

# *Micro-courses for education to scanning probe microscopy*

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**Abstract** — This paper describes impact of micro-courses to education in the field of the nanoscience. The feature of the subjects which are related to nanoscience is the combination of new modern research methods and the foundations of physics and chemistry. While there are well-developed textbooks to study the fundamentals, it is necessary to refer to freshly written articles of scientists and data from technical sites. Rapidly developing fields demands flexible form of materials to study and an innovative change in the presentation of an online environment. Here we consider education to scanning probe microscopy techniques in terms of micro courses. This type of microscope is became an important tool for three dimensional surface studies with nanoscale resolution.

**Keywords** — teaching, studying, nanoscience, micro-course

## I. INTRODUCTION

The widespread introduction of high technologies and the openness of the learning process are gaining more and more space in the higher education, in order to develop of highly complex knowledge structures, generic skills as well as transferability of knowledge and skills to future professional work [1-3]. The trend of the modern learning process, for the effective assimilation of material along with classical teaching, a strong place is occupied by micro-courses [4].

The micro-course concept is aimed at obtaining and fixing certain knowledge and skills by the student, being an instrument of internal learning. The step-by-step constructed algorithm will allow to optimize the learning tasks to a greater extent, to structure the information contained in this micro-course of microscopy. The volume course of the training material is given in small doses, one topic is one course, which simplifies the control over the assimilation of the educational material. The time allotted for the video lesson or short lecture is from 5-10 minutes, it is the time interval when the concentration is maximum, hence the probability of obtaining a satisfactory result is high. A logically constructed chain consisting of a set of interrelated topics, with the correct design of the curriculum, creates favorable conditions for memorization.

Efficient SPM education involves wide range of activities from operator-level problem solving to training specialist for research activities. Currently, there are a large number of manufacturers of the microscopes. The scope of microscopy provides ample opportunity to study nanostructures. In addition to high-quality and quantitative surface analysis, modern microscopes are equipped with additional devices for modifying and engineering the surface of samples. Students need to understand the advantages and limitations of the applicability of the technologies introduced in the market for SPM microscopes. Considering specificity of this modern field of study, new education methods should be applied in order to fulfill expectations of future employee [5].

## II. MOTIVATION FOR IMPLEMENTATION OF MICRO-COURSES

Students will constantly remember what they learned earlier, and receive new information. New information will be placed on a newly formed database and be perceived much more efficiently [2].

The motivation for micro-studying is relevant factors such as: visibility and availability of the material, saving time, choice of the level of training, the opportunity to learn without interrupting work, learning small parts is easier, availability (using different types of communication, regardless of location); no dependence on external circumstances; unlimited viewing; visual memory is involved. As part of the implementation of adaptive learning using micro-course, it is important to cover all the issues: how the program is arranged, the conditions for switching from one module to another, how long it will take. The main aspect is full transparency as you progress through the course of the program, the ability to display progress in the percentage or percentage ratio, which is a stimulating factor in mastering the material.

In one video lesson, a lot of information is concentrated, which is perceived, both visually and by ear, which is very effective. With the video material everyone can learn and everything is basically clear.

### III. DESIGN OF MICRO-COURSES IN MICROSCOPY TEACHING

The scanning probe microscopy can be applied to various problems in a wide range of disciplines of the natural sciences, including solid-state physics, semiconductor science and technology [6-8], molecular engineering, polymer chemistry and physics [10, 11], surface chemistry [12-14], surface science [15-17], molecular biology, cell biology [18], and biomedical sciences [9, 10].

SPM is a physical interaction of a fine probe/tip with the surface of the sample to scan the surface and collect data, typically obtained as a two-dimensional grid of data points and displayed as a computer image. Teaching to SPM is complicated by the fact that this area is located at the intersection of scientific fields: engineering, fundamental science, processing of graphics. It is necessary to design the education process for teaching the student to work with the equipment, to understand the physical basis of the surface scanning and accurately process the data for extraction maximum reliable information.

The main principle in the choice of educational material for microscopy, in particular, scanning probe microscopy, is the relevance of topics and their accessibility in the understanding of the material being studied (for examples: probe-sample interface, electronics for detection of the probe-sample interaction, etc.). The concept of quality of activity includes following aspects: easy assimilation of the material; high learning efficiency at relatively low loads; ease of perception of the material. According to [4] the design of micro-coursed should contain following elements: time, objective, content, method and technology.

