OBUDA UNIVERSITY

Doctoral School on Materials Sciences and Technologies

Institute of Technical Physics and Materials Science
Centre for Energy Research

‘Combinatorial Preparation and Characterization Methods for High Through-put Study of Advanced Functional Materials’

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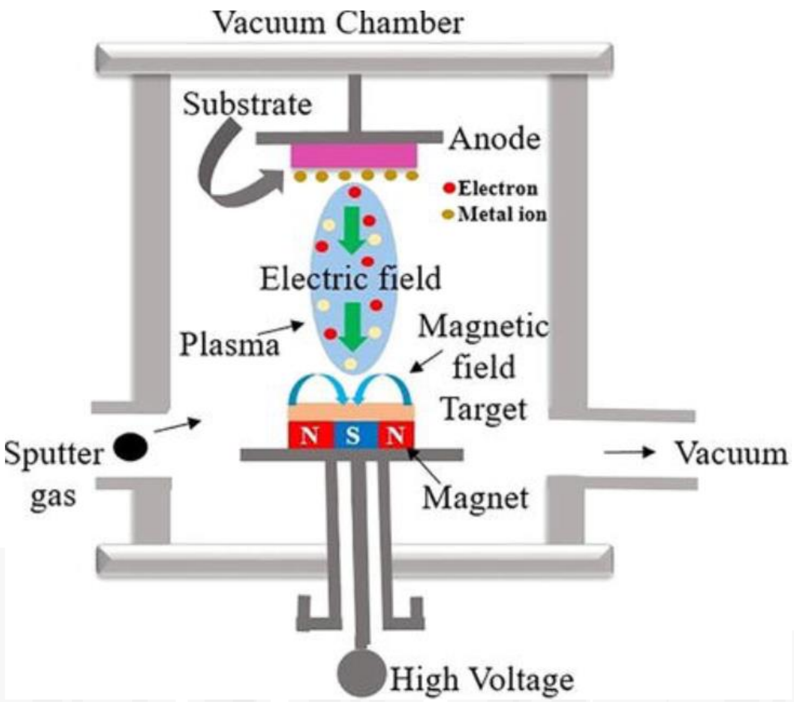
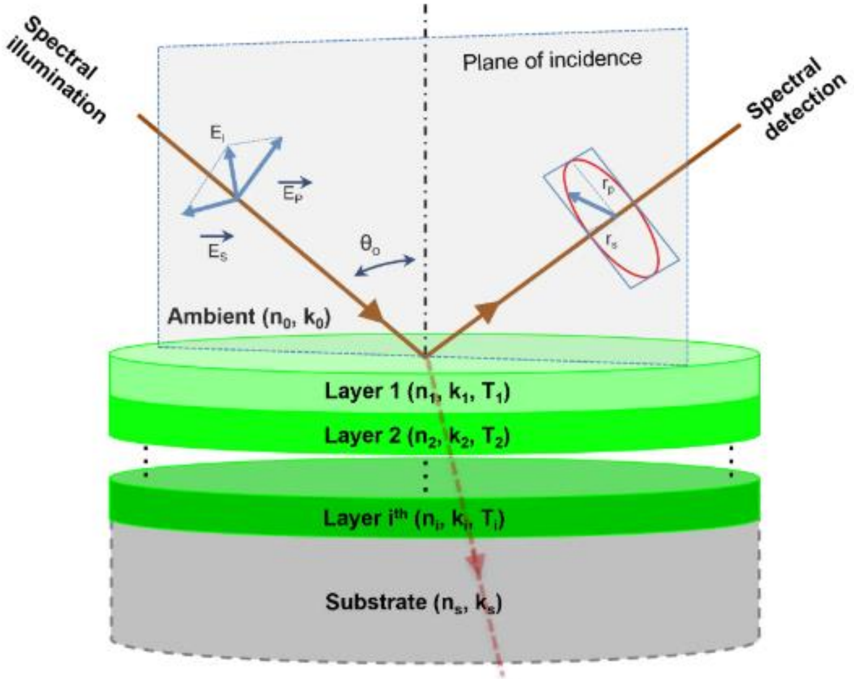
Research Topic

‘Combinatorial Preparation and Characterization Methods for High Through-put Study of Advanced Functional Materials’



