ISSM 2004 Paper: E-Learning for Microelectronics Manufacturing

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Abstract – In this paper, we report on an EC-funded project concerning the creation of content for e-learning for microelectronics manufacturing. The project E-LIMM (E-Learning for Microelectronics Manufacturing) aims at addressing the shortage of highly skilled industrial staff in the microelectronics industry by creating high-quality training and e-learning courses and modules. This demands qualification and continuous re-qualification by training programs for operators, technicians, engineers, freshmen, and managers. The goal of the project is the application of information technology and especially multimedia learning content integrated into networked systems for training and further education of the staff in microelectronics manufacturing. The four main topics for content creation are process technology, factory automation and operation, process and metrology equipment as well as environment, safety, and health. Training and learning material for microelectronics skills will be created and integrated into web-based training platforms. Based on this project, the development of skills and knowledge share will be considerably strengthened.

INTRODUCTION

For the application of new technologies with ever shorter lifecycles, the availability of the most recent knowledge is mandatory. Therefore, the intervals within which the acquired knowledge bases have to be updated become shorter and shorter. Training and education in a time of rapid technological changes become a task which is much more important than ever before. It is well known that the microelectronics manufacturing techniques including process and equipment technologies as well as software control systems are getting more and more sophisticated, and the learning expenditure for the personnel is growing accordingly. Furthermore, the technological progress and the improvement of the information exchange facilities lead to increased requirements with respect to further professional training. In particular, to fulfill the requirements of factory operation and automation as well as environment, safety, and health specific to microelectronics professional training for qualification and re-qualification of workforce is urgently required. Microelectronics manufacturing-specific skills and knowledge are only partly covered in courses and education.

Furthermore, the microelectronics industry and related business sectors (e.g. MEMS) are extremely innovative and knowledge-based. Students, engineers, scientists and others need to develop, transfer and share knowledge. The knowledge flow from researchers and universities to industry and vice versa needs to be strengthened to achieve and ensure a leading-edge position for companies and institutes in this market.

The reported results are part of the E-LIMM project [1] which aims at improving and accelerating the development of microelectronics-specific skills by setting up new training and learning courses, material and schemes. The E-LIMM project contributes to fast and appropriate training and re-training to keep skills up-to-date. Furthermore, during the employees' career it assists them in the process of change their skills to acquire different and new knowledge. The lifelong learning process is also supported.

SCIENTIFIC AND TECHNOLOGICAL OBJECTIVES

Professional training requires the use of adequate training and knowledge management methodologies, the conservation of the existing knowledge and also the extension of the knowledge base with respect to new problem areas. Web-based training systems are ideal for this purpose. Therefore, the training and learning material for microelectronics skills is prepared for integration into web-based learning management systems. Appropriate systems were specified and chosen. Content according to the educational and industrial needs has been integrated into the different systems. The learning and training material is based on the requirements of the semiconductor industry and is prepared in a platform-independent structure. The comprehensive work package integration is responsible for the technical issues and puts special emphasis on didactic and pedagogical issues as well on a suitable media mix.

The material developed is capable for integration into different commercially available learning management systems by using the SCORM standard [2]. In the course of the project, two systems have been used: The learning management system "s.mart by s.team" and "JCollege by T-Systems". Two central web-based systems with limited user access were installed by project partners for use within the framework of the project. Both systems are operated in parallel and host the identical course material. Additional decentralised systems at different partners' sites are planned.

The focus is on industry-needed content adjusted to the application in a manufacturing environment. Therefore, the training and learning material covers four main areas:

Process Technology

An understanding of the principle of process technology is necessary for the entire microelectronics manufacturing staff

with different degrees of expertise depending also on the depth of involvement in this topic. Therefore, this material covers the basic understanding of the general process flow, starting with the definition of CMOS and FETs, and answers the question as to why process technology is constantly evolving. People should not only get a good idea of both device manufacturing and front-end-of-line issues but also of interconnect manufacturing and backend-of-line issues. The higher level provides a more detailed insight into individual processing steps. The processing steps are complex physicochemical interventions on the substrate, often requiring highly complex equipment, extremely pure chemicals, and rigidly controlled conditions. Skills require a good understanding of the individual processing steps, and awareness of the fact that these steps can affect circuit behaviour and manufacturing yield.

Factory Automation and Operation

Amongst the process technology aspects, a lot of knowledge is necessary for the operation of a semiconductor manufacturing site. A highly automated manufacturing environment with complex and non-linear process flow and logistics has to be controlled by means of different facility monitoring and control systems. The operation of such control systems and optimisation of the production plant concerning throughput, cycle-time and efficiency requires fundamental knowledge and also continuous staff training. The same is valid for the automation systems in a semiconductor fab including material distribution systems, material storage systems, wafer containers and wafer handling tools.

Process and Metrology Equipment

Process and metrology equipment is an important part in the value-added chain of a microelectronics manufacturing factory and has a large impact on the progress of the semiconductor industry. Equipment has to deal with different levels of diversity, extendibility, flexibility and scalability. The use and operation of production equipment includes many different aspects: operation, physics, mechanics, automation, control (real-time and run-to-run), advanced process control, communication with host computers (factory interfaces), loadports, maintenance, overall equipment efficiency, cycle time, safety, installation, supply, clean-room aspects etc. Effective and efficient equipment operation is essential to keep the costs of semiconductor processing and thus the costs of integrated circuits as low as possible. A processing fault in one single process step might lead to the scrapping of one or more production lots of considerable value. Therefore, the appropriate qualification of staff operating that equipment is extremely important and appropriate skills are essential to achieve good yields.

Environment, Safety, and Health

The reduction of energy consumption is required to address the problem of global warming as well to reduce manufacturing costs. Resource conservation for water, chemical compounds, materials and other raw materials are future challenges. Preserving our environment implies the substitution of toxic materials and the recycling of industrial waste. Worker protection programmes and information prior to the use of new equipment and chemical compounds have to guarantee safety, and health of the industrial staff and requires continuous improvement programmes. Due to government legislation, all these environment, safety, and health concerns, which affect all aspects of electronics manufacturing, have been transformed into an integral part of the design and manufacturing process. To meet these requirements, the industrial staff member has to be prepared for all of the above topics. Training, education, qualification and re-qualification as well as creation of environmental awareness are required to minimize the environmental pressures and the risks to health and safety.

Figure 1 gives an overview of the areas of training and learning material as well as a rough idea of the content.

PROJECT PARTNERS

The consortium has been formed to bring together the necessary expertise and active support and guidance from industry by leading semiconductor manufacturers and research insti-

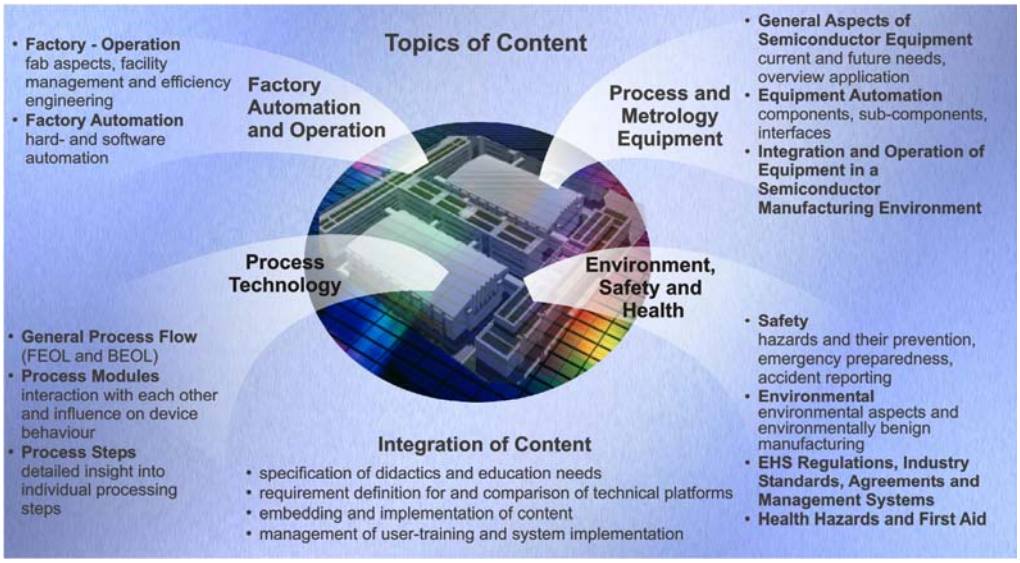

Fig. 1 Main subjects and content of the E-LIMM project

tutes as well as software and e-learning experts for this challenge. The consortium consists of 12 partners which are grouped according to their main tasks in the project:

The partners leading the different work packages are:

- IMEC, Belgium, for Process Technology Content
- M+W Zander, Germany, for Factory Automation and Operation Content
- Fraunhofer IISB, Germany, for Process and Metrology Equipment Content and Project Management
- NMRC, Ireland, for Environment, Safety, and Health Content
- s.team, Germany, for Integration of Content

The other industrial/institutional partners are:

- AMD, Germany
- AMI Semiconductor, Belgium
- ATMEL Rousset, France
- digital spirit GmbH, Germany
- FhG IZM, Germany
- Infineon Technologies Dresden, Germany
- Philips Semiconductors, Netherlands

Five major semiconductor manufacturers are participating. M+W Zander, a company for the planning and realization of turnkey chip factories, is responsible for the topic factory automation and operation. Software issues, systems and integration are within the competence of the e-learning companies s.team and digital spirit. R&D issues will be covered by the institutes NMRC, IMEC and the Fraunhofer institutes IZM and IISB. The project is coordinated by Fraunhofer IISB.

CREATION OF CONTENT

Didactics and Educational Needs

Didactical issues for the creation of e-learning modules have become of special interest [3, 4]. In the beginning, the content was specified for each area and together with the industrial partners, the learning goals were defined. During the process of defining the learning goals for each work package, a list of topics was generated which is somewhat similar to the table of contents of a book. These lists or tables of contents provided the basis for subsequent work.

In e-learning, modular structures are common practice. Therefore, the created e-learning modules are small portions of material which provide easy access to the content. The user does not have to work through a lot of information at one time, like when reading a book. These modules have an approximate learning time of 20 minutes. It is in the nature of a modular structure that an individual module can be used without necessarily going through the whole row of its linear predecessors. Due to this flexibility, the modules are not numbered. Instead, the titles indicate the interrelations, e.g. “Efficiency engineering: An Overview”. The tables of contents created in the beginning served as a base to define these modules for each work package. A module should always be self-understandable, i.e. cover the topic that it is about in a closed way. However, there may exist references to other modules. This modular structure also requires modules which serve as an introduction to the topic. Tests and examinations for the different topics are considered as separate “test” modules and can cover the topics of more than one “information” module.

Each module has a determined structure and sequence of pages: the first page briefly introduces the topic with the learning goals and required time, followed by several chapters (with several content pages including graphics, animations, videos, sometimes interactions in each chapter) and a summary page that sums up the main aspects. A standard template for the first page, the page containing learning goals and the summary page as well as a variety of templates for the content pages is used to ensure uniformity over different modules and work packages.

Each page can have a graphic, animation or video that illustrates or accompanies the text and may also include interaction to motivate the user and to catch the user’s attention. To make the material more attractive from a design point of view, graphics, photos and pictures may also be used for design issues only. But in general, it is preferable to use them for didactic reasons. Special emphasis is put on using multimedia technology, especially two- and three-dimensional animations to easily explain complicated interrelations.

Creation Process for e-learning Modules

The creation of e-learning follows a detailed and defined multi-step procedure. The agreement on the content list for every area and rough learning goals had been approved at the beginning. First, the creation of a storyboard for every module is started and after checking and evaluation of these storyboards, the e-learning modules are created. For storyboard and module creation, templates had been created earlier. This ensures that every content creator uses the same structure for the storyboard and e-learning module. Between the storyboard and e-learning module creation and finalization, several checks and review steps have to be performed. The following list gives an overview of the steps and states, respectively:

0: planning of module
1: storyboard in preparation
2: draft version of storyboard
3: internal review storyboard
4: storyboard available for formal review
5: storyboard available for technical review
6: storyboard released for production of e-learning module
7: animations finished
8: e-learning module available for review
9: e-learning module integrated into learning management system reviewed by end users
10: first user training

Storyboards and modules will undergo several review procedures. The first major review is the formal and didactical check of the storyboard concerning its structure and parts to be included. There are also checks on whether the user is ad-

dressed sufficiently, whether the user is invited to be active, whether the language is correct, etc. After that check, where changes might also be necessary, the storyboard is reviewed by the expert in the corresponding field on content, text, language, figure and animation correctness etc. Here also, rework might be necessary. After the creation of the e-learning modules, two groups of people have to approve them: the experts (who already reviewed the storyboard) review the learning module and a group of users who test it for usability and understanding. For all reviews, