eLearning as a support in education of young experimenters

Šebok Ján, Stuchlíková Ľubica, Nemec Michal, Benkovská Jana, Harmatha Ladislav, Donoval Daniel
Dept. of Microelectronics
Faculty of Electrical engineering and Information technology, Slovak University of Technology
Ilkovičova 3, 812 19 Bratislava, Slovakia
lubica.stuchlikova@stuba.sk

Abstract—**The paper presents the authors' motivation, experience in a design, development and a realization of the interactive course "Semiconductor materials and devices electrical characterization". This course is oriented on the preparation and start of young experimenters research activities in the SemiTest Laboratories. These laboratories on the Department of Microelectronics at Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava are responsible for investigation of the semiconductor materials quality and device reliability by capacitance-voltage measurements, current-voltage measurements and deep-level transient spectroscopy technique. The course "Semiconductor materials and devices electrical characterization" is assigned mainly for students working on individual projects in these laboratories. This eLearning project is accessible on the educational portal „eLearn central".**

Keywords- interactive web course; eLearning; semiconductor materials and devices; flash animations; SemiTest laboratories

I. INTRODUCTION

At the present time the information technology is important part of human life. The increasing volume of information requires the implementation of the most effective education processes in practice. These progressive technologies including eLearning, offer a wide range of applications and are characterized by creativity and interactivity.

The greatest advantages of eLearning: e.g. multimedia elements, time and place independence, wide information sources inspired authors to use this form of education as support by teaching the students – young experimenters – who are participating in the research activities in the SemiTest Laboratories as a part of their study individual projects.

A. Individual projects on Department of Microelectronics

Students' individual projects are very important part of Bachelor Study Programme Electronics and Master Degree Programme Microelectronics at Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava.

Bachelor projects engage students of third year Bachelor Study Programme Electronics. The main aim of these projects is to absorb the knowledge related to methods and techniques of handling relatively large projects. They should be able to show the ability to solve complex problems quite individually and creatively and according to modern methods and instructions used in sphere of Electronics. The students firstly have to master the problematic by finding and processing the corresponding references, than analyze the issues and as a result they must submit their final thesis in writing and also present it orally.

Diploma projects and Diploma thesis involve the students in first and second year of Master Degree Programme Microelectronics. As a part of these projects, students have to master the methods and techniques of solving difficult tasks involved in Microelectronics field. They must learn how to individually and creatively handle complex problems within experimental projects according to modern methods and instructions used in this sphere. Essential part of their work is to gain the ability to analyze all possible solutions leading to suitable result and create models if it is needed.

These projects are focused on educating students so they can easily integrate into working process. During the projects on Dept. of Microelectronics, students get the opportunity to become co-workers of researchers in research activities. It is very important to ensure the high quality conditions for realization of these projects as we need them to be completed successfully.

B. SemiTest Laboratories on the Dpt. of Microelectronics

SemiTest laboratories as a part of the Department of Microelectronics at Faculty of Electrical Engineering and Information Technology serve for research and analyzing of semiconductor materials and structures. These laboratories exploit techniques like current-voltage measurements, capacitance-voltage measurements and deep-level transient spectroscopy.

There are three basic automation measuring workplaces in this laboratory:

Capacitance – Voltage measurements workplace deals with a high frequency capacitance-voltage (C-V) method [1 - 3], non-equilibrium C-t method [4], a time-domain constant capacitance (cC-t) technique [5] and their limitations. C-V, C-t and cC-t measurements are being performed using the 4280 1 MHz C Meter/C-V Plotter Hewlett-Packard, Agilent

4284A 20Hz-1MHz Precision LCR Meter. The output data are stored e.g. with programs HERMES, IRIS...

Current – Voltage measurements workplace exploits the Keithley measurements set up (Keithley 238 High Current Source Measure Unit and 237 High current source measure units, Keithley 478 High Voltage Source Measure Unit - picoampermeter/ voltage source, Keithley 617 Programmable Electrometer, all with computer control system) [2] and also Agilent Technologies N5767A System DC Power Supply, Tektronix TDS3054B eScope Four Channel Digital Phosphor Oscilloscope. This workplace is controlled by program DCAT, etc.