Modules of micro-education should contain small practical tasks that help in fixing basic and new acquired knowledge. Video course, as a visual way of information transfer, greatly facilitates the learning process and the formation of the knowledge base, which makes it easier to do self-education. With video courses, the students can learn anywhere from their mobile devices: laptops, tablets or smartphones. The video contains a maximum of useful information. To periodically monitor the assimilation of educational material and consolidate the acquired knowledge, a successful methodological tool is testing.

### IV. TIME ALLOCATION FOR SPM TEACHING

An important aspect of micro-course design is the distribution of the teaching time across theoretical education and practical activities.

Visual illustration is important for quick perception of information. The use of interactive presentations reduces the operation time of expensive equipment. The alternation of teaching methods: practice in the laboratory, lectures, interactive web pages, can improve the effectiveness of training. Student can pass independently though chosen theoretical parts of education material and it saves the time of the teacher.

Education time in the case of micro-courses implies its most effective use on the principle: better to keep maximum attention for a short time than to absentmindedly observe for a long time. As a result, there is a variation of studying activities during the education process.

Presence of easy-operating microscopes and accessories for demonstration of basic principles makes learning interesting and not time-consuming. Internet resources provide information about processes at the nanoscale level [19, 20] for their easier perception. Available free software (Gwyddion, ImageJ, etc.) have a number of YouTube tutorials which demonstrate data processing. Teaching model based on micro-courses implies that after determine the gaps in knowledge the student can devote more time to incomprehensible problems at any step.

### V. AIMS AND OBJECTIVES OF SPM TEACHING

It was mentioned by R. Blonder et al. [21] that atomic force microscopy (which is one member of SPM group) attracted a lot of attention being "excitement of exploring matter at the nanoscale". Besides this possibility of imaging the nano-topography, SPM is important of surface visualization and modification in various scientific files.

One of the main objectives of SPM teaching is explanation of correlation between SPM data and surface properties.

The basic concepts of physics and chemistry of surface in nanoscale should be explained. The aim of SPM teaching using micro courses can cover more than one SPM technique in dependence of specialization field (physics, biology, chemistry, material science). Most set-ups with they native software allows students to carry out following standard procedures: preparation to measurements: exchange of the probe, fix of the sample; measuring the samples: navigation using optical system (could be build-in optical microscope), trying different techniques (atomic force microscopy, scanning tunneling microscopy, scanning near-field optical microscopy, spectroscopy methods, etc.), trying scanning parameters (scanning rate [16], area, direction, etc.); processing of the results: evaluation of spectroscopy data; estimation of the physical values (in case of electrical, mechanical, optical measurements), image processing and extraction quantitative data (statistical data, filtering, fractal analysis [12, 14], etc.)

SPM measurements should also provide insight to features and peculiarities of the other studies in nanometer and angstrom scale. For example, the quality of the received data (images, spectroscopic data, and lithography) is influenced by external and internal noises. External noises include mechanical and acoustic vibrations of the building, ventilation, classroom conversations, electro-acoustic noise (power lines in walls, mobile phones). Internal noise is associated with the presence of mechanical and electrical elements of the microscope and depends on the instrument configuration. As every education, the SPM-teaching has the aim to provide sufficient information support for preparation well-skilled students. For this purpose, the feedback of the students should be considered. Module character of micro-courses makes them flexible and has advantages for improving quality of education.

### VI. CONTENT OF MICRO-COURSES FOR SPM TEACHING

Since SPM has a great application potential from ordinary scanning of surface topography to surface modification, it is necessary to make a right choice of the measurement (or engineering) technique. Study of the principles should begin from the physical fundamentals of interaction between probe and sample surface. A set of micro-coursed at this step should

include such concepts as inter-atomic interaction (for atomic-force microscopy), tunneling effect (for scanning tunneling microscopy), wave properties of light (for scanning near-field optical microscopy), etc. On the basis of this background the specific of the suitable type of SPM should be investigated in details: choice of probes, sample preparation, conditions of measurements. Various types of SPM needs its own preparation procedure and demands in order to provide correct and reliable data.

