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Microelectronics Technology Course for a Virtual Campus

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Abstract

The presented work deals with the development of an interactive course available on a website, related to microelectronics technology, and that can implement the database of a virtual campus. The advantage of such a product is to get in addition of traditional text, animations of technological steps which are involved in the fabrication of an integrated circuit, some basic modeling of technological steps such as oxidations or diffusion of doping atoms, animations of complete process such as CMOS one. It can be used as a long distance learning tool, and thanks to the possibility of student testing it can constitute a credit of a university diploma. The first version written in French is currently translated in English, Finnish and Romanian.

1. Introduction: a new approach is needed

The teaching of the microelectronic technology similarly to other engineer studies needs a lot of figures, graphs and technical explanations. Our experience in this approach gave evidence that a majority of French students as well in engineer schools as in universities find the technology lectures mainly boring and/or difficult to understand. In order to make easier the understanding of such a study new educational approach has to be developed.

In parallel, recent assessment made by SEMI International [1] showed that the number of graduate students in the field of microelectronics is much lower than the expected need for the five next years; thus new tools have to be adapted and accessible to a large spectrum of students as well in basic education as in continuing education, long life learning or long distance learning, in order to adapt graduate student or engineers to microelectronics.

Thanks to the recent strong improvements of computing equipment as well as multimedia possibilities, presently at a relatively low cost, a new interactive educational tool was developed in the field of integrated microelectronics technology. This tool is interactive and available on a website (http://gmv.spm.univ-rennes1.fr). The advantage of such a product is to get in addition of traditional text, of course links between several chapters and items but also several types of animations, simulations or special applets. It can complete efficiently the traditional teaching, in presence of the professor or can be used as previously mentioned in distance learning program. Indeed, this tool is now expected to be a component of a larger number of modules to constitute a virtual campus in electrical and information engineering as proposed in another presentation of this conference.

This paper gives several indications about the development of this tool and how we expect to use it in a virtual campus.

2. Objective of the course

The present course is devoted to students who want to get some specialization in microelectronics and more especially in microelectronics technology, at second or third university cycle levels (graduation or post-graduation levels) or for a continuing education in this field. This module can complete the lectures, which prepare students to work in clean rooms that are accessible in the microelectronics centers of the (French) National Committee for Education in Microelectronics [2-3]. It is also a preparation to the use of several other education products existing on CD-ROM [4-6]

3. Features of this tool

One can connect to this tool via Internet. The document is written in html format and uses Java applet possibilities for special calculations, simulations or animations. This allows to any user to minimize the transfer of data via the network and thus to save time, the Java version in common browser being suitable to activate the animations or modeling. The present website address is **http://gmv.spm.univ-rennes1.fr**. This realization is the result of a European Community support in the frame of INEIT-MUCON Socrates Intensive Program and of a bilateral collaboration between Universities of Sibiu (Romania) and Rennes 1. The first stage of this work was presented at EAEEIE’2000 [7] and EWME’2000 [8]. The first version is written in French language but new versions are in progress especially in English, Finnish, and Romanian before other translations made by other partners of the THEIERE Network (Socrates program) following the INEIT-MUCON one. The total course volume is equivalent to about one hundred web pages with extra pages for animations and simulations .The web page presentation is shown figure 1. The main menu is displayed on the left hand side each item being a link to the mentioned chapter. The upper part contains the sub-chapters links.

