief introduction to this joint degree program, whose course modules — in accordance with the research focus of the four institutions — are taught at the different campuses. The degree program conforms to the Bologna Agreement, and the degree of «Master of Science» is conferred on graduates.

We look forward to hearing from you and would like to invite you to join us on a journey into the fascinating worlds of micro and nanotechnologies.

1. Introduction / Technology

Prerequisite: Bachelor Diploma in a technical discipline

Goals

A Review of Materials Science
Structure
Defects in Solids
Bonds and Bands in Materials
Thermodynamics of Materials
Kinetics
Nucleation
An Introduction to Mechanical Behavior

Chapter 1
Contents

PVD-Coatings

Thin-Film Evaporation Processes
The Physics and Chemistry of Evaporation
Film Thickness Uniformity and Purity
Evaporation Hardware
Evaporation Processes and Applications
Discharges, Plasmas, and Ion-Surface Interactions
Plasmas, Discharges, and Arcs
Fundamentals of Plasma Physics
Reactions in Plasmas
Ion Bombardment Modification of Growing Films
Plasma and Ion Beam Processing of Thin Films
DC, AC, and Reactive Sputtering Processes
Magnetron Sputtering
Plasma Etching
Hybrid and Modified PVD Processes

Chapter 2
Contents

CVD-Coatings

Chemical Vapor Deposition
Reaction Types
Thermodynamics of CVD
Gas Transport
Film Growth Kinetics
Thermal CVD Processes
Plasma-Enhanced CVD Processes
Some CVD Materials Issues
Substrate Surfaces and Thin-Film Nucleation
An Atomic View of Substrate Surfaces
Thermodynamic Aspects of Nucleation
Kinetic Processes in Nucleation and Growth
Experimental Studies of Nucleation and Growth

Lead	Language
NTB	German or English

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Chapter 3

Contents

Special Technologies

Epitaxy

Manifestations of Epitaxy
Lattice Misfit and Defects in Epitaxial Films
Epitaxy of Compound Semiconductors
High-Temperature Methods for Depositing Epitaxial
Semiconductor Films
Low-Temperature Methods for Depositing Epitaxial Semiconductor Films
Mechanisms and Characterization of Epitaxial Film Growth

