COURSE DESCRIPTION

name	**Superconductive materials**
shortname/ abbr.	**SCM**
course objectives	**see in syllabus (Knowledge, Competences)**
description	**see in syllabus**
target students	**bachelor, master, Ph.D. students**
intro	**see in syllabus**
developed by	**Technical University Berlin, Institute for semiconducting- and high-frequency technologies (HFT)**
evaluation	**see in syllabus**

Syllabus
"Superconductive materials"

Course topic

A both, theoretical- and practice- oriented course, for understanding modern thin film (mostly from metal oxide materials) techniques which are broadly used in energy saving technologies.

Number of credits

3 ECTS

Course responsible

Technical University Berlin
Dr. Ruslan Muydinov

Course lecturers

Dr. Ruslan Muydinov

Prerequisites

General interest in material engineering, chemistry and physics. Knowledge of solid-state chemistry/physics, material science and first experience in instrumental analytics (mostly XRD) and experience with vacuum technique are required.

Learning outcomes

Knowledge: Knowledge in the field of thin film deposition technologies; applications of HTS-wires, energy efficiency and thin film photovoltaic technologies.

Competences: Instrumental analytics in practice applied to thin films, data processing and presentation.

Abstract

The course introduces students to modern thin film techniques which are broadly used in energy saving technologies. A thin film is a layer of material ranging from fractions of a nanometer (monolayer) to several micrometers in thickness. Electronic semiconductor devices and optical coatings are the main applications benefiting from thin-film construction. A familiar application of thin films is the household mirror, which typically has a thin metal coating on the back of a sheet of glass to form a reflective interface. The process of silvering was once commonly used to produce mirrors. A very-thin-film coating (less than about 50 nanometers thick) is used to produce two-way mirrors.

The performance of optical coatings (e.g., antireflective, or AR, coatings) are typically enhanced when the thin-film coating consists of multiple layers having varying thicknesses and refractive indices. Similarly, a periodic structure of alternating thin films of different materials may collectively form a so-called superlattice which exploits the phenomenon of quantum confinement by restricting electronic phenomena to two-dimensions.

Contents

1. Overview of the film fabrication techniques.
1.1. Vacuum technique.
1.1.a. Vacuum equipment.
1.1.b. Gas dynamics, diffusion.
1.1.c. Energy of particles.
1.2. Plasma technique.
1.2.a. Equipment (generator, magnetron).
1.2.b. Plasma properties.
1.2.c. Reactive and nonreactive sputtering process.
1.3. Film growth mechanisms: thermodynamics and kinetics of the film growth resulting in different microstructures.
1.4. Overview of Plasma Deposition Methods.
1.4.a. DC/MF/RF Magnetron Sputtering.
1.4.b. Megatron, HIPIMS, other techniques.
1.5. CVD – Chemical vapor deposition.
1.5.a. CVD principles, theory.
1.5.b. Hardware of CVD (evaporation systems, hot wall, cold wall reactors, R2R).
1.5.c. Examples of CVD processes, industrial use.
1.5.d. PECVD (plasma enhanced CVD), APCVD (atmospheric pressure CVD), water assisted CVD.
1.6. Overview of other vacuum methods.
1.6.a. PLD (pulsed laser deposition).
1.6.b. Texture generating methods: ISD (inclined substrate deposition), IBAD (ion beam assisted deposition).
1.6.c. ALD (atomic layer deposition).
1.7. Overview of some wet-chemical methods (sol-gel, spray pyrolysis, ink-jet printing, spin-coating, dip-coating).

2. Overview of some important instrumental analytics for thin films.
2.1. XRD (X-Ray Diffraction).2.1.a. Texture analysis, determination of sizes of coherent scattering areas.
2.1.b. Determination of stresses in the film.
2.1.c. Determination of crystalline, polycrystalline and amorphous parts of the film.
2.2. Electron diffraction methods: EBSD, RHEED/LEED.