Magnetron sputtering



spectroscopic ellipsometry

OUTLINES

1. Introduction
    1.1. Purpose and Process of the Research
    1.2. Research Methods
    1.3. Characterization methods
2. Results of the Actual Semester
3. Plans For the Future Work

1.1 Purpose and Process of the Research

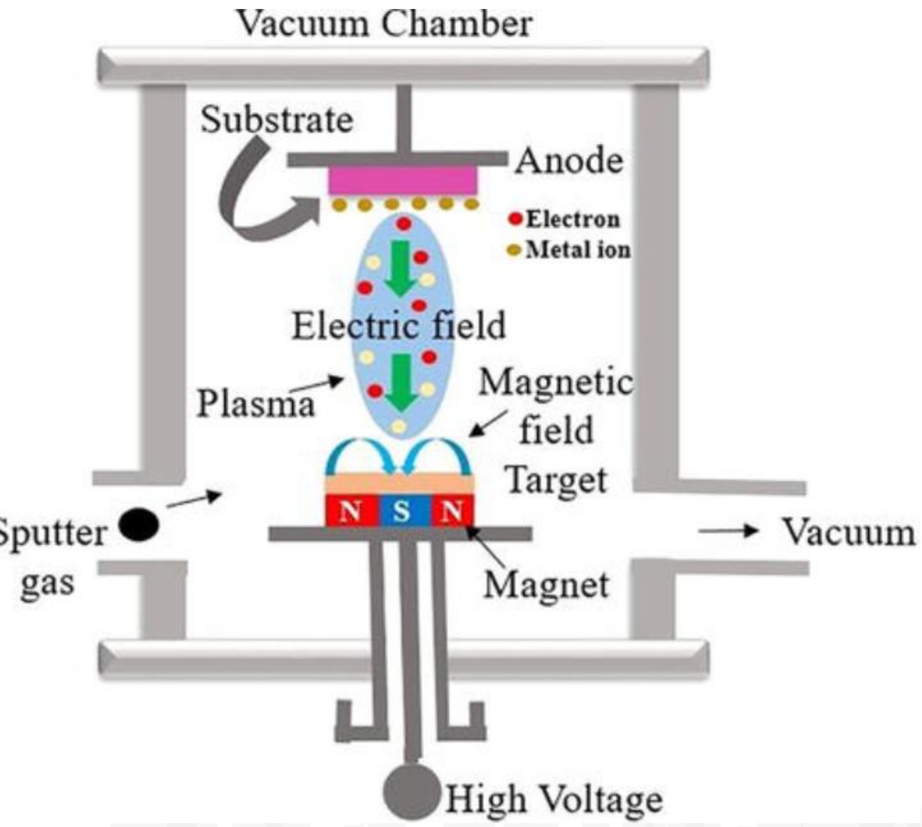
Óbuda University

- Search more efficient advanced functional materials for micro- and optoelectronics, energy converters (solar cells) or different (optical or gas) sensor systems.
- Programming the data collection and data processing software
- Investigating combinatorial samples made by a reactive DC magnetron sputtering system

*The basis of the work (from our Institute): “Optimized sensing on gold nanoparticles created by graded-layer magnetron sputtering and annealing, and this research was funded by the National Research, Development and Innovation Office (NKFIH) in Hungary through the Grants Nr. K146181, K-143216, K-134258 and PD-146479.

1.2 Research Methods

Magnetron sputtering



Magnetron sputtering

Basic Principle

•In a vacuum chamber, an inert gas (e.g, argon).

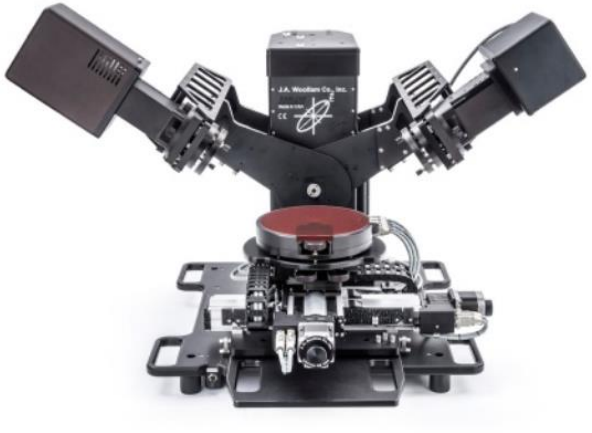
•A high-voltage electric field ionizes the argon gas into charged argon ions.

•The argon ions are accelerated by the electric field and bombard the target material, dislodging atoms from its surface.

•The sputtered atoms then deposit on the substrate to form a uniform thin film

1.2 Research Methods

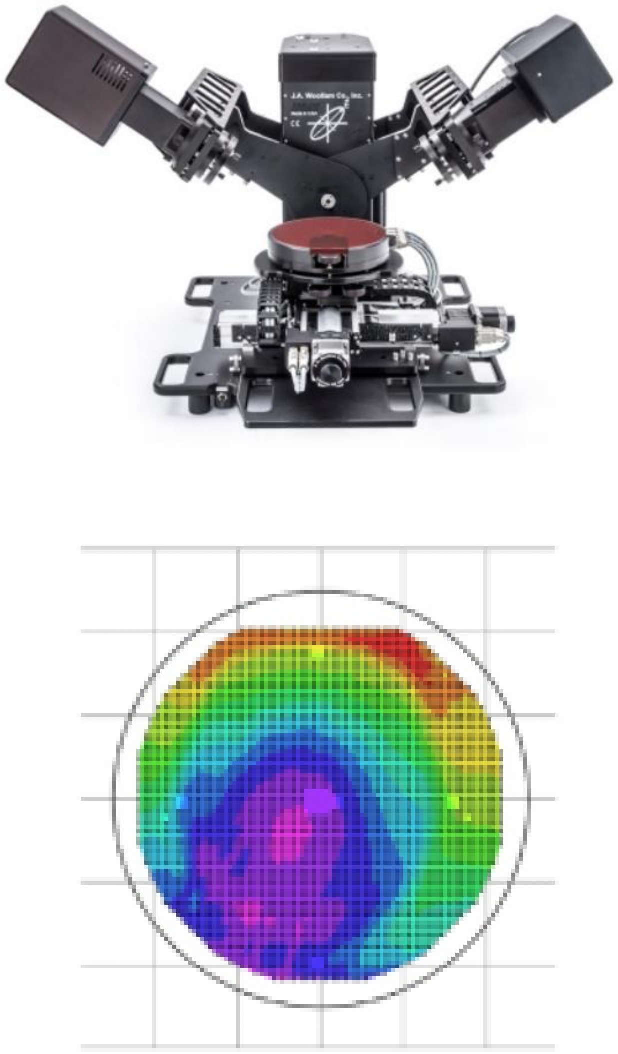
Spectroscopic Ellipsometry (SE)



Woollam M-2000DI Spectroscopic Ellipsometer

Working Principle:

- **Incident light** is polarized before striking the sample surface.
- Upon interaction with the sample, the polarization state of the reflected light changes.
- Two key parameters are measured:
    - **Ψ (Psi):** Ratio of the amplitudes of parallel and perpendicular polarized light.
    - **Δ (Delta):** Phase difference between the two polarization components.
- These parameters are analyzed using a **mathematical model** to determine the **film thickness** and **optical properties**.



Measurement

Data interpretation

Model

Data fitting

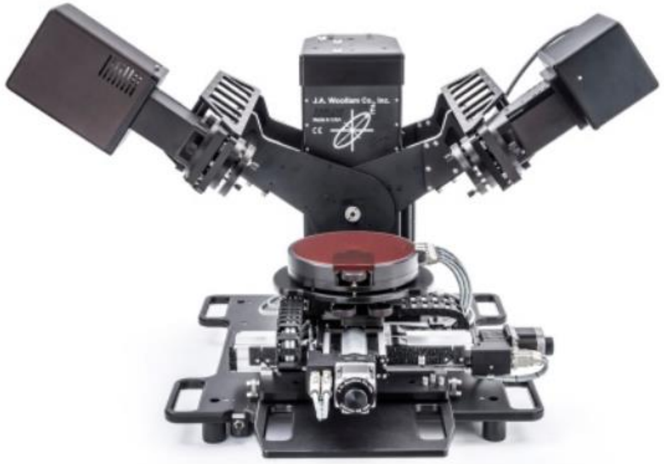
Evaluation

Results

Figure 1: SE Technique Flow chart

1.2 Research Methods

Spectroscopic Ellipsometry (SE)



Woollam M-2000DI Spectroscopic Ellipsometer

☑ **Advantages:**

- **Non-contact and non-destructive**
- High precision for nanometer-scale measurements
- Simultaneous determination of **thickness** and **optical constants**