Laser

Nanomaterials

Electroforming

Synchrotron

LIGA / UV LIGA

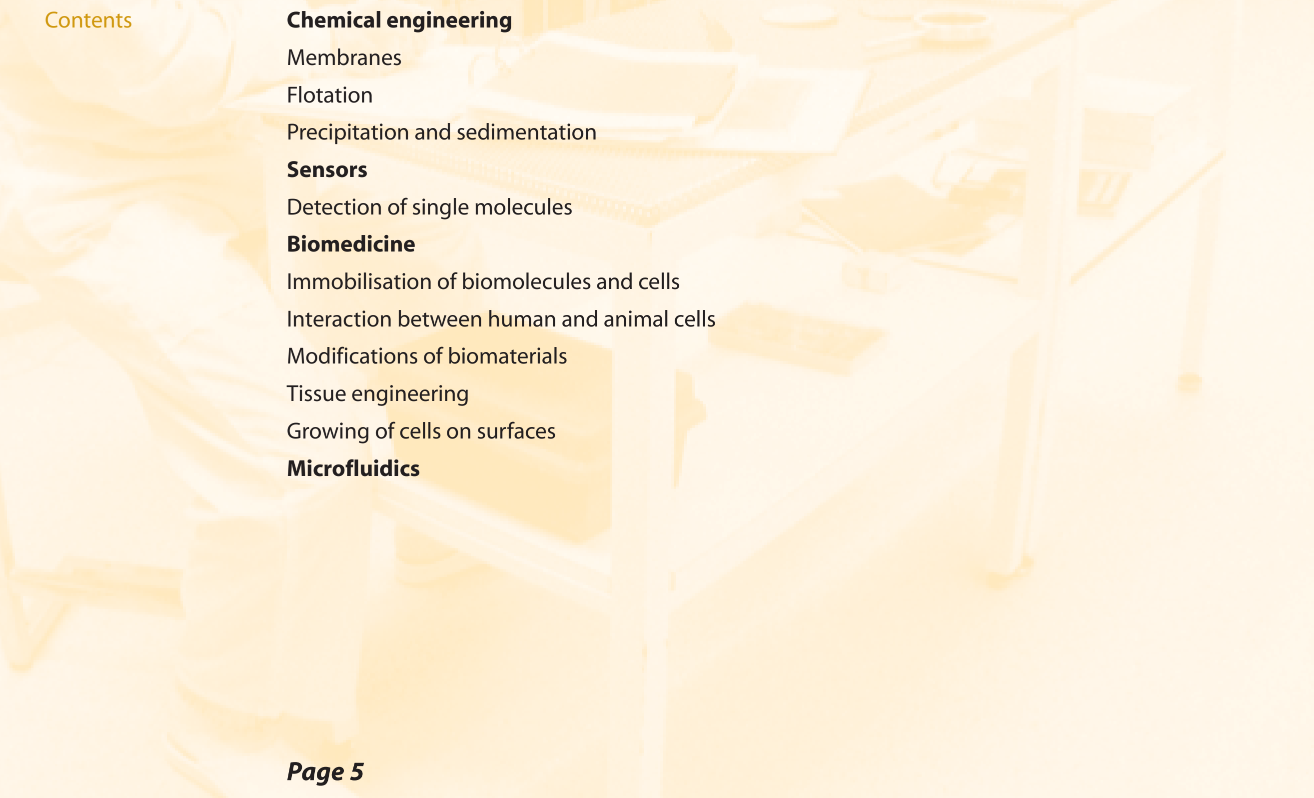
LIGA
Design rules for UV LIGA
Sacrificial technology for LIGA
Multilayer technology

Replication

Tool fabrication
RT casting
UV-Casting
Hot embossing
Injection moulding

Chapter 4

Contents



Selected technical applications

Chemical engineering

Membranes
Flotation
Precipitation and sedimentation

Sensors

Detection of single molecules

Biomedicine

Immobilisation of biomolecules and cells
Interaction between human and animal cells
Modifications of biomaterials
Tissue engineering
Growing of cells on surfaces

Microfluidics

2. Nano Measuring Techniques

Prerequisite

Bachelor Diploma in a technical discipline

Goals

Detailed description of the instrumentation used in the nanometer range. For each techniques, theory, application and practical training will be given
This lecture aims to provide a good understanding of AFM instrumentation in order for the potential AFM user to get rid of most of the common artifacts and to acquire reproducible and meaningful data

Chapter 1
Contents

Electron Microscopy and Chemical Analysis

1. Scanning Electron Microscopy (SEM): operation modes
2. Environmental Scanning Electron Microscope (ESEM)
3. Scanning Transmission Microscopy (TEM): Instrumentation & operation modes
4. Spatial resolved chemical analysis with EM: ESD, EELS

Chapter 2
Contents

Scanning Tunneling Microscopy (STM)

1. STM principle & tunnel effect
2. STM instrumentation: Piezoelectric materials, tunnel current pre-amplification, scanner linearization (hard- & software), VT-STM, LT-STM, STM in liquids & electrolytes
3. Applications: Surface reconstruction, epitaxial growth, molecular self-assembly, magnetic domains, oxidation & corrosion
4. Scanning Tunneling Spectroscopy (STS): Local density of states (LDOS)

Chapter 3
Contents

Scanning Force Microscopy (AFM)

1. AFM principles & interatomic forces
2. Cantilever's geometry, spring constant, resonance frequency, fabrication
3. AFM modes: Contact, non-contact, magnetic-force
4. Detection modes: optical, capacitance, strain gauge
5. Feedback loop & electronics: Amplitude & phase detection