2.3. Analysis of composition: EDX/EPMA, XPS.
2.4. Analysis of microstructure: SEM, AFM.

3. Superconductive wires.
3.1. Superconductivity phenomenon, history, materials.
3.2. 1st and 2nd generation (G) of high temperature superconductive (HTS) wires.
3.2.a. Comparison of superconductive materials and concepts used in 1G and 2G-HTS-wires.
3.2.b. Overview of fabrication technologies for 2G-HTSW.
3.3. Application of HTS-Wires.
3.3.a. Awaited profit, cooling systems, very future technologies.
3.3.a. Cables, FLCs (fault-current limiters).
3.3.b. Generators, motors.
3.3.c. Energy reserves, Inductive heaters.

4. Photovoltaic.
4.1. Basics and overview of existing technologies.
4.2. Main thin film technologies.
4.2.a. a-Si/μ c-Si tandem cells, structure, production.
4.2.b. CIGS based cells, structure, production.
4.2.c. TCO (transparent conductive oxides) in solar cells.
4.3. Characterization of efficiency (sun simulator, I-V curves, mapping).

5. New concepts and materials in energy saving technologies.
5.1. New concepts and materials in Photovoltaics (PV).
5.1.a. Hybrid organometallic halide perovskite absorber based PV.
5.1.b. Dye-sensitized solar cells, organic PV.
5.1.c. New concepts of batteries.
5.2. Oxide electronics: advantages, state-of-the-art.

Teaching methods

An overview of *deposition techniques (PVD, PLD, CVD, PECVD, ALD, spin-coating, dip-coating)* and *consideration of films' growth mechanisms* will be taught during the lectures. *Instrumental analytics of thin films (XRD- stresses' analysis, mechanical properties, EBSD, SEM, AFM, EDX, EPMA, XPS)* will be treated within lectures, seminars and laboratory work. In form of individual work the participants will be asked to familiarize with XRD technique and optional SEM / EDX, profilometry, AFM. *Superconductivity, HTS-wires, application* will as well be part of lectures and seminars where the participants will have the task to observe and discuss superconductivity effects. *Photovoltaic, thin film technologies (Si, CIGS)*, *dedicated instrumental analytics* will be taught in lectures, practical work and laboratory work. *New materials in energy saving technologies* such as *OPV, oxide film electronics*, etc. will be object of the lectures, seminars and practical work. In addition, the study of the theoretical material will be part of the individual work.

Evaluation/Assessment

The evaluation is based on controls that include the attendance, practical work, writing tests and oral exams and consists of the following components:

Assessment strategy	**Weight in %**	**Deadlines**	**Assessment criteria**
Running control 1	40	10th week	Attendance, practical work, writing test
Running control 2	20	14th week	Attendance, writing test
Running control 3	40	18th week	Attendance, seminar activity, oral exam

Essential reading

Author	**Year of issue**	**Title**	**Printing house ISBN**
Amit Goyal	2004	Second-generation Hts Conductors	ISBN 978-1402081187 Internet
Milton Ohring	2001	The Materials Science of Thin Films, Academic Press	ISBN: 978-0-12-524975-1 Google-Books, Elsevier
R. Martins, E. Fortunato, P. Barquinha, L. Pereira	2012	Transparent Oxide Electronics: From Materials to Devices	ISBN: 978-0-470-68373-6 Internet
Satishchandra B. Ogale	2005	Thin Films and Heterostructures for Oxide Electronics (Multifunctional Thin Film Series)	ISBN: 978-0-387-25802-7 978-0-387-26089-1 (Online) Springer Link
Karl Jousten	2008	Handbook of Vacuum Technology	ISBN 3527407235, 9783527407231 Google-Books

Recommended reading

Author	**Year of issue**	**Title**	**Printing house ISBN**
Donald L. Smith, McGraw-Hill,	1995	Thin-film deposition: principles and practise, chapter 1: thin film technology/chapter 5: deposition	0-07-058502-4
O. Brümmer, J. Heydenreich, K. H. Krebs, H. G. Schneider	1980	Festkörperanalyse mit Elektronen, Ionen und Röntgenstrahlen.	VEB Deutsche Verlag der Wissenschaften, Berlin
Durrant, Alan	2000	Quantum Physics of Matter.	CRC Press. 0750307218.