Workplace for measuring Deep Level Transient Spectroscopy (DLTS) serves for identification of parameters of deep traps in semiconductors. DLTS workplace has two complex equipments: new Digital DLTS system DL8000 Accent (Fourier DLTS) and a Polaron Bio-Rad DLTS spectrometer measurement equipment with a boxcar detection system for acquiring the DLTS output signal [6, 7]. Both equipments use liquid nitrogen cryostats.

These methods are used to determine the semiconductor material quality and device reliability [8, 9]. Semiconductor materials and devices have a pre-eminent technological position because of their importance in integrated electronic systems building for wide range of applications. A key ingredient of this technological dominance has been the rapid advance in the quality and processing of materials and devices.

The researchers, teachers and students working (operative) in SemiTest laboratories need sufficient information about the measurement equipments and software; knowledge about physical processes in measured structures and also the set-up possibilities of real automatized measuring stations is needed. Student participating in the research activities of SemiTest laboratories in individual and team projects have only very short time for learning basic knowledge mentioned above. And often we also meet with the basic knowledge gap. This knowledge is very specific; therefore assistance of teachers and research workers is indispensable.

One of the ways how to create a database of educational material and research papers concerning study topic; to make study process more effective, more attractive, easier; is to design web interactive course "Semiconductor materials and devices electrical characterization" [10].

II. THE COURSE "SEMICONDUCTOR MATERIALS AND DEVICES ELECTRICAL CHARACTERIZATION"

This eLearning project is a standard interactive course in a course category "Electronics" accessible on the educational portal „eLearn central" (http://ec.elf.stuba.sk). The current version of „eLearn central" uses a course management system Moodle 1.9 [11]. Moodle (Modular Object-Oriented Dynamic Learning Environment) is a software package for internet-based courses and web sites producing. It is an open source software.

The course "Semiconductor materials and devices electrical characterization" deals with electrical measurement techniques: current-voltage measurements, capacitance-voltage measurements, a deep-level transient spectroscopy and barrier structures - Schottky structure, PN junction, MOS structure and transistor investigated by these measurements.

The focus is set on the basic principle of these methods and the set-up possibilities of real automatized measuring stations in our SemiTest laboratories [1 - 6].

The course was made as a modular system (Fig. 1), which was divided to the three different levels

- The first level is representing diagnostic methods. This level is oriented on automation measuring workplaces in the SemiTest Laboratories and basic principles of measuring barrier structures (Fig. 2 - 4).
- The second level defines barrier structures which are measurable by diagnostic methods – Schottky barrier structure, PN-junction, MOS structure and transistor. This level can be used as a support for face to face education of subjects dealing with these topics (Fig. 5).
- The third level is concerning with single measurements applied on ideal and real structures and examination of their behavior (Fig. 6).

Graphic design of the course is processed so that the user can see how the structures are related to measurement methods (Fig. 1). The users have displayed the entire scheme of the course and thus have access to all methods of measuring the individual structures. After passing the mouse cursor over each button, the related topic is highlighted. The individual buttons serve as links to information prepared for easy intuitive learning.

A. The format of course lessons

If a student enters the course, he can see three basic parts (Fig. 1). The main part is in the middle – Topic outline. After the first information: News forum, The aim of course, How to study in this course and Course authors follows an Interactive site map of the course (Fig. 1) and seven topics with educational materials.

On the left side there are blocks: People/Participants; Activities/Forums, Resources, SCORMs; Administrations; Random term in glossary.

On the right side there are blocks: Latest news, Virtual tours in SemiTest laboratory, Upcoming News and Recent activity.

The course "Semiconductor materials and devices electrical characterization" includes seven lessons, sixteen interactive flash animations and a number of hypertext references. The basis of an educational text in this course is composed by Diploma Thesis, Dissertations and papers presented on domestic and international scientific conferences and in journals produced during research activities in the SemiTest Laboratories.

The course lessons were created by an adaptation and conversion of the education text according to the requirements of Internet studies – eLearning. The lessons were converted into SCORM packages (Fig. 2 - 5).

Figure 1. Visitor´s view of the Student menu "Semiconductor materials and devices electrical characterization"; interactive site map of the course content

The specification SCORM (Shareable Content Object Reference Model) was developed by ADL - Advanced Distributed Learning [12]. It is a model defining relations among course components, data models and protocols with the aim to permit interchange of these courses among individual learning systems satisfying the SCORM specification.

SCORM helps define the technical foundations of a Web-based learning environment. At its simplest, it is a model that references to a set of interrelated technical specifications and guidelines designed to meet high-level requirements for learning content and systems.

SCORM currently provides an Application Programming Interface (API) for communicating information about a learner's interaction with content objects, a defined data model for representing of this information, a content packaging specification that enables interoperability of the learning content, a standard set of meta-data elements that can be used to describe learning content and a set of standard sequence rules which can be applied to the organization of the learning content. SCORM packages were developed using a software THESIS Professional.

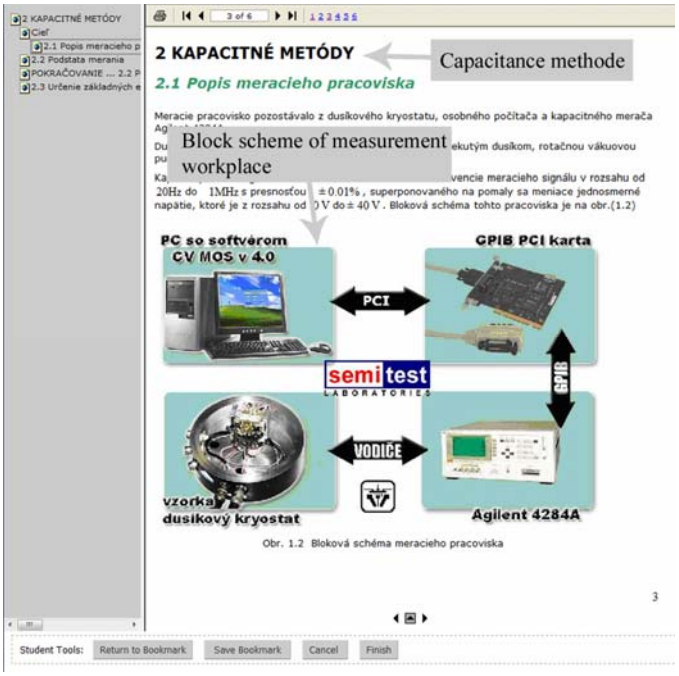

Figure 2. SCORM lesson – "Capacitance methods" – Description of measurement workplace