Measuring physical properties with AFM

6. Lateral Force Microscopy (LFM): Tribology
7. Force Modulation Microscopy (FMM): Composites materials
8. Magnetic Force Microscopy (MFM): Superconductivity, magnetic domains (data storage media)
9. Eelectrical Force Microscopy (EFM): Electrical conductivity imaging, Ex. conductive polymers
10. Scanning Thermal Microscopy (SthM): Thermal conductivity imaging, Ex. Polymerblends
11. Force Distance Curves: Surface Forces, Polymer- & Protein-folding

Chapter 4
Contents

Lateral Resolved Chemical Surface Analysis

1. Electron Spectroscopy (ES): XPS, AES, principles
2. Auger Electron Microscopy
3. Photo-Electron Emission Microscopy (PEEM)
4. Time off Flight Secondary Ion Mass Spectroscopy (TOF-SIMS)

Lead	Language
EMPA	Lecture: English

Chapter 5

X-Ray analysis

Contents

1. High Resolution X-Ray Diffraction (HRXRD): Concept of reciprocal lattice/peak
2. Broadening
3. Experimental situation in HRXRD to determine
4. Determination of average crystallite size, strains and tilts parallel and perpendicular to a growth surface
5. Texture determination
6. Crystalline defects

Chapter 6

Micro- & Nano-mechanics

Contents

Understand nanomechanical properties of surfaces
learn to execute correctly and to interpret nanoindentation measurements of nanomechanical properties.

1. Micro- & Nano- mechanical properties
2. Nano-indentation: principle and relation; hardness, friction coefficient and strain-stress relation measurements
3. Relation nano-mechanics and friction

Chapter 7

Nanopositioning und -manipulation

Contents

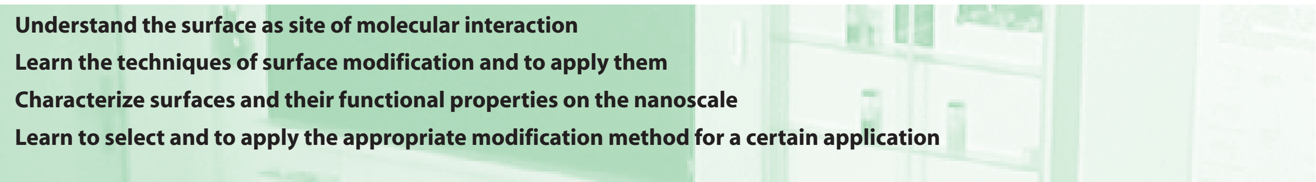
1. Focused Ion Beam: Principle, SEM & TEM-sample preparation, nano-structuring,
2. Lithography
3. Electron- & ion-beam deposition
4. Nano-positioning (micro-robotic)

