

## OPTIMISATION OF A SOLAR CELL

*Exercise in simulation based training using the MODEM Tele-learning concept*

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### 1. Abstract

Simulation based education supports active learning, enables students to acquire knowledge easier and get acquainted with the professional simulation software.

Using Telematics within the courses introduces more openness and flexibility: the courses can be kept more up-to-date and adjustments to specific user needs can be implemented easier. Next to this it creates new training facilities at a distance, e.g. Tele-teaching, Tele-conferencing or Tele-assistance. MODEM – Multimedia Optimization and Demonstration of Education in Microelectronics – an EC funded project exploits both technologies to establish a European wide training service for the microelectronics industry and higher education. MODEM uses a virtual campus by which access is given to its services. A one week course – Optimization of a Solar Cell – has been developed to demonstrate the concepts of using Telematics together with simulation based exercises. This paper discusses the course itself and the evaluation results of a pilot run.

### 2. Introduction

The MODEM project is focussed on exploiting new and emerging techniques in the area of simulation based learning, co-authoring and flexible delivery in order to enable better use and access to knowledge and resources available in the field of microelectronics. The goal of the project is to investigate the feasibility of a self-sustaining European wide training service for the microelectronics industry and higher education. This will be done using a *virtual campus*, a sort of market place where needs for education and training in microelectronics can be met with tailor made modules, courses and exercises. Amongst others, Tele-based courses are developed enabling peer learning as well as group exercises using synchronous and asynchronous techniques to communicate. One of the exercises, developed to show (some of) the concepts of this project, is a Tele-based interactive course on the optimization of solar cells. This course covers several Tele-techniques like: Stand-alone teaching with real-time access to a remote simulation server, peer learning, in which a group of students need to collaborate to solve a task, using shared resources (shared whiteboard or server application) and Tele-assistance using either synchronous (Chatbox) or asynchronous (E-mail) tools.

### 3. The Solar Cell Course

The solar cell course is derived from an already operational laboratory assignment given at the University of Twente as part of a broader education project (“Trimester 3.1 Integration project”). The text-based instruction handouts and always-available tutor have been replaced with MODEM’s simulation based learning environment (Fig 1).

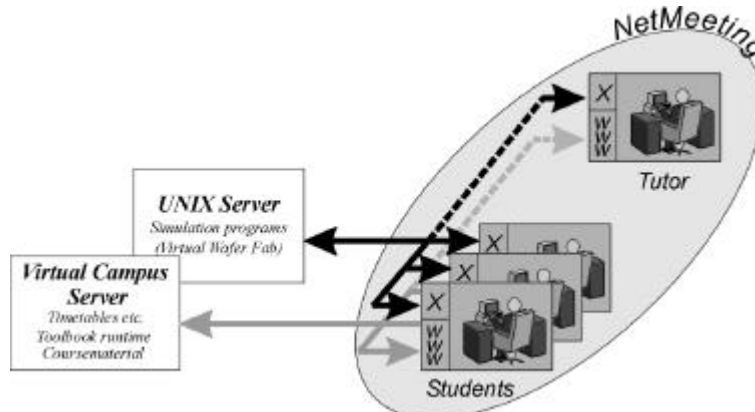


Figure 1: The MODEM learning environment.

Figure 2 shows a screenshot of the solar cell course running the Virtual Wafer Fab (left), the Toolbook course itself (upper right) and a Chatbox session (NetMeeting) (left).

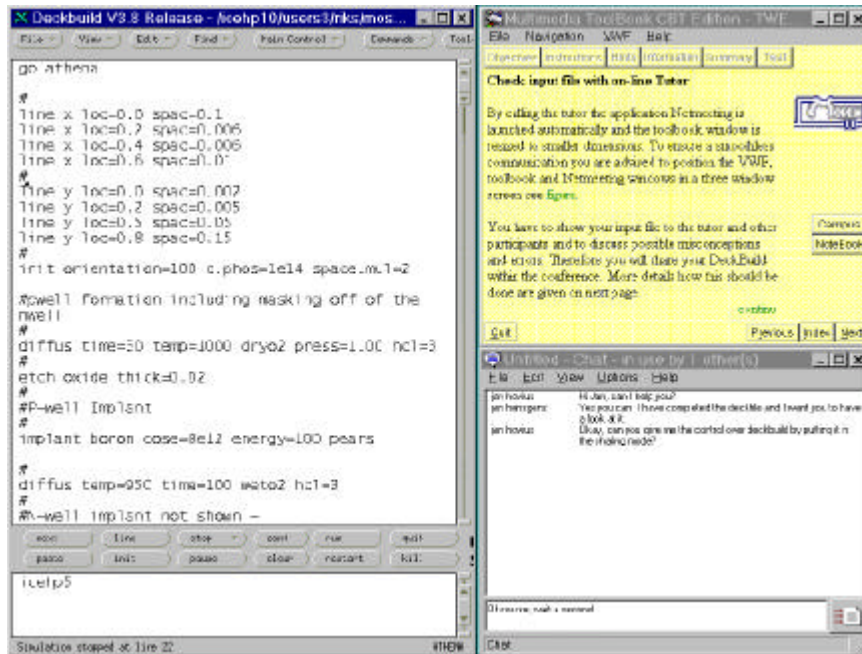


Figure 2: Screenshot of the Solar Cell Course: Left a simulation window (VWF’s Deckbuild), the course itself in the upper right corner and a Chatbox (NetMeeting) in the lower right corner.