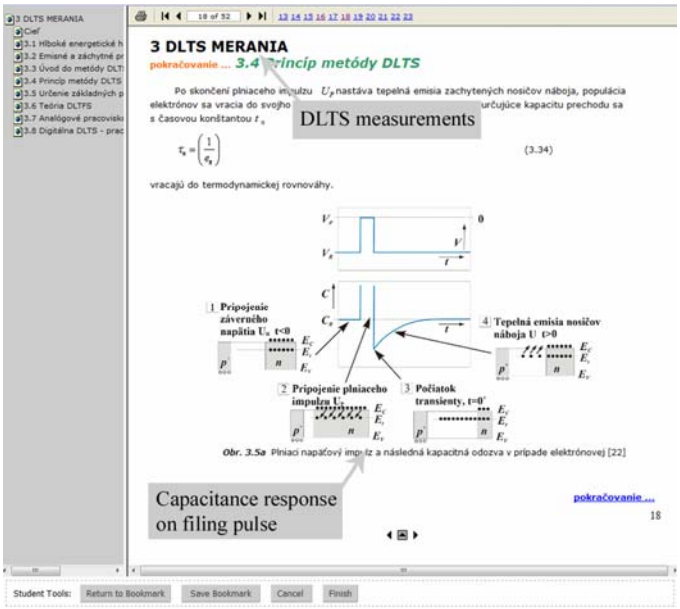

Figure 3. SCORM lesson – "DLTS measurements" - The principle of DLTS method

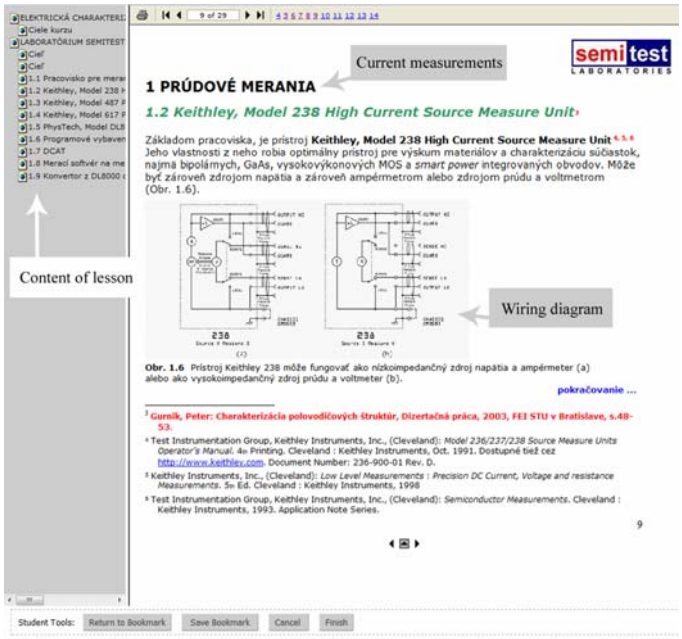

Figure 4. Student's view of the SCORM lesson –"Current measurements" – Kethley, Model 238 High Current Measure Unit

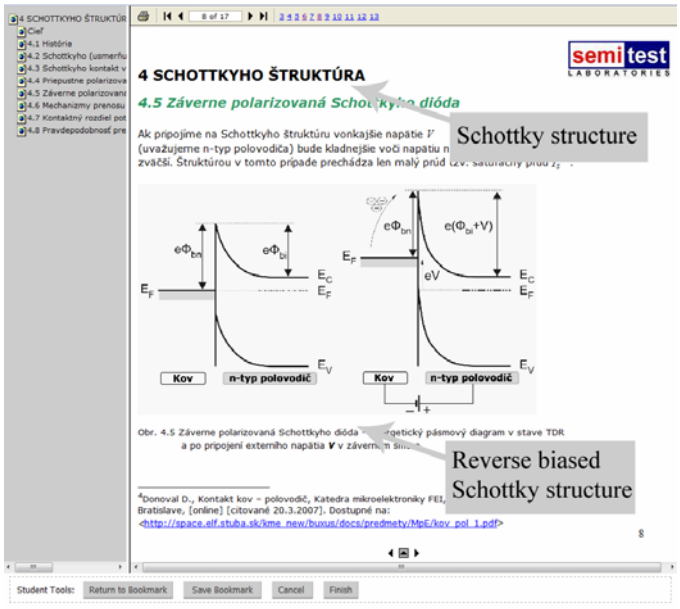

Figure 5. SCORM lesson – "Schottky structure" - Energy diagram of Schottky structure at reverse bias.

Each lesson is introduced with a definition of study objectives. The lesson texts had to be divided into short well-defined units enriched by content-related schemes, illustration photos and images. Each lesson has also prepared a printable version of the educational material in pdf format. The texts were complemented by numerous navigation elements (Fig. 2 - 5), such as the active navigation menu bar on the left side of the screen. It provides a full lesson content overview, so that the student just selects the topic and the matching study section immediately appears on the screen. Further navigation elements include the arrows in the page heading and footing. In the case a text exceeds the page scope, the active continuation link enables to jump to the next page.

The new part of course is also hyperlink on databases of research articles about Gallium nitride – very perspective semiconductors wide bandgap materials. This database has been creating by students – young experimentations in diagnostic laboratories at Dept. of Microelectronics [13].

