Title: Laser micro-processing and surface functionalization

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Coordinator: Prof. Gustavo Pino

1) Background

This course is dedicated to all students working in the field of Chemistry, Physics, Material Science, Technology and/or Surface Engineering and related fields.

2) Objectives

The students will learn about basic interactions of laser light with materials as well as on different laser based technologies, which are used today for functionalizing surfaces. The course includes basics aspects of laser processing (e.g. light-matter interaction) and also different technological aspects which are relevant when selecting for instance a laser source to treat a specific material as well as the possible processing speeds and cost that are associated. At the end of the course, the students will have the necessary tools which are necessary for selecting a laser base microfabrication method for surface functionalization.

3) Program

Chapter 1 - Motivation: Why do we deal with laser precision microfabrication?; Properties of surfaces; Surface structures that can be produced by laser precision microfabrication; Morphology changes induced by laser beams; Surface topography characterization; Bionic prototypes for 2D microstructures; Bionic prototypes for 3D microstructures; Micro- and/or nano fabrication methods; Advantages of laser precision microfabrication.

Chapter 2 - Introduction to lasers/types of lasers: Definition of “Laser”; Outline history of the development of the LASER; Fields of Application of Laser Material Processing; Peculiarities of laser radiation; The population inversion; The laser source; Lasers for microprocessing; Operation modes; Parameters defining laser; Calculation of laser parameters; Defining a laser system; Specifications of typical lasers; Overview of laser machining processes; Main components of a laser beam system.

Chapter 3 - Material-light interaction and temperature distribution: Excitation Mechanisms; Thermal and photochemical processes; Absorption, Reflection and Transmission; Reflection of metals; Optical penetration depth in metals; Reflection dependence on polarization and inclination angle; Calculation of light reflection; Optical response in non-metals; Influence of pulse duration on laser ablation process; Interaction of laser light with polymers; Calculation of temperature distributions.

Chapter 4 - Direct Laser Writing and Laser drilling: Direct Laser Writing principle; Focusing of laser beams; Diffraction limit; Aberration limit; Sample scanning techniques; Cartesian axis; 2D-beam deflection; Applications of DLW; Laser drilling methods; Drilling techniques without relative movement between laser spot and workpiece; Single shot (or pulse) drilling; Percussion drilling; Drilling techniques with relative movement between laser spot and workpiece; Trepanning drilling; Helical drilling; Influence of process parameters on drill hole quality.

Chapter 5 - Direct Laser Interference Patterning: Interference methods; Direct Laser Interference Patterning; Principle of DLIP and laboratory setup; Structuring of polymers using ns-DLIP; Structuring of metals; Structuring of conducting polymers thin films; Interference Lithography; Fabrication of 2D, 2,5D and 3D patterns; Fabrication of sub-μm channels; Application examples; Development of DLIP Systems.

Chapter 6 - Two Photon polymerization and stereolithography: basic principle of 2PP; Elements of two-photon polymerization; Lasers for two-photon polymerization; Materials for photopolymerization; Optical configurations for 2PP; The fabrication process; Voxel creation and control; Application examples; Challenges for 2PP in production; Definition and principle of operation in SLA; Modes of operation; Available systems for SLA; Micro-stereolithography; Applications of SLA and μSLA; Comparison of μSTL with 2PP.

Chapter 7 - Laser Induced Periodic Surface Structures: Introduction; What are LIPSS?; Types of LIPSS; Analyzing and characterizing LIPSS; Formation mechanism of LIPSS; Applications of LIPSS; Last developments on LIPSS.

Chapter 8 - Polygon scanner processing: Polygon scanning principle; Geometric polygon errors/position accuracy; Principles of polygon scanner micro processing; Factors limiting high-speed laser micro processing; System comparison; Applications of polygon scanners; New concepts for high throughput processing.

Chapter 9 - Laser Safety: Laser-tissue interaction; Absorption of laser radiation by the human; Cooking with laser light; Absorption of laser by the eye; Laser pointers; Summary of absorption by the eye and the skin; Laser exposure limits; Hazard potential of laser equipment; Laser safety goals and industrial realization.

4) Evaluation Methodology

Final examination test

5) Bibliography

Material will provided by the chair.

Demonstration videos will offered to the participants.

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20 h in total

Lessons Plan		Total	
1	Motivation	1.5 h	1.5 h
2	Introduction to lasers/types of lasers	1.5 h	3.0 h
3	Material-light interaction and temperature distribution	1.5 h	4.5 h
4	(4a) Direct Laser Writing (DLW) (4b) Laser drilling	1.5 h	6.0 h
5	Direct Laser Interference Patterning (DLIP, LIL)	1.5 h	7.5 h
6	Two Photon polymerization (2PP) and stereo lithography	1.5 h	9.0 h
7	Laser Induced Periodic Surface Structures methods (LIPSS)	1.5 h	10.5 h
8	Polygon scanner processing	1.5 h	12 h
9	Laser Safety	1.5 h	13.5 h
10.	Seminar 1: Basic calculations and Material – light interaction	1.5 h	15 h
11.	Seminar 2: Temperature distribution calculations	1.5 h	16.5 h
12.	Seminar 3: FEM simulation of laser pulse interaction	2.0 h	18.5 h
13.	Consultation/reserved slot	1.5 h	20 h