3. Functional Surfaces

Prerequisite

Bachelor Diploma in a technical discipline

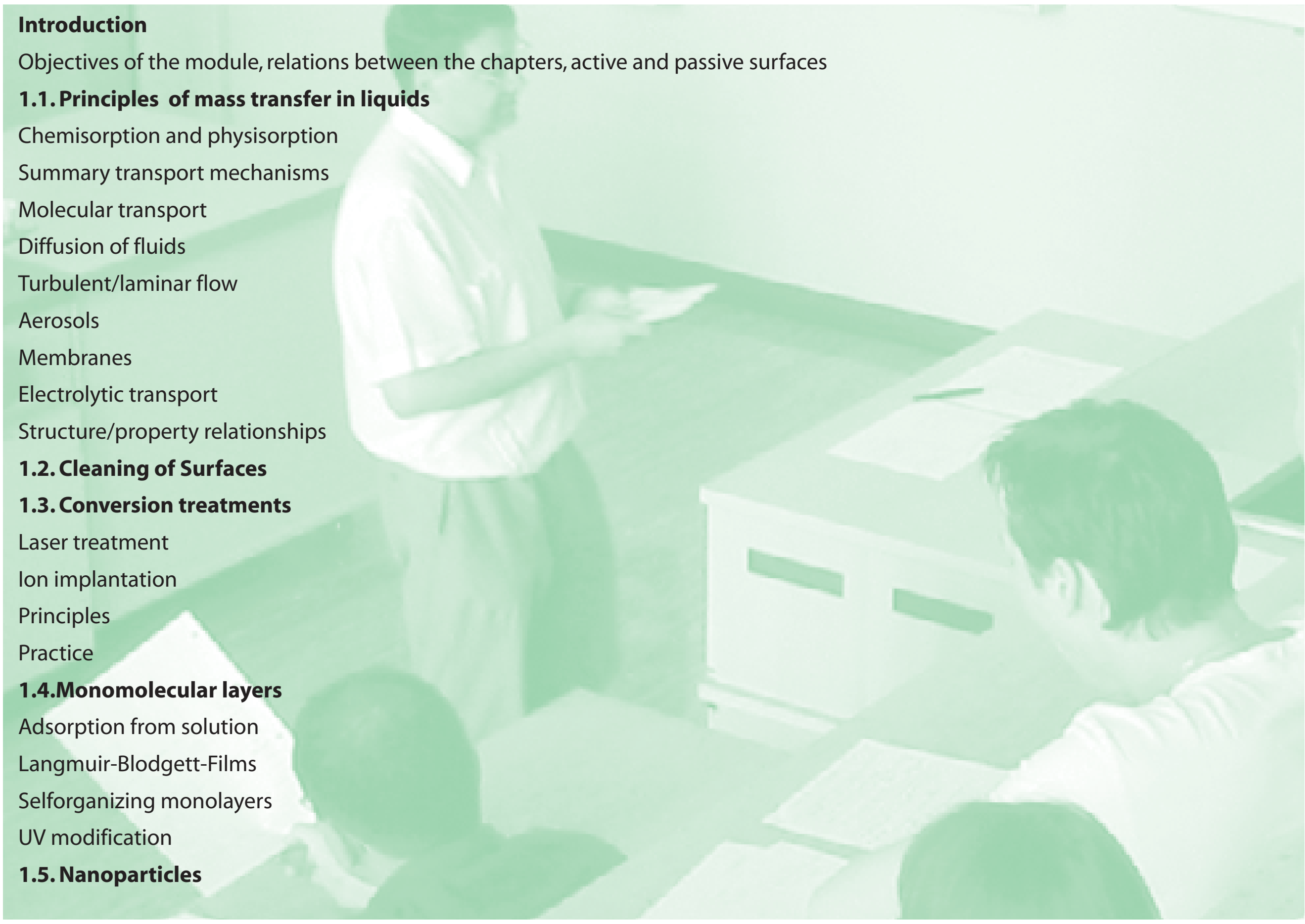
Goals



Understand the surface as site of molecular interaction
Learn the techniques of surface modification and to apply them
Characterize surfaces and their functional properties on the nanoscale
Learn to select and to apply the appropriate modification method for a certain application