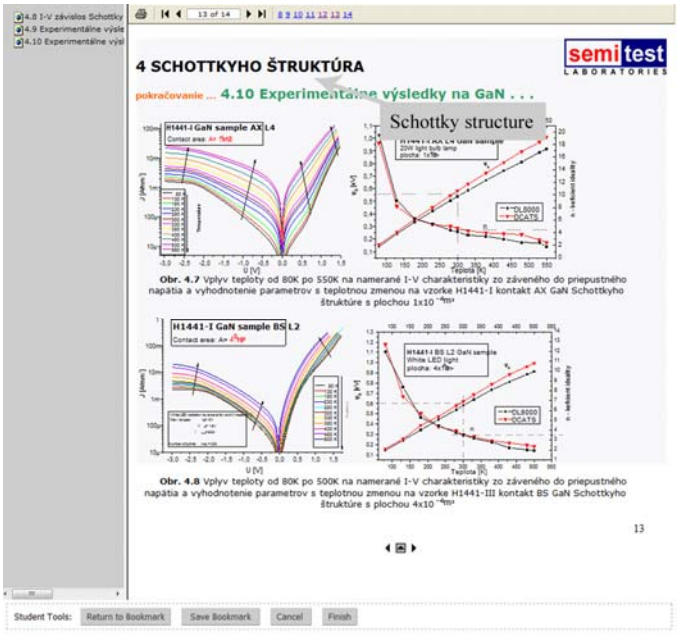

Figure 6. SCORM lesson – "Schottky structure" -
The experimental results on Schottky structure on GaN.

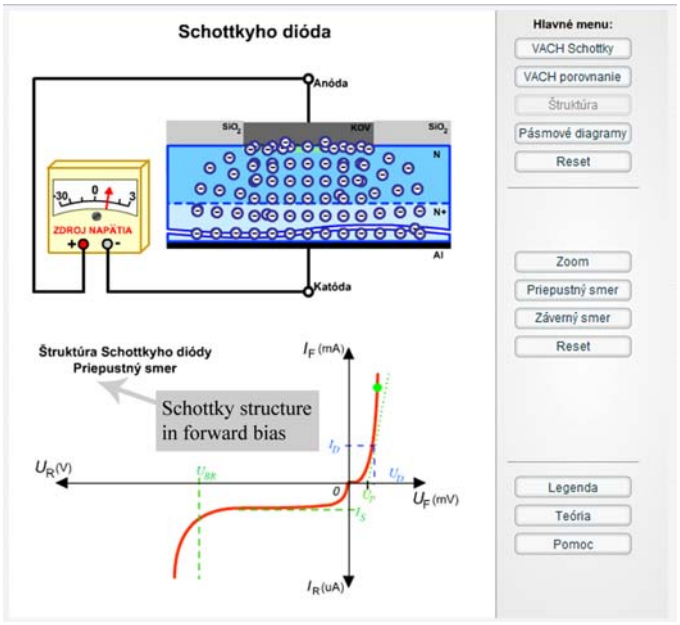

Figure 7. Interactive flash animation – "Schottky structure" -
The inner processe in Schottky structures in forward bias

B. *The interactive flash animations*

Sixteen interactive animations developed in Adobe Flash are added in this course. These animations are displaying inner processes in Schottky structure (Fig. 7), pn junction, MOS structures and work with software Hermes. Our goal was to help the students to understand these processes and measuring procedures through various interactive animations. The animations have been designed in such a way that they would show animated details of a given object and so help obtaining the knowledge much easier and faster. These original animations are uniqueness of our portal. All interactive animations are free available for everyone interested [14].

III. CONCLUSION

The initial plan was to use the potential of eLearning in education for young experimenters. We used our practical knowledge of designing eLearning courses on educational portal "eLearn central" and our long-term experiences with experimental work in Semitest laboratories.

The course "Semiconductor materials and devices electrical characterization" is being developed by members of the eLearn Central Team. It is a result of cooperation of teachers and students participating at individual and team projects. All our outcomes are a result of reciprocal interactions between teachers and students in the „eLearn central team".