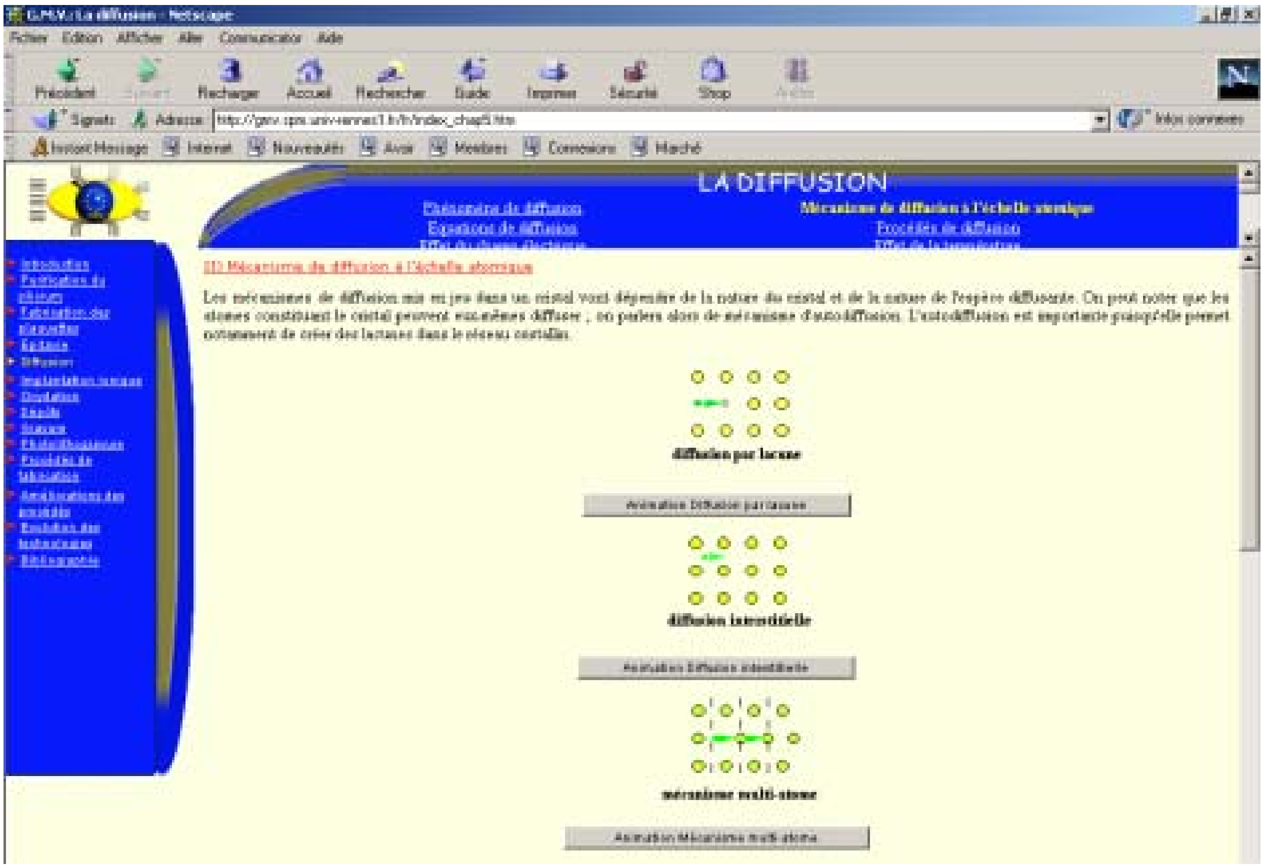

Figure 1. Web page presentation of the course. The main menu is displayed on the left hand side each item being a link to the mentioned chapter. The upper part contains the sub-chapters links. Figures with animations contain a hot spot to activate this animation.

4. Course content

The first part consists in several chapters about the basic steps of a technological process with some animations allowing the understanding of basic physical phenomena such as diffusion of atoms in a crystal or technological steps such as ingot fabrication, ionic implantation or oxidation steps.

Indeed, we have for example included animation of the technique to pull an ingot by the Czochralski method. Figure 2 shows the animation proposed in our tool. It is also possible to describe technological phenomena occurring for example in the diffusion mechanisms, or animations of basic technological steps, which are involved in the fabrication of an integrated circuit. Figure 3 shows an example of a multi-atom diffusion mechanism. In this simple example, by moving the atoms of the lattice, it makes easier the understanding at microscopic level. Figure 3 shows the diffusion mechanism in presence of a big doping atom in the silicon lattice. Other mechanisms are described similarly such as amorphization during ion implantation or oxidation reaction.

The interest of such an approach was confirmed after discussion with students who have tested this tool.

