Tutorials Abstracts NNUM-2019

Analysis/Characterization, Room S010

C1: X-ray Photoelectron Spectroscopy: a powerful characterization tool in material science and biotechnology - Basic

Amin H. Zavieh, Senior Engineer, NanoLab, Norwegian University of Science and Technology

XPS, also known as electron spectroscopy for chemical analysis, is a surface-sensitive tool that provides nondestructive, quantitative and most importantly state analytical characteristics. It reveals elements as well as chemical states and binding energy shift of atoms that are suitable for through analysis of complex compositions. In this introduction, after explaining the technique, applications of XPS will be covered in different material science and biotechnology areas not limited to: Electrochemistry and corrosion, battery technology, solar cells, thin/thick films and biotechnology. The focus would be on how the XPS open the possibilities to investigate surface, depth and map elements or compositions as well as understand formation of oxides, hydroxides or other complex species.

C2: FT-IR and Raman Spectroscopies: Principles and Applications - Basic

Philip M. Weiser (University of Oslo)

Fourier Transform-infrared (FT-IR) and Raman spectroscopies are non-destructive, analytical techniques that are used primarily to study the vibrational properties of a material. They have found applications across a multitude of scientific disciplines due to their ability to deduce information about both the structure and the chemical composition of a material. The ease of use, availability and affordability of these instruments have made them common tools in analytical laboratories. In this talk, I will review the basic principles of these techniques, examine the common features present on commercial instruments and discuss several applications that demonstrate both the power and the limitations of these techniques.

C3: Diffraction techniques in the Scanning Electron Microscope (SEM) - Advanced

Alice Bastos S. Fanta

The scanning electron microscope is a very versatile instrument which allows detail and quantitative characterization of material in a large range of length scales. Although electron diffraction was, at its early ages, mainly a transmission electron microscopy (TEM) technique, it is now a widely spread and stablished SEM technique, which is continuously evolving. In this presentation a short introduction to the leading SEM diffraction techniques will be given and applications and developments for materials characterizing will be presented. A special focus will be given to the transmission Kikuchi diffraction (TKD) technique, which was recent developed and has potential to become widely applied in nanocrystalline material characterization. The possibilities, the limits and the ongoing development of TKD will be presented and discussed.

C4: Transmission Electron Microscopy (TEM): Combining analytical methods of imaging, diffraction and spectroscopy - Advanced

Lars Riekehr

The transmission electron microscope (TEM) is a versatile tool for materials characterization. It can be used for imaging, electron crystallography and spectroscopy.
Part one of this tutorial shows how to use the CrystBox [1] software suite to analyze electron diffraction patterns and atomic resolution images of crystals. This includes using CrystBox to calibrate diffraction accurately, to automatically index selected area electron diffraction patterns and to process atomic resolution images.
Part two of this tutorial shows the advantages of using Matlab for image display compared to the software ESPRIT 1.9 by Bruker, which is commonly used with SuperX energy dispersive X-ray (EDX) spectrometers in FEI microscopes. After acquisition and (standardless) quantification of an EDX map, image display and filtering options provided by ESPRIT 1.9 are limited. Importing the spectral image data into Matlab allows the user to display and process the data in a more flexible way.

C5: Intermodulation AFM: material properties at high speed and high resolution - Advanced

Daniel Forchheimer (Kungliga Tekniska Högskolan)

The atomic force microscope (AFM) has since its invention in the 1980's become a standard tool for investigating the 3d shape, or topography, of surfaces with nanometer resolution. Part of its success must be attributed to the AFMs high versatility to probe also other surface properties, such as mechanical, electric or frictional properties. Careful measurements of these “additional” properties are however typically associated with long measurement times or low resolution images. In this tutorial we will present Intermodulation AFM, a set of improved AFM measurement modes developed at KTH over the past 10 years and which are now commercially available. These techniques are based on a multifrequency drive and detection scheme to ensure that the property of interest (mechanical, electrical, friction) can be measured in the frequency range where the AFM cantilever is most sensitive, i.e. near its resonance frequency. The high sensitivity allows for high speed and high resolution measurements.

Thin Film technologies, Room S01

T1: Thin film deposition techniques - Basic

Kristin Bergum, Oslo UiO

This tutorial session will introduce several thin film deposition techniques; how they work, their advantages and disadvantages. Most of the session will focus on physical vapour deposition (PVD) techniques (thermal evaporation, e-beam evaporation and sputtering), however, some chemical vapour deposition (CVD) techniques (CVD and atomic layer deposition (ALD) and their plasma enhanced versions) will also be briefly introduced. Typical properties of thin films deposited with all mentioned deposition techniques will be compared, providing a guide to which technique to use for your film deposition.

T2: Magnetron sputtering - Advanced

Tomas Kubart, Uppsala Ångström

Magnetron sputtering is widely used for synthesis of various thin films from laboratory to industrial scale. This tutorial aims at understanding principles of the technique and highlights the relation between the process conditions and properties of the resulting films. Different modes of operation (dc, pulsed dc, rf) are covered and reactive sputtering is briefly discussed. Special focus is paid to ionized sputtering implemented using High Power Impulse Magnetron Sputtering. To illustrate various physical processes, challenges related to metallization, deposition of transparent conducting oxides, and various nitrides are described.