Chapter 1
Contents

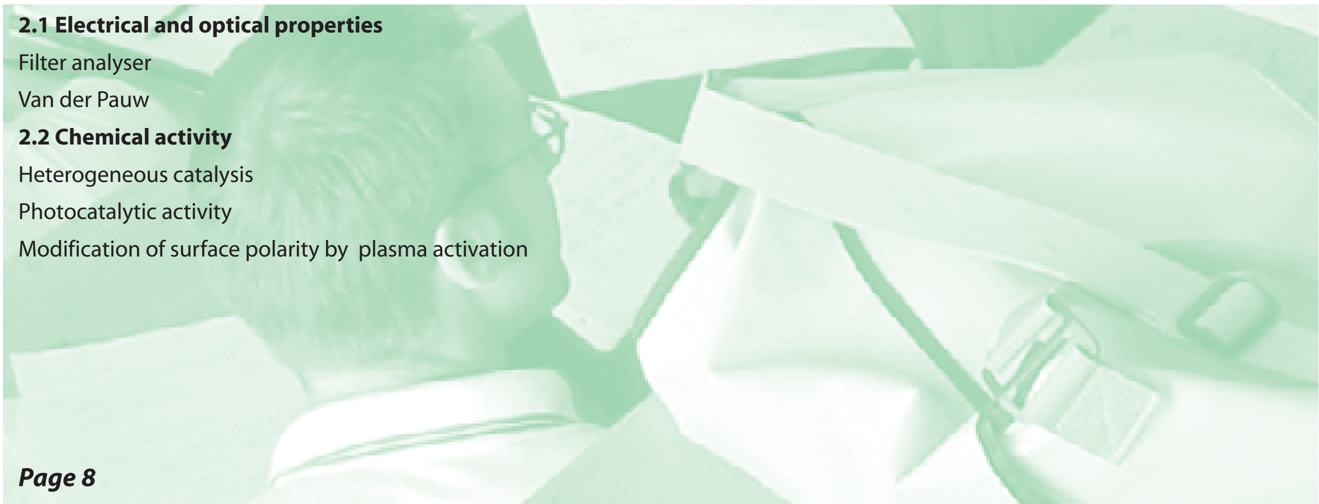
Functionalization of surfaces



Introduction
Objectives of the module, relations between the chapters, active and passive surfaces
1.1. Principles of mass transfer in liquids
Chemisorption and physisorption
Summary transport mechanisms
Molecular transport
Diffusion of fluids
Turbulent/laminar flow
Aerosols
Membranes
Electrolytic transport
Structure/property relationships
1.2. Cleaning of Surfaces
1.3. Conversion treatments
Laser treatment
Ion implantation
Principles
Practice
1.4. Monomolecular layers
Adsorption from solution
Langmuir-Blodgett-Films
Selforganizing monolayers
UV modification
1.5. Nanoparticles

Chapter 2
Contents

Functional Characterization



2.1 Electrical and optical properties
Filter analyser
Van der Pauw
2.2 Chemical activity
Heterogeneous catalysis
Photocatalytic activity
Modification of surface polarity by plasma activation

Lead	Language
ZHW	English or German

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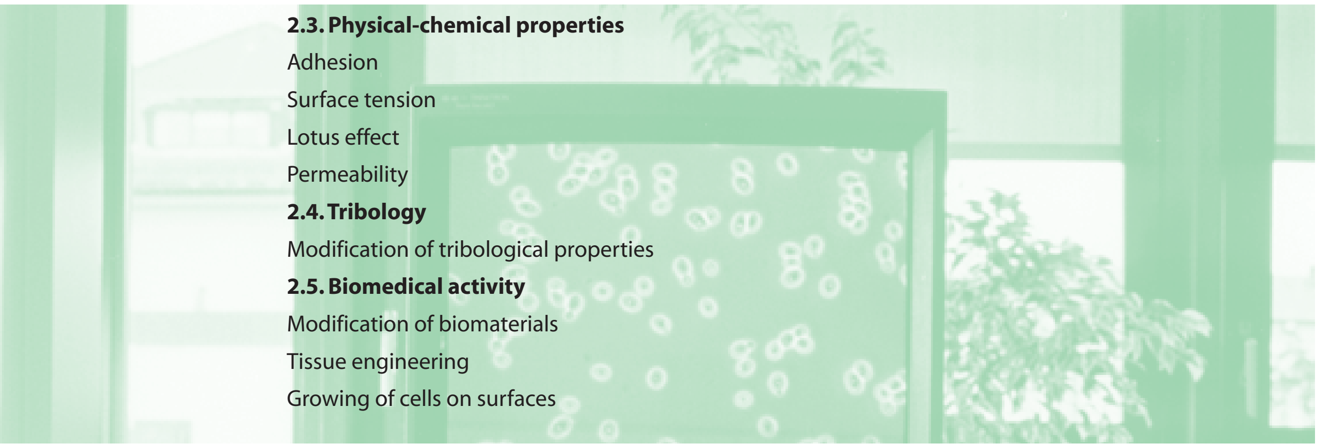