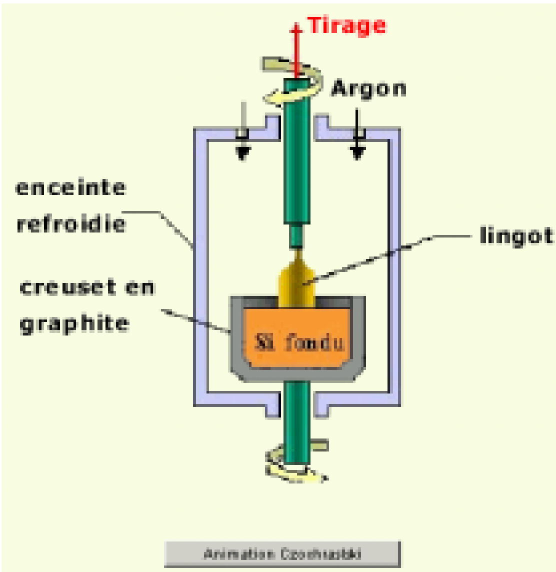

Figure 2. Example of a Java applet giving animation of the pulling of a monocrystalline ingot by Czochralski technique.

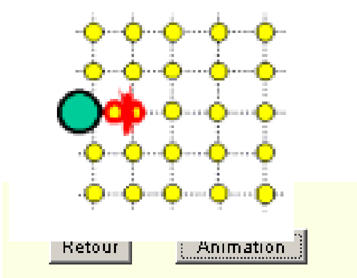

Figure 3. Example of animation giving an idea of the diffusion mechanism at atomic level.

We have also included basic modeling of technological steps such as diffusion of doping atoms in the silicon, dry or wet oxidations for which the student can change the physical parameters. Figure 4 shows thus a Java applet that allows a modeling of the oxide growth for a wet or dry oxidation. In this case, based on the Grove's model, the applet calculates the variation of the thickness in function of the duration for the parameters entered by the user, which are in this case the nature of the oxidation, the temperature and the duration of the process step. The proposed example concerns a wet oxidation processed at 1100°C. The thickness is plotted in function of the duration of the wet oxidation. By varying the parameters, the student can appreciate their strong influence on the final result.

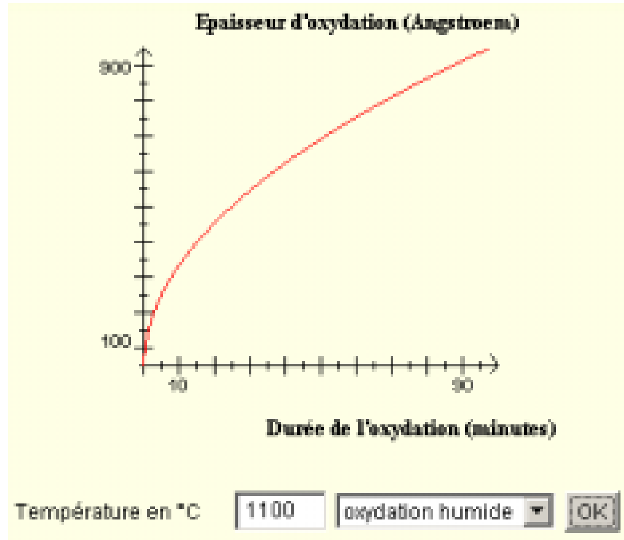

Figure 4. Example of simulation based on Grove's model that calculates the thickness of the oxide in function of the oxidation conditions. The student can act on the choice of the physical parameters.

After the presentation of technological steps, the second part is devoted to the description of the main complete processes such as bipolar, NMOS or CMOS ones. In addition, animations of complete process such as bipolar or CMOS ones can be performed, which allow progressing step by step, layer by layer, but also to go back in the case of understanding difficulties. Figure 5 shows an example of this interactive animation.

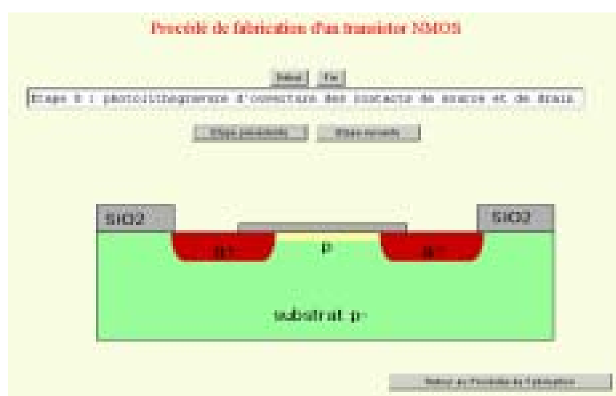

Figure 5. Example of animation describing a basic NMOS process. Each step is displayed.

All these animations and simulations carry much improvement in comparison with a classical book or a monographic document. Because the server of this tool can be located in any place, it is of course a potential component of a numerical campus. But to achieve this function, evaluation of the student must be included in the package. We present in the following some elements about the control of students.

5. Student evaluation

In order to test the students, a specific student control applet was created. It contains a multi-choice questionnaire splitted in two levels: beginner ("*debutant*") and advanced ("*expert*"), which allows a self-evaluation of the students, and which appears at the end of each chapter, as shown in figure 6.

For the second level, the questions are more precise and time-limited. A score is displayed at the end of the evaluation and the good answers are displayed in case of mistakes. Figure 6 shows the icons added at the end of each chapter. After clicking on the "control "icon, the control applet is activated. Figure 7 gives an example of the multi-choice questionnaire proposed in the case of beginner.

Figure 6. These both blue icons establish a link with multi-choice questionnaire control applets; two levels are proposed: beginner ("*debutant*") and advanced ("expert").

The score of the student who has answered the questions proposed in the control of the figure 7is shown figure 8.

Figure 7. Example of multi-choice questionnaire submitted to the students. They have to click the good answer. After their choice, the students get their score.

Figure 8. Example of score after answered the questionnaire shown figure 7. The good answers are also mentioned.

At this stage, the proposed applets are mainly involved in self-evaluation. But, the content of the questionnaire is brought by a specific file loaded in the server, which can be changed or renewed at any time by the professor, that means especially for a training control or an exam. The software aspect is thus easy solved; however, the identity of the tested student and its direct environment, such as presence of a friend, access to a database or another interactive system, cannot be checked easily. The presence of a "tutor" cannot be avoided at present time.

6. Conclusion

We have thus tried to involve all the specificities of an interactive course. The first version was developed mainly thanks to the support of INEIT-MUCON European project; written in French it is currently translated in English, Finnish and Romania, thanks to the implication of partners of our THEIERE European network [9]. Thus this module can constitute a piece of a larger set of similar tools devoted to the education in Electrical and Information Engineering. That is the reason of works started in the frame of the French Club EEA Association [10], that has the objective to build a database [11], at least at the French level, in the field of electronics, microelectronics, automation and control system, telecommunication, or power electronics with this type of interactive tool. It corresponds to the new trend at international level, as proved by the recent position (May 2001) of the Massachusetts Institute of Technology, which announced giving access to all its courses on Internet. To analyze our impact, we have added a simple statistical tool [12] that allows controlling the number of connections, the number of different origin sites, and the number of pages that were read by the visitors of the site. In addition, information about the origin of the connections can be displayed, especially the country. Figure 9 gives evidence of the huge increase of connections and visits during the last academic year 2000-2001; a deeper analysis shows that more than 50% of the origin sites of the visits are from foreign countries. Note that for the last month, June 2001, this statistic corresponds to the first week only.

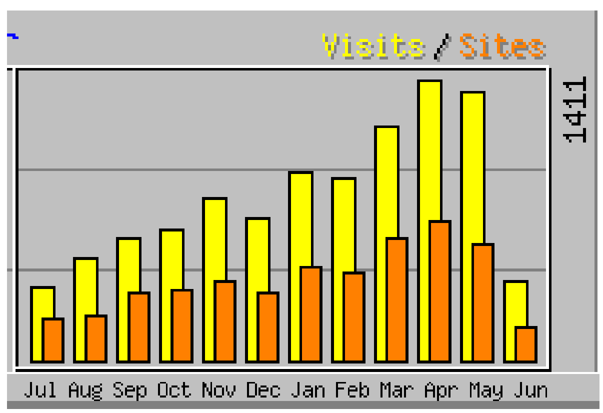

Figure 9. Statistics use of the website [12]. We observed a strong increase all along the academic year 2000-2001. This statistic was made at the beginning of June 2001.

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[10] The author is President of the French "Club EEA" Association, "*Club des Enseignants et des Chercheurs en Electronique, Electrotechnique et Automatique*". He works on the development of a virtual campus in electrical Engineering field with the President of The Education Commission of this Association, Professor Y. Danto. See their common paper proposed in the same conference [11].

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[12] Bradford L. Barrett, software loaded from, website: http://www.mrunix.net/webalizer/

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