⚠ **Limitations:**

- Requires a **known optical model** for analysis
- **Complex data fitting** process

1.3 Characterization Methods

Main characterization instruments

Spectroscopic Ellipsometry

Scanning Electron Microscope

Transmission Electron Microscope

1.3 Characterization Methods

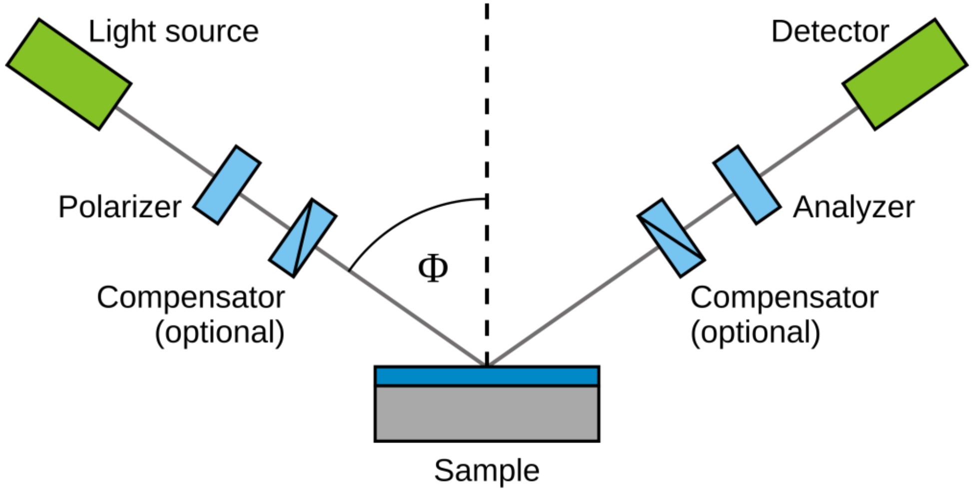


Figure.2 Schematic diagram of ellipsometry experiment

$$\rho = \frac{r_p}{r_s} = \tan(\Psi)e^{i\Delta}$$

r_p and r_s are the reflection coefficients for parallel and perpendicular polarized light, respectively.

- Data Acquisition: Measures the polarization state changes (Ψ and Δ) of reflected light across different wavelengths.
- Data Analysis: Fits data using mathematical models to extract thin-film thickness and optical constants.
- Results Output: Provides key optical parameters, including thickness, refractive index, and extinction coefficient.

1.3 Characterization Methods

- Ellipsometry requires powerful software to get full benefit from the measurement. CompleteEASE™
- (in situ/ex situ) software packages provide easy calibration, data acquisition, and analysis for all of our applications