The micro-courses of this level should include study of the probes characteristics, the methods of samples processing before measurements. Following familiarization with the tool and its software applications are aimed to demonstrate the measurements in practice. In spite the similar physical principles, the existing types can differ a lot in operation way.

A number of micro-coursed should be concentrated on description of the set-up, software of the microscope, necessary safety instructions. The special areas of this field are evaluation of results and processing of the data. In case of competent approach the important conclusions can be done.

The micro-courses should be oriented on description of possible artifacts of measurements and elimination of their negative effects and at the same time they should teach to extract maximum of useful information about the studied surface (at both visual and numeric style).

#### VII. ADVANCED METHODS OF SPM TEACHING

Noting the advantages of micro courses for the training of specialists in the field of SPM, it is also worth to mention that micro-courses can be used by students at any stage of education, and also act as an independent single training program.

The integrity and consistency of a teacher's activities combined with the comprehensible hierarchy of the topics provided to students ensure achievement of the desired result. Already at the initial stages of the teaching process, a forecast for further actions and potential corrections can be made. Methods can be divided into following categories:

- Preparation - the use of micro-courses before the start of basic training - involvement into the motivational process (videos, explanation of the fundamental laws on the basis of which the microscope principle is laid down).

- Focusing - is an addition to the basic training (working on specific tasks in the laboratory and processing the data obtained).

- Consolidation - consolidation of the received information, skills and knowledge (through independent work on the instrument).

Micro-courses provide both psychological comfort (stress states are minimized) and create favorable conditions for the educational process with maximum independence in an environment of realizable possibilities (temporal, physical, physiological).

The choice of optimal teaching methods is carried out by taking into account the total amount of all intermediate decisions: principles, goals and specifics of this discipline, as a result of which knowledge transfer, reinforcement of skills, and expected learning outcomes are ensured. In this regard,

micro-courses are very effective for teaching microscopy, their format simplifies knowledge transfer from person to person and delivers information to a user in small pieces that can act as independent elements, while being at the same time integrated into a common training strategy. Micro courses are also advantageous as regards to time and budget, what is especially important given the expensive equipment and the need for preliminary preparation of students for measurements.

#### VIII. TECHNOLOGY OF SPM EDUCATION

Not only are the content of the course, supported by appropriate methods, but also the technology of the courses preparation of great importance. The fundamental strategy of micro courses is 100% implementation of goals and objectives, consolidation of the material, the introduction of knowledge and skills in the field of nanotechnology. The proper implementation and use of micro-courses are achieved when their form (content) and the way of their introduction (techniques) are conducive to the desire to be trained in techniques of microscopy.

Educational technologies by using methods, forms, tools and techniques are always focused on the implementation of the pedagogical process with a guaranteed result.

The development of a micro-course strategy consists in:

- setting goals with an emphasis on clarity - course content is dosed;
- accessibility – speed and accessibility to any section of the course;
- evaluation - assessment of how well the given information is internalized (by doing of tasks or taking tests);
- multimedia ways of presenting material;
- use of mobile devices;
- breaking into blocks and combining microcourses into a single unit.
- The format of micro-courses taking into account modern technologies provides optimal and rational opportunities for both students and teachers:
- For students:
  - Concentration - the micro-course is presented as a micro lesson (10-15 minutes), during such a short period of time the learning efficiency is at its maximum. It also allows more students to make measurements independently and with high quality.
  - Web Surfing - each lesson of each course has a link to a micro-course, which is a detailed version of this lesson.
  - Budget and time - on the one hand, a person gets the opportunity to pay only for the knowledge he needs, on the other - not to waste time in case the course has not met expectations.
- For teachers:
  - Easy creation of micro-courses - free and fast.

- Informativeness – micro-courses can be edited, improved and adapted to user expectations.
- Income generation - (paid courses).

## IX. CONCLUSION

Interdisciplinary fields need special design of education which includes modern technologies. Nanotechnology covers a wide range of engineering and science. Micro-courses are suitable approach to reach high academic level. Here we describe possible application of micro-courses for education to SPM. This methodology could be applied for other parts of education to nanotechnology. Such, single-topic parts of image processing procedures could be independently applied to a number of visualization techniques. Advanced design of micro-course ensures better understanding of the studying material at short time. The micro-courses are supposed to be useful for education of modern fast developing occupations.

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