T3: Atomic Layer Deposition (ALD) - Basic

Pernille V. Larsen & Evgeniy Shkondin, DTU Nanolab

In this presentation, the Atomic Layer Deposition (ALD) technique and different tool setups will be explained. The main advantages and limitations of the technique compared to other thin film deposition methods will also be mentioned.

With ALD it is possible to deposit many different materials, e.g. oxides, nitrides and metals, on almost all kinds of the samples including samples with very high aspect ratio structures.

The chemicals used for ALD depositions are called precursors. These can either be liquids, solids or gases, or reactive species generated by a plasma.

ALD depositions take place in cycles, where the precursors react on a sample surface one at a time. In this way, a thin and uniform layer is being deposited monolayer by monolayer everywhere on the sample surface. The reaction is self-limiting, and the thickness of the deposited layer is easily controlled by the number of cycles.

The reaction between reactants and the sample surface can be either thermally driven, or plasma enhanced. In Plasma Enhanced ALD (PEALD), very reactive species generated by a plasma deliver the necessary activation energy for the reaction to take place. This allows an increased choice of materials and precursors, depositions at lower temperatures and good control of film stoichiometry.

Finally, some selected ALD applications will be presented. These include back-end-of-line (BEOL) processing, high-k dielectrics, encapsulation, optical coatings and applications within metamaterials and plasmonics.

T4: Epitaxial growth - Basic

Mattias Hammar, Department of Electronics, KTH, Kista

This tutorial will regard epitaxial growth of compound semiconductor materials, focusing on III/V compounds and predominantly metal-organic vapor-phase epitaxy (MOVPE). Topics covered will include a general overview of epitaxial growth technologies with specific pros and cons, MOVPE basics and instrumentation, precursor chemistry and safety, application examples, some general guidelines regarding process development, and an overview of III/V-based epitaxial resources available within the Nordic Nanolab Network.

T5: From atoms to microfilms: a journey in thin film deposition technology - Basic

Ruggero Verre, Chalmers

Thin film deposition has enabled and revolutionized the way we manipulate nature today. To date, almost all nano and mesoscopic devices present in the world involve some sort of thin film deposition technique. In this general talk, we make a journey into this world, starting from atoms and submonolayer depositions and arriving to structured microfilm. We discuss some of the relevant and critical parameters which influence the films quality and be the base for real applications.

This presentation is general, but it aims to be an inspirational talk: via some interesting examples and practical applications, the audience could be shed with new insights and a more general picture of why thin film deposition is still an active and important science we should still investigate and develop today.

Etching technologies, Room S02

E1: Generic build-up of etch process: 3D-sculpturing by Si plasma etching - Advanced

Bingdong Chang, DTU Nanolab

3D silicon micro- and nanostructures enable novel functionalities and better device performances in various fields. Fabrication of real 3D structures in a larger scale and wider applications has been proven to be limited by the technical difficulties during the fabrication process, which normally requires multiple process steps and techniques. Direct top-down fabrication processes by modifying a plasma etch process have been proposed and studied in previous studies. However, the repeatability, size uniformity and the maximal number of stacked layers were limited. In DTU Nanolab we have developed a facile single run fabrication strategy for 3D silicon micro- and nanostructures, mostly by employing the induced coupled plasma (ICP) etching machine DRIE Pegasus (SPTS). A good uniformity of suspended layer thickness has be achieved and up to 10 stacked layers have been fabricated in a single run without other additional steps or post-process procedures. This is enabled by a modified multiplexed Bosch etch process, so called DREM (Deposit, Remove, Etch, Multistep), while the DREM etch is used to transfer the patterns into silicon, an extra isotropic etch creates a complete undercut and thus freestanding structures come into form. This method is easy to program and provides well-controlled etch profiles.

E2: Chemical Mechanical Polishing – Basic

Corrado C. M. Capriata, KTH

The presentation on chemical mechanical polishing (CMP) will be built around 4 main sections. In the first section, an introduction on the CMP processing necessity is presented and a landscape of possible applications of the process are illustrated. In the second part, the tool itself is presented together with its main components and the influence of each of these parts is explored. This section will give the audience the necessary ground on which one can build an understanding of the working principle of the tool. The theory section comes next and the most common processing defects are here eviscerated, this can help to understand how to integrate a CMP step into a process flow. The last and concluding section is focused on the tool installed in Electrum Laboratory and what kind of processes we are currently working with. This part allows the audience to understand what we can currently do and at the same time what are the future perspectives in the CMP usage.

E3: Wet Etching Techniques - Basic

Karin Hedsten, Chalmers

In this tutorial simple wet chemical etching processes are described. Basic definitions and figures of merit are identified. Some examples of common wet etching processes, and isotropic and anisotropic etching are given.

Wafer cleaning processes and liftoff are also briefly discussed.

E4: Atomic Layer Etching - Basic

Sabbir Ahmed Khan, KU/NBI

In this talk I will discuss basics of atomic layer etching (ALE) process and also demonstrate examples of ALE on nanostructures. Examples include highly selective ALE of thin film Ga-polar GaN (0001) and crystalline Si (100) using Cl_2 and low energy Ar ions in standard reactive ion etching (RIE) system (Oxford Plasmalab 100) [1]. Nano-patterning and ALE patterned substrates for high resolution nanoimprinting will also be demonstrated [2]. Finally, ALE on semiconductor nanowires will be shown [3].

Reference:

1. Christoffer Kauppinen, Sabbir Ahmed Khan, Jonas Sundqvist, Dmitry B. Suyatin, Sami Suihkonen, Esko I. Kauppinen and Markku Sopanen. Atomic Layer Etching of Gallium Nitride (0001). Journal of Vacuum Science & Technology A, 35, 6, 060603 (2017).

2. Sabbir Khan, Dmitry B. Suyatin, Jonas Sundqvist, Mariusz Graczyk, Marcel Junige, Christoffer Kauppinen, Anders Kvennefors, Maria Huffman, Ivan Maximov. High-Definition Nanoimprint Stamp Fabrication by Atomic Layer Etching. ACS Applied Nano Materials, 1, 6, 2476–2482 (2018).

3. Sabbir Khan, Dmitry B. Suyatin, Jonas Sundqvist, A Method for Selective Etching of Nanostructures. WO2017157902A1, Patent Application (2017).

E5: Etching AlGaN alloys using ICP-RIE - Basic

Leidulv Vigen, NTNU

I will present an introduction to the ICP-RIE etching method, give an overview of the main parameters and their effects on the etching environment, and lastly talk about some of the challenges encountered when etching tough and chemically inert materials such as the AlGaN alloys.

Lithography, Room S04

L1: EBL hardware basics and craftmanship – Basic

Marcus Rommel, Chalmers

L2: Electron Beam Lithography – process, principles and capabilities - Basic

Jakob B. Vinje and Einar Digernes, NTNU

The ability to write patterns with nanometer precision has made electron beam lithography (EBL) a cornerstone for nanotechnology related research. Introduction of dedicated EBL systems in the Nordic Nanolab Network has made working with EBL easier than ever before.

In this tutorial the basic steps of the EBL process will be covered. We will introduce core principles explaining what happens at the microscopic scale. Understanding these concepts is critical to achieve efficient processes and ultimate resolution. Finally, capabilities and limitations of the EBL process will be discussed.

L3: Talbot Displacement Lithography: Definition of Sub-100 nm Structures by UV-exposure - Basic

Mariusz Graczyk, Lund Nano Lab

In my lecture I will outline the basic principles of Talbot Displacement Lithography (TDL), its performance and recently obtained results. The TDL is a relatively new technique, that exploits 3D diffraction pattern of UV-light to create a regular, high-resolution two-dimensional pattern with sub-100 nm feature size. The main advantage of the technique is its non-contact nature, which reduces the risk of damaging the mask and its parallel exposure with high throughput. This lithographic method allows formation of regular structures down to 50 nm over 4 inch wafers, and it is possible to make arrays of lines, hexagonally placed holes and other regular patterns.

The TDL will be described in terms of its applications in different projects, e.g growth of III-V nanowires, where additional process steps of selective dry etching of TDL-specific resist layers have been developed and optimised. I will give examples of lithographic process conditions, including dependence of line-width on the exposure dose, development time and other conditions.

L4: Block Copolymer Nanolithography - Basic

Anette Löfstrand, Lund Nano Lab

Modern technology devices often require a high-density pattern to achieve the desired functionalities. One interesting, low cost method to obtain these patterns is block copolymer nanolithography, which is a technique that can be easily integrated into a standard nanofabrication cleanroom. Block copolymer nanolithography typically has a pattern periodicity of 10-50 nm, usually uses patterns of vertical cylinders in a hexagonal lattice, or lamellae or horizontal cylinders in a finger-print pattern.

This basic tutorial aims to present how block copolymer lithography works in principle, what is controlling the self-assembly, and the self-assembled pattern types; what to consider before choosing polymer system; different annealing approaches to increase the long-range order, such as thermal, solvent vapor, and microwave annealing; directed self-assembly by the use of chemically modified surface areas or by using topography; methods to remove or modify one polymer block, such as dry etching to remove one block, surface reconstruction to extract one block to the surface, or sequential infiltration synthesis, which infiltrates metal oxide into one of the blocks. Furthermore, how to use this modified block copolymer film as an etch mask in reactive ion etching to transfer the pattern into the underlying layer, and, lastly, different possible applications of the resulting patterns. In essence, the basic principles, the possibilities and limitations of block copolymer nanolithography will be presented.

L5: Introduction to maskless UV-lithography – Basic

Lean Gottlieb Pedersen, DTU Nanolab

An overview of different lithography techniques are given to distinguish between mask and maskLESS lithography.
Several different maskless lithography techniques will be introduced.
Pros and cons will be explained for each of these.
The primary focus will be on Heidelberg tools from the maskless series (MLA100 and 150).