Nowadays the course is in a process of updating of the educational materials. The modular structure of the course allows the course to be innovated constantly according to users' demands.

This course is accessible on the portal "eLearn central" for students on the link http://ec.elf.stuba.sk with access rights only. The aim of this course in future is to prepare the complex educational study material for students participating in the SemiTest Labs' research activities. During the course creating process we have used well known benefits of the e-learning.

The implementation in practice will show, whether we can help students in their work in SemiTest Laboratories in this way.

ACKNOWLEDGMENT

Authors' acknowledgment goes to all who participated on the development of this course; most of all to the Dr. P. Gurnik and Dr. M. Ťapajna, for their huge effort and participation on building SemiTest laboratories and team co-workers Ing. M. Benkovič, Ing. R. Šramatý, Ing. M. Vallo, Bc. M. Petrus, M. Hanáček and many others.

This work was performed under the Center of Excellence CENAMOST (VVCE-0049-07) project and supported by the Slovak Scientific Grant Agency VEGA 1/0507/09, and by the project KEGA 3/7248/09.

REFERENCES

[1] Gurnik, P.: *The characterization of semiconductors structures,* Dissertations, FEI STU, Bratislava, 2003.

[2] Kulikov, V., Donoval, D.: *The Parameter Extraction of Schottky Contacts by the "DCATS" Direct Current Automated Test System.* In:APCOM 2000, Liptovsky Mikulas, 2000, pp. 57-60.

[3] Gurnik, P., Harmatha, L.: *An Assembly for Diagnostics of Semiconductor Structures*, J. Electrical Engineering, 48, 1-2, 1997, p.52.

[4] Ťapajna, M., Gurnik, P., Harmatha, L.: *Fast Determination of Generation Parameters of MOS Structures*, In: J. Electr. Eng. 53, 2002, 9-10, 272.

[5] Písečný, P., Harmatha, L.: *A Set-up for Low-frequency Capacitance Measurement of Unipolar Structures*. In: APCOM 2002, Liptovský Mikuláš, 2002, pp. 86-89, ISBN 80-8040-186-1.

[6] Benkovič, M. *Identification of deep energy levels in semiconductor structures using DLTS method*, Diploma project, FEI SU, Bratislava, 2008.

[7] Benkovská, J.: *Electrical characterization of Schottky structures based on 4H-SiC,* Diploma thesis, FEI SU, Bratislava, 2008.

[8] Valent, P., Harmatha, L., Písečný, P., Benko, P.: *Physics of Breakdown in Thin Dielectric Films in MIS Structures*. In: Elitech 2005. Conference Proceedings. Bratislava : FEI STU, 2005, s. 109-111.

[9] Benko, P., Ťapajna, M., Fajta, M., Fröhlich, K.: *Determination of Electrical Parameters on Gate Stack with Metal Gate and Bevelled Thin Oxide*., In: APCOM 2006. Applied Physics of Condensed Matter : Proceedings of the 12th International Workshop. Malá Lučivná, Slovak Republic. 21.- 23. June 2006. - Bratislava : STU, 2006. - ISBN 80-227-2424-6. - S. 235-238.

[10] Semiconductor materials and devices electrical characterization, [online], 2008, The educational portal "eLearn central", Januar 2010, < http://ec.elf.stuba.sk/moodle/course/view.php?id=128>

[11] Moodle, 2006, [cit. 2010-08-04], <http://moodle.org/>

[12] SCORM 2004. Advanced distributed learning, 2006, [cit. 2010-08-04], http://www.adlnet.gov/Pages/Default.aspx

[13] Ryger, I., Hronec, P., Meszaros, B., Michniak, P., Piták, T., Petrus, M.: Coming new king of semiconductors Will be GaN?, Team project, Dpt. Of Microelectronics, 2009, Bratislava, Slovak Republic

[14] Interactive flash animation, [online], 2006, The educational portal "eLeran central", Last revision June 29, 2009 [cit.2009-09-10], < http://ec.elf.stuba.sk/moodle/course/view.php?id=39>

.