2.3. Physical-chemical properties

Adhesion
Surface tension
Lotus effect
Permeability

2.4. Tribology

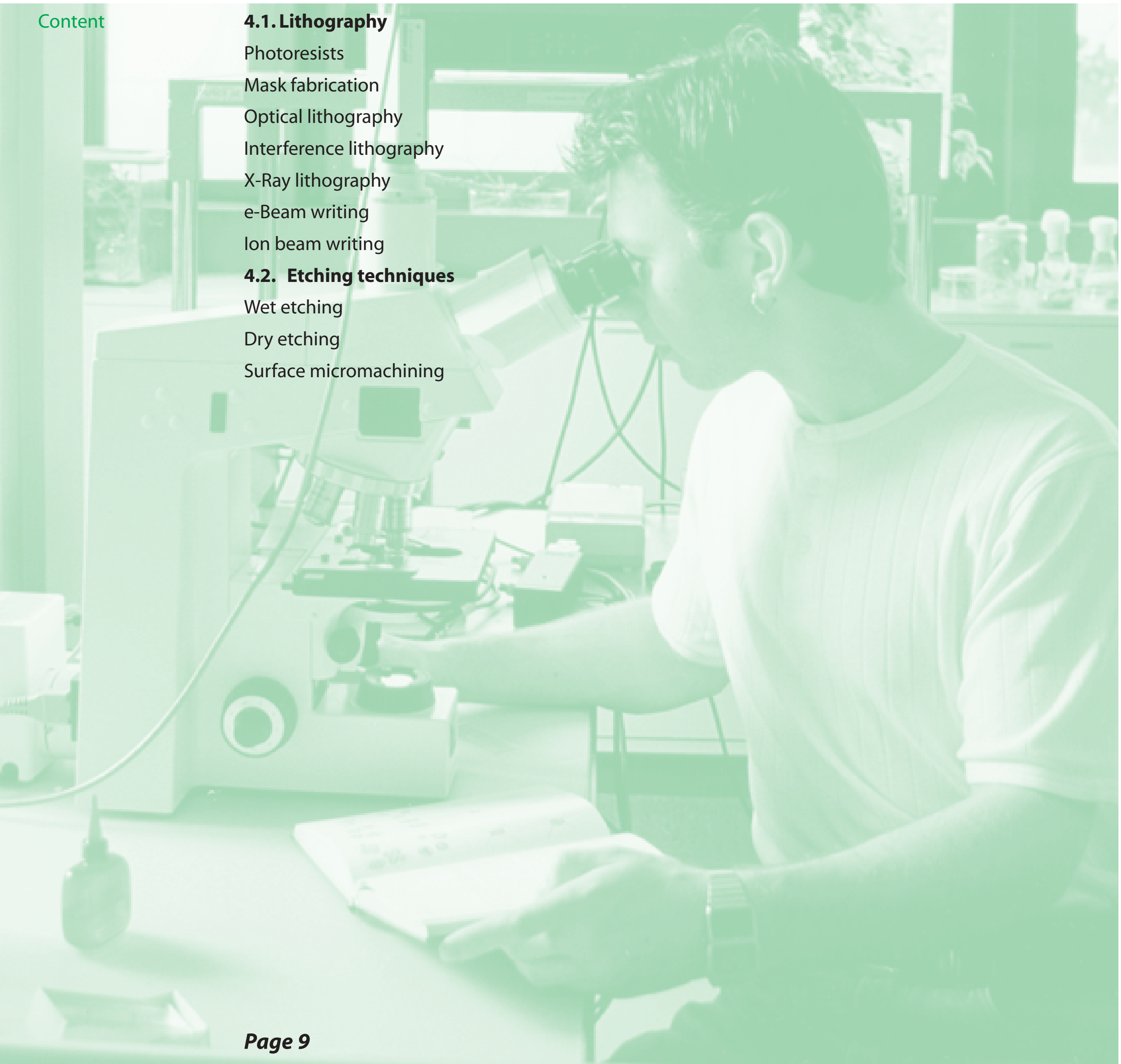
Modification of tribological properties

2.5. Biomedical activity

Modification of biomaterials
Tissue engineering
Growing of cells on surfaces

Chapter 3
Content

4. Topographical structures



4.1. Lithography

Photoresists
Mask fabrication
Optical lithography
Interference lithography
X-Ray lithography
e-Beam writing
Ion beam writing