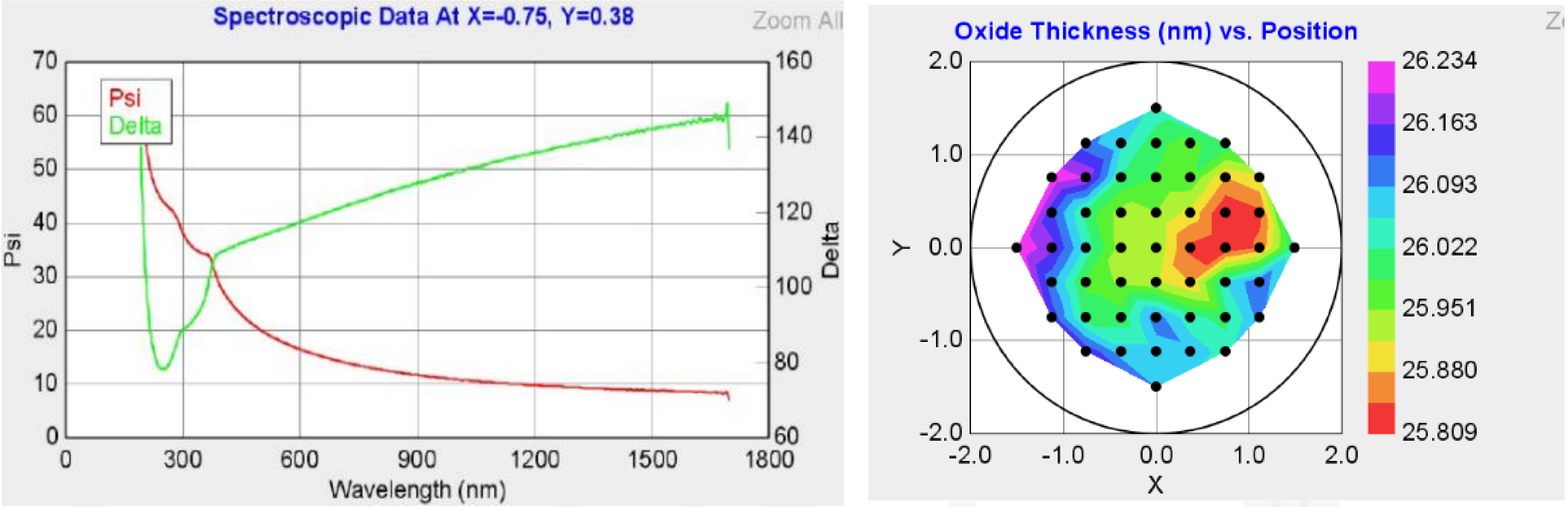


Figure.3 SiO_2 wafer thickness, measured from M2000DI ellipsometer for control measures

1.3 Characterization Methods

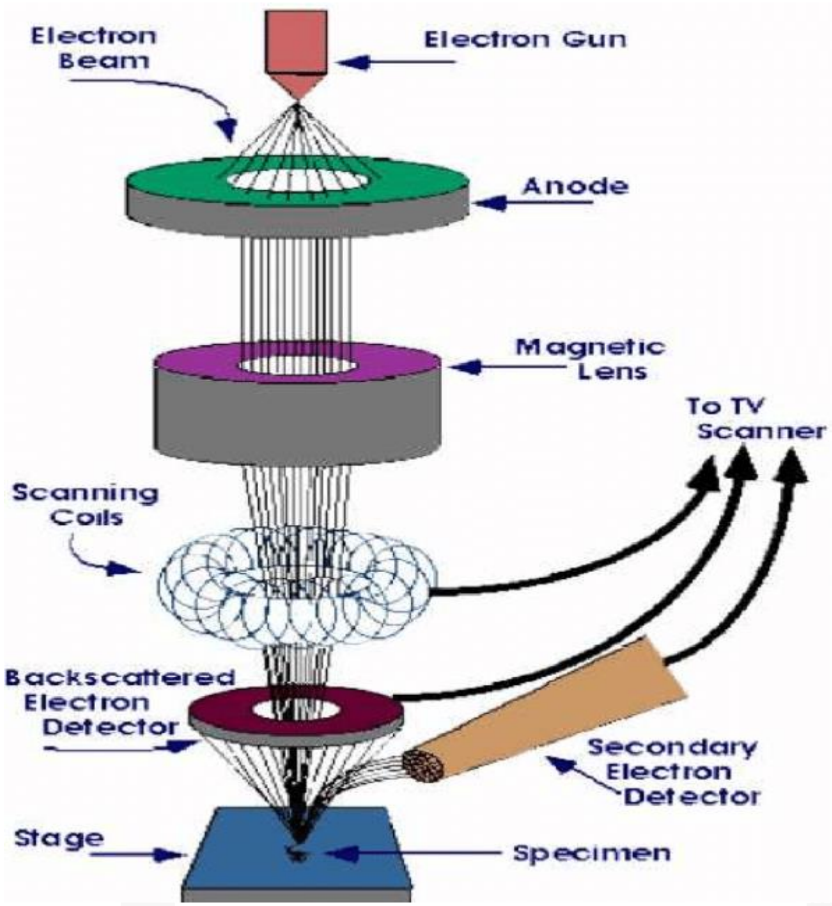


Fig.4 The basic structure of SEM microscope

Working Principle

- The focused high-energy electron beam to scan the sample surface and generate high-resolution surface morphology images by detecting signals such as secondary electrons and backscattered electrons.

Sample Preparation

- Cleaning: Remove dust and contaminants
- Conductive Coating: Apply a metal coating (e.g., gold or carbon) for non-conductive samples.
- Vacuum Compatibility: Ensure the sample is stable under vacuum conditions.
- Surface Smoothness: Keep the surface as flat as possible to avoid focus issues.