Since the course is designed with Asymetrix's Multimedia Toolbook<sup>®</sup>, every student needs to have a runtime Toolbook library installed on his workstation (downloadable from the virtual campus) as a pre-requisite. Next to this Microsoft's NetMeeting<sup>®</sup> (shipped with Internet Explorer 4.0) is used for communication purposes and finally an X-Server package (Hcl Exceed<sup>®</sup>) takes care for communicating with the X-based Simulation package (Silvaco's Virtual Wafer Fab<sup>®</sup>) running centrally on a UNIX server. The exercise focuses on optimizing a solar cell device for maximum power efficiency when used in sun light conditions. By varying junction depth, doping level of the top layer, properties of the anti-reflection coating and layout of the metallisation of the top electrode the maximum achievable power output has to be determined. Device simulation using Silvaco's *Virtual Wafer Fab* and circuit simulation using SPICE provide the means for determining the electrical output of the device. The exercise itself is preceded by a short theoretical study on the operation principle of a solar cell together with a short hands-on exercise exploring (some of) VWF's capabilities. The students conclude their assignment with a final report on the results obtained and send this via E-mail to the tutor.

The reserved time for completing this course has been determined at 40 hours. This is a significant longer period than is involved in working with "traditional" courseware.

#### **4. Pedagogic scenario of the course**

The pedagogic scenario of The Solar Cell course has clear constructivistic aspects, uses the Internet environment and has incorporated aspects of collaborative learning. Students are expected to be actively constructing knowledge by seeking for information and testing hypotheses, and discussing results with others. To give them some sort of guidance in this complicated environment and complex task, some form of scaffolding is implemented and some other elements to reduce cognitive load:

- To make sure the students are active and can do simulations quickly VWF commands are presented combined with copy/paste facilities.
- Simulations can be started by pressing buttons in the courseware program
- Information is available about the course structure and objectives
- Background information about VWF is available
- Important figures and tables can be enlarged, and are also available via the menubar
- Each sub-task contains some open questions and assignments
- To get help while solving questions/tasks hints are available
- Students are promoted by the instructional program to discuss answers or work together with others and can contact other students or a tutor by pressing certain buttons (starting NetMeeting or E-mail facilities)
- There is a link to an editor to make notes and write down answers to questions and assignments.

#### **5. Pilot run, evaluation and conclusions**

A small group of students from the department of Electrical Engineering of the University of Twente evaluated the course using pre-configured workstations (WINTEL based) connected to the Internet via the TCP/IP protocol. They were working at

different locations. All actions undertaken were recorded by observers and evaluated after each session.

An overview of the results, as extracted from the filled in questionnaires (based on Raven & Johnson (1989)) is given.

- The students gave the course a high score on aspects like learnability, functionality, navigability, interface design, speed, workload and precision.
- A less good score was obtained on aspects like helpfulness, controlability, likeability and groupwork suitability.

Some of the remarks sorted by scenario used:

- *Stand alone* – The students didn't encounter many problems using the course in a stand alone setting except for becoming familiar with the VWF environment (different Windows/Mouse definitions).
- *Tele assistance* – Main problem encountered with this discipline was a good planning of the (pre defined) time slots at which the tutor was available for online assistance: since every student works at his/her own pace it appeared to be difficult to schedule such synchronized sessions. This sometimes forced students to stop the session and wait! It was remarkable that the use of a trial and error strategy was preferred over consulting the online manuals in such a case.
- *Group work* – In this setting a group of students need to solve a problem together using the Chatbox and shared applications. Except for some small problems (bugs) with the communication software (NetMeeting) chatting and sharing applications didn't give rise to complaints from a technical point of view. On the other hand it appeared to be difficult to use such tools with more than two people involved. You need to be very disciplinary in order to prevent "mouse wars" (who's in control of the application) and chaos in the Chatbox.

As a result of the pilot run some general conclusions towards Telematics based courses and the Solar Cell course in particular, can be drawn:

- The acceptance of online communication tools (E-mail, Chatbox, and Whiteboard) doesn't appear to be problematic. In this era of internetting those tools are already of common use.
- The Internet can provide an efficient way for online sharing of expensive resources (e.g., remote use of professional TCAD software).

## 6. References

- Hensgens, J., Rosmalen, P. van, Hovius, J., Mouthaan, T., Merriënboer, J. van & Leemkuil, H. (1997). *Network-based training for microelectronics using simulation tools*. Paper presented at the European Materials Research Society Spring Meeting in Strassbourg (June 16-20, 1997).
- Leemkuil, H., Meikle, F. & Trayhurn, D. (1998). *MODEM Evaluation report*. Deliverable 7.2<sup>1</sup>

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<sup>1</sup> MODEM deliverables can be downloaded from the following WWW-location: <http://nmrc.ucc.ie/projects/modem/deliver.html>