4.2. Etching techniques

Wet etching
Dry etching
Surface micromachining

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4. Components, Systems and Design for Micro and Nanotechnology

Prerequisite

Bachelor Diploma in a technical discipline

Goals

Engineering methods for MNT
Computer Aided Engineering
System integration
Nanopositioning
Nanomanipulation
Packaging

Simulation and Optimization
Methods of numerical simulation and optimization
Design tools
Sensor and actuator modeling and validation

Production methods for MNT systems and modules
Technical and economic aspects

Chapter 1
Contents

Sensors and Actuators

1.1. Sensor principles and applications
Capacitive
Piezoresistive
Piezoelectric
Thermal (also for Position)
Optical
Chemical
Biological

1.2. Actuator principles and applications
Electrostatical
Elektrodynamical
Thermal
Piezoelectrical
Chemical
SMA

Chapter 2
Contents

Fibres, planar waveguides and micro optics

Motivation - the role of optics in micro technology
Integrated optics - planer waveguide technology
Guiding properties of waveguides
Optical fibre technology
Integrated planer waveguides
Material systems for integrated optics
Waveguide design and fabrication

Lead
FH Vorarlberg

Language
German or English

Loss considerations
Absorption mechanisms
Coupling losses
Packaging concepts for planar waveguides
Basic modules for integrated optical circuits
Micro optics
Design of refractive and diffractive micro lenses
Manufacturing processes for binary optics
Manufacturing processes for free form lens shapes
Replication technologies
Actual research and development (examples)

Chapter 3
Contents

System integration

2.1. Processdesign of Microsystems

Thinking in a multilayer planar layout
Batchprocessing
Top down and Bottom-Up procedures of integration
Integration of Micro mechanics, microelectronics and micro optics
Bipolar Processes
CMOS Processes
Compatibility

2.2. Packing: Construction and bonding techniques

Wafer level Integration

Design of Bonds
Eutectical Bonding
Anodic Bonding
Silicon direct Bonding
Bonding by glueing, soldering

Hybrid integration

Diebonding
Wirebonding
TAB-Technique and Flip-Chip-Technique
Polymers, mainly adhesive in construction and connection technology
Interfaces to the outside world, standardization of packaging
Thermo mechanical stress, /FEM simulation and tools
Automation (incl. Robotics and tools)

2.3. Electronic circuits

Sensor readout
Interfaces

4. Components, Systems and Design for Micro and Nanotechnology

Chapter 4

Contents

Design in Micro- and Nanosystemstechnology

Design process

Methods and tools for process, device, network, logic and system simulation

Mapping physical effects to RLC-type network models

Conservation laws and constitutive equations

Numerical discretisation methods for field problems (Finite Element Method, box method, etc.)

CAE software tools and limitations (Matlab/Simulink, NMSESES, ANSYS), functionality, program interfaces, pre- and postprocessing

Coupling types (domain coupling, boundary coupling, bi- and unidirectional coupling, algorithmic implementation)

Requirements with respect to packaging (system integration), classification of the effects for sensors/actuators

Model validation

Optimization algorithms and tools, application-specific algorithms with implementation in an open simulation environment

Chapter 5

Contents

CAE MNT Lab Course

Computer simulation lab on sensor and actuator applications and students projects (in collaboration with industry) with a finite element software tool:

1. Optical design of thin film structures
2. Laser material processing
3. Microfluidics (sensors, mixers etc.)
4. MEMS (electrostatic microrelais, cantilever structures, etc.)
5. Piezosensors and -actuators
6. Organic electronics (OLEDs, OFETs)