1.3 Characterization Methods

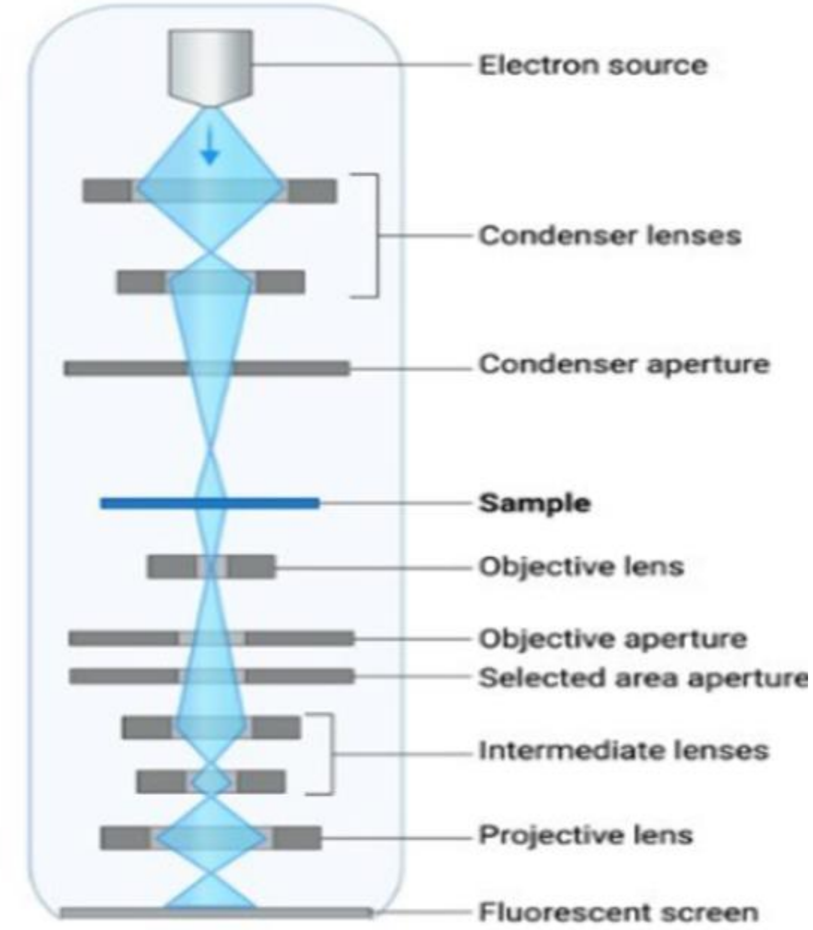


Figure.5 The basic structure of STM microscope

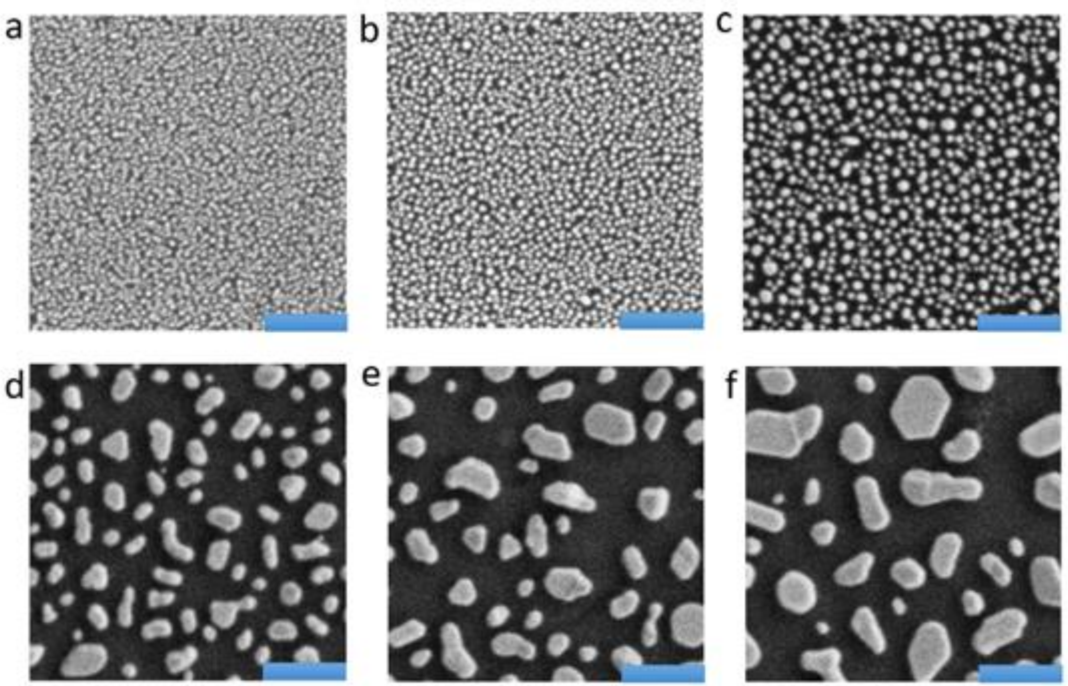
Working Principle

- A beam of electrons passes through a thin specimen and gives information about inner structure of the sample, like crystal structure, morphology structural defects and impurity

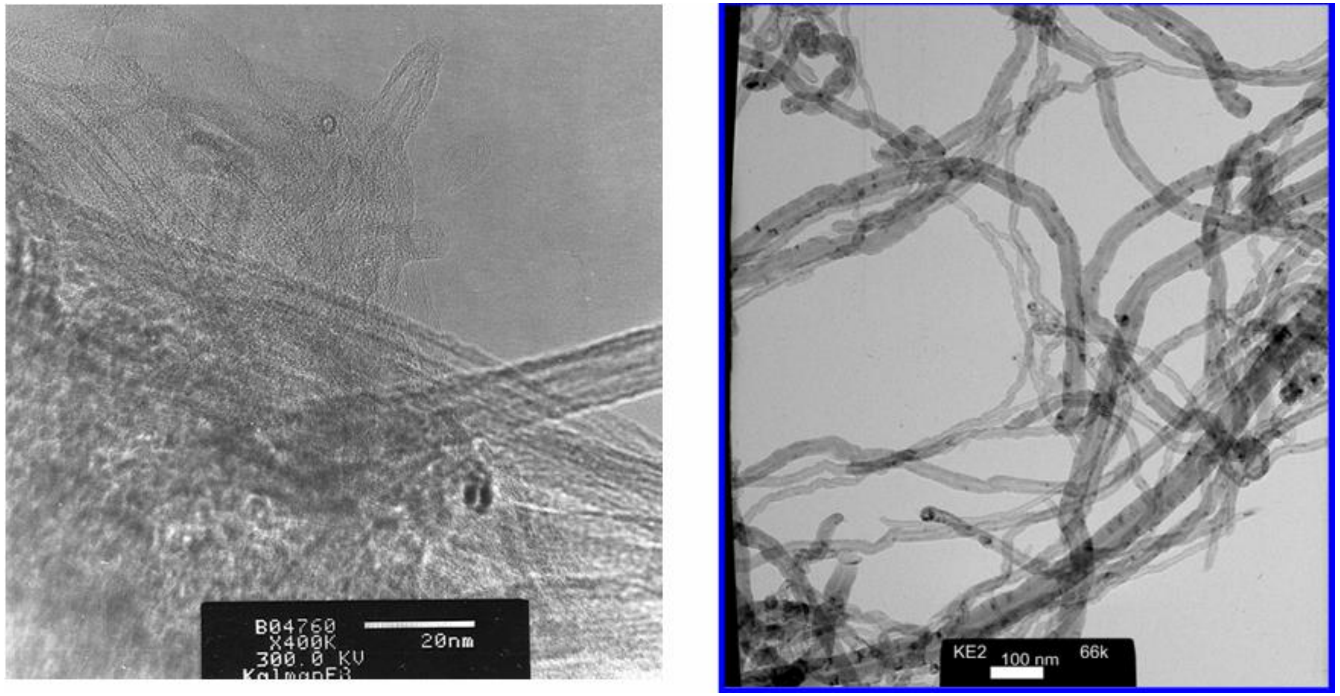
Sample Preparation

- Ultra thin, electron transparent, typically <100nm
- Nanocharacterization range (< 1 nm to 100 nm) to micrometer range and beyond.
- Direct measurement technique

1.3 Characterization Methods

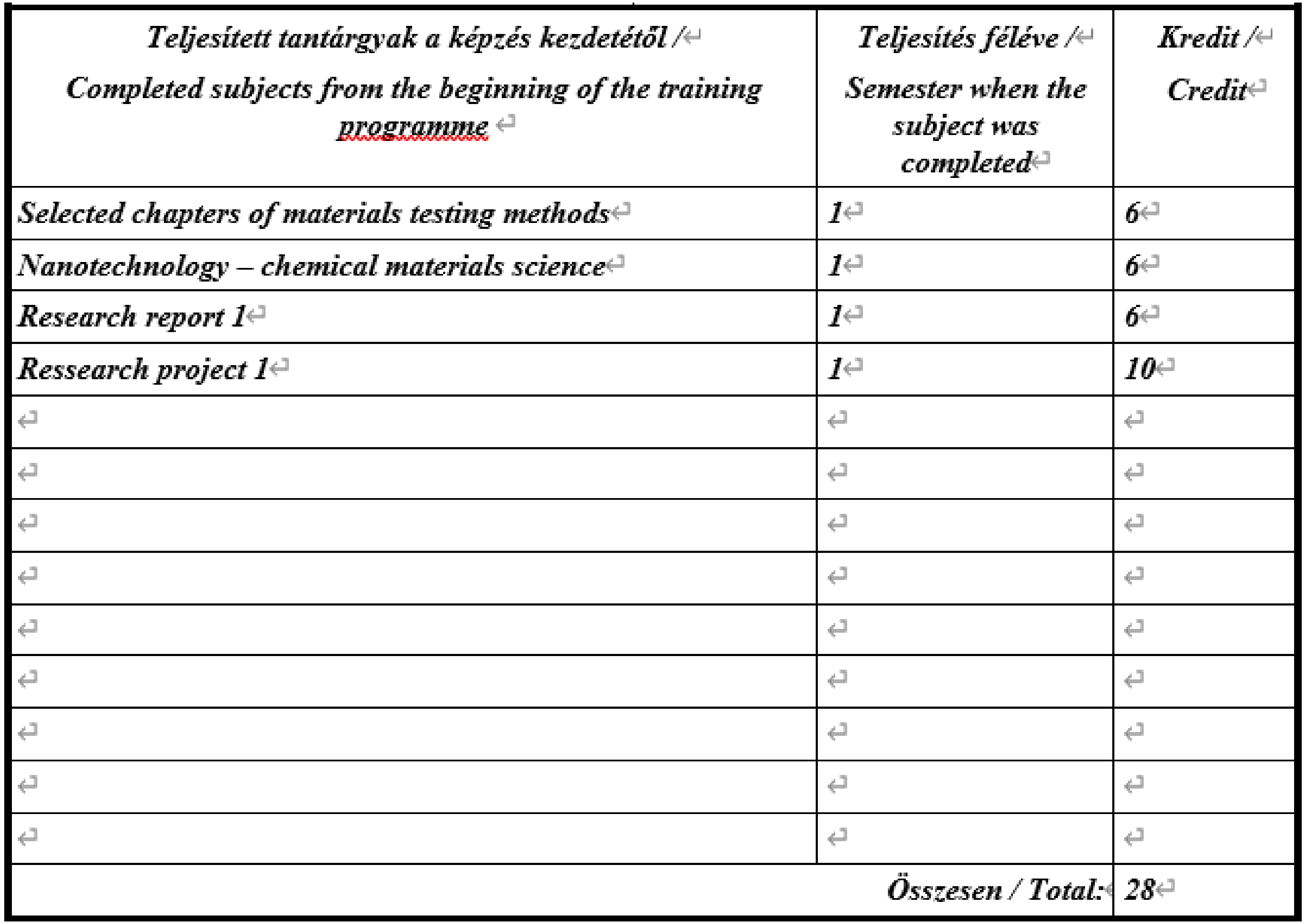


SEM of Gold nanoparticles surface



TEM of Carbon nanotubes

2.Results of the Actual Semester



Teljesített tantárgyak a képzés kezdetétől / *Completed subjects from the beginning of the training programme*	*Teljesítés féléve /* *Semester when the subject was completed*	*Kredit /* *Credit*
Selected chapters of materials testing methods	*1*	*6*
Nanotechnology – chemical materials science	*1*	*6*
Research report 1	*1*	*6*
Ressearch project 1	*1*	*10*
	Összesen / Total:	*28*

3. Plans For the Future Work

- Understand and master the magnetron sputtering technology
- The M2000DI ellipsometer will be used for control measurements.
- Combinatorial samples will be made by a reactive DC magnetron sputtering system such as Au and Al mixed layers on Silicon.

köszönöm !