

**AGH**AGH UNIVERSITY OF SCIENCE  
AND TECHNOLOGY

Module name: Advanced Methods of Electron Microscopy

Academic year: 2019/2020 Code: ZSDA-3-0077-s ECTS credits: 6

Faculty of: Szkoła Doktorska AGH

Field of study: Szkoła Doktorska AGH Specialty: —

Study level: Third-cycle studies Form and type of study: Full-time studies

Lecture language: English Profile of education: Academic (A) Semester: 0

Course homepage: —

Responsible teacher: dr Kryshtal Oleksandr (kryshtal@agh.edu.pl)

### Module summary

The course focuses on practical aspects of electron microscopy (EM) studies of a vast range of materials. The lectures refresh the basics followed by a discussion of more advanced topics of the EM. The practical sessions are to demonstrate various TEM techniques and provide the students with the opportunity to work with the most advanced electron microscopes currently available. Intensive image analysis, simulation, and data processing will be supported by freeware software and open databases.

### Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Connections with FLO	Method of learning outcomes verification (form of completion)
Skills: he can			
M_U001	Is able to select the appropriate method for characterization of various materials.	SDA3A_U06, SDA3A_U02, SDA3A_U01	Report on completion of a practical placement, Participation in a discussion, Involvement in teamwork, Execution of exercises, Execution of a project, Activity during classes
M_U002	Has basic skills of operation of advanced scanning and transmission electron microscope in different modes.	SDA3A_U07, SDA3A_U06	Involvement in teamwork, Execution of exercises, Execution of a project
M_U003	Can understand and interpret electron microscopy images, diffraction patterns, EDX and EELS spectra	SDA3A_U06, SDA3A_U03, SDA3A_U02, SDA3A_U01	Execution of exercises, Execution of a project, Report on completion of a practical placement, Participation in a discussion, Involvement in teamwork, Activity during classes
Knowledge: he knows and understands			

M_W001	Knows main electron microscopy techniques for materials characterization and understands what kind of information is possible to obtain from their use	SDA3A_W03, SDA3A_W02, SDA3A_W01	Report on completion of a practical placement, Participation in a discussion, Examination, Activity during classes
M_W002	Knows the major processes of electron-matter interaction and their relation to the microscopy techniques	SDA3A_W01	Participation in a discussion, Execution of exercises, Execution of a project, Activity during classes
M_W003	Understands the basics of electron microscopy, electron diffraction, and chemical composition microanalysis	SDA3A_W03, SDA3A_W02, SDA3A_W01	Participation in a discussion, Execution of exercises, Activity during classes

## Number of hours for each form of classes

Suma	Form of classes										
	Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
60	30	30	0	0	0	0	0	0	0	0	0

## FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
Skills: he can												
M_U001	Is able to select the appropriate method for characterization of various materials.	+	+	-	-	-	-	-	-	-	-	-
M_U002	Has basic skills of operation of advanced scanning and transmission electron microscope in different modes.	-	+	-	-	-	-	-	-	-	-	-
M_U003	Can understand and interpret electron microscopy images, diffraction patterns, EDX and EELS spectra	+	+	-	-	-	-	-	-	-	-	-
Knowledge: he knows and understands												

M_W001	Knows main electron microscopy techniques for materials characterization and understands what kind of information is possible to obtain from their use	+	+	-	-	-	-	-	-	-	-	-
M_W002	Knows the major processes of electron-matter interaction and their relation to the microscopy techniques	+	-	-	-	-	-	-	-	-	-	-
M_W003	Understands the basics of electron microscopy, electron diffraction, and chemical composition microanalysis	+	+	-	-	-	-	-	-	-	-	-

## Student workload (ECTS credits balance)

Student activity form	Student workload
Udział w zajęciach dydaktycznych/praktyka	60 h
Preparation for classes	20 h
przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania	30 h
Realization of independently performed tasks	20 h
Examination or Final test	2 h
Contact hours	5 h
Inne	20 h
Summary student workload	157 h
Module ECTS credits	6 ECTS

## Additional information

### Module content

#### Lectures

##### Basics of electron microscopy

- Electrons vs light. Resolution. Low and high order aberrations.
- Electron optics. Aberration correctors. Wiener filter.
- Electron – matter interactions

##### Scanning electron microscopy (SEM)

- Optics of the SEM
- Image contrast
- Ultimate resolution in SEM
- Low voltage and environmental SEM
- EBSD
- EDX in SEM
- FIB-SEM tomography

Transmission electron microscopy (TEM)

- a. Specimen preparation for TEM
- b. Optics of the TEM
- c. Electron diffraction (SAED, nano, CBED, precession)
- d. Contrast mechanisms
- e. HR TEM. Contrast transfer function.
- f. Image analysis in electron microscopy
- g. EELS and EFTEM
- h. In situ TEM

Scanning transmission electron microscopy (STEM)

- a. Optics.
- b. Image contrast in STEM (BF, DF, Z-contrast)
- c. EDX in STEM
- d. EELS spectral imaging
- e. Electron tomography

**Auditorium classes**

1. SEM. Align, operation, image acquisition, and optimization. EDX. EBSD.
2. Indexing electron diffraction patterns. Crystallographic structure databases.
3. Basic TEM. Align, operation, image contrast.
4. HR TEM. Contrast transfer function. Simulation of HR TEM images.
5. Basic STEM. BF, ADF, HAADF imaging.
6. HR STEM. Correction of aberrations. Simulation of HR STEM images.
7. Practical EDS microanalysis. EDX mapping of chemical elements.
8. Electron energy loss spectroscopy (EELS). Low- and core-loss spectra.
9. Tomography. Reconstruction of 3D images.
10. Image processing and data analysis.

**Teaching methods and techniques:**

Lectures: Lecturing, class discussions

Auditorium classes: demonstrations, practice, group projects and discussions, self-learning, written reports.

**Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:**

Students will be encouraged for writing and submitting a group/individual report from the classes.  
Open-book final examination.

**Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:**

Lectures:

- Attendance is mandatory: No
- Participation rules in classes: Nie określono

Auditorium classes:

- Attendance is mandatory: Yes
- Participation rules in classes: Nie określono

**Method of calculating the final grade**

Project Reports - 70%

Final Examination - 30%

## **Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:**

individual project report

## **Prerequisites and additional requirements**

Basic knowledge of materials science.

## **Recommended literature and teaching resources**

1. Williams D., Carter C.B.: Transmission Electron Microscopy, Plenum Press, New York, 1996 and 2009 (vol. 1-4).
2. De Graef M.: "Introduction to conventional transmission electron microscopy", Cambridge University Press 2003
3. Brydson R. (ed.): Aberration-Corrected Analytical Transmission Electron Microscopy, J. Wiley and Sons Ltd. 2011
4. Hawkes P.W., Spence J.C.H.: "Science of Microscopy", Springer 2007
5. Keyse R.J., Garrat-Reed A.J., Goodhew P.J. and Lorimer G.W.: "Introduction to Scanning Transmission Electron Microscopy", Taylor and Francis / BIOS Scientific Publishers, 1997

## **Scientific publications of module course instructors related to the topic of the module**

Additional scientific publications not specified

## **Additional information**

None