Validation of numerical model calculations with experimental data

Lead	Language
FH Vorarlberg	German or English

Chapter 6

Sensors for Nanopositioning

Contents

1. Physical Effects

Hysteresis of piezoactutators (characterization:
strech measurement tates and STM)
Voice-Coil actuators with friction
Interferometry for optical positinierung

2. Measurement and Control

Sensors fo nanopositioning (capacitive, inductive, optical)
Quantization errors, measurement and actuator noise
Control loop aspects (bandwidth, resolution, sampling frequency, positioning and measurement speed ...)
Electronic aspects (requirements for the electronics: processor power, interfaces and resolution, temporal aspects, communication)

3. Contactless Measurement Methods

Eddy current sensors
Capacitive proximity sensors
Optical triangulation method with PSDs / with CCDs
Positional interferometrty
Velocity interferometry with short coherence lengths
Modulation and demodulation methods
Temperature compensation
Scaling
Compensation of Nonlineartities
High-resolution A/D converters

Fachhochschule Vorarlberg

Research Focus – Vorarlberg University of Applied Sciences

Main R&D Topics:

- UV and Deep-UV Lithography
- Microplating
- Microstructuring using Excimer and Solid-State Lasers
- LIGA-Technology
- SEM incl. EDX
- Microassembly
- Sensors and Actuators

Services:

- Scanning Electron Microscopy
- Lithography
- Laserablation

NTB
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Research Focus of the Institute for Microsystems (IμS)

Main R&D Topics:

- Development of new Coating Process Technologies for electronic and MEMS devices
- Industrialization of new Process Technologies
- X-Ray Structure and Defect Analysis (HRXRD, XRD, XRF)
- Advanced Packaging Technologies
- Integrated Optics like Sensors and Telecommunication Systems for Space Application

Services:

- Structure and Defect Analysis (HRXRD, XRD, XRF)
- Surface Analysis (AFM, NCAFM, STM, SEM, Optical Microscopy)
- Micromechanical Analysis (e.g. Nanoindentation)
- Courses on Coating Technology and Customer Specific Workshops
- Support for production setup
- Feasibility studies

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Zürich

Research Focus at Zurich University of Applied Sciences Winterthur in Micro and Nanotechnology

Main R&D Topics:

- Surface modifications: e. g. metals, glasses, silicon wafers, ceramics, textiles, plastics
- Tissue engineering: colonization of porous biomaterials and surfaces with cells and tissues
- Development of flow measurement systems based on microelectrodes and microelectrode arrays
- Computer Aided Engineering based development of integrated sensors and actuators
- Coupled electrothermomechanical finite element analysis of MEMS and microfluidic systems
- Design of optical thin film structures and organic semiconductor devices using numerical simulation tools

Services:

- Problem solution for coating with the objectives: adhesion, protection, lubrification, nanostructuring
- Investigation of biocompatibility and bioconductivity
- Numerical modelling and simulation of device characteristics

EMPA

Research Focus at Empa in Micro and Nanotechnology

Main R&D Topics:

- Powder Technology
- Micro and Nanomechanics
- Thin Film Technology
- Molecular Self-Assembly
- Molecular Electronics
- Electron Emisson from Carbon Nanotubes
- Reliability and Failure Analysis of Microelectronic Circuits
- Materials and Tissues for Medicine
- Biomimetic Engineering

Services:

- Micromechanical Analysis (e.g. Nanoindentation)
- Structure and Defect Analysis (FIB, TEM, HRXRD, XRD)
- Surface Analysis (AFM/STM, ESEM/SEM, Optical Microscopy)
- Chemical Surface Analysis (XPS, Auger, TOF SIMS, GDOS)
- X-Ray Tomographic Microscopy (at SLS/PSI)
- Ceramic Processing
- Empa Academy (Workshops, Seminars)

Contact

Euregio Bodensee
Micro and
Nanotechnology Network (MNT)

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Aktualisierter Nachdruck Herbst 2004. 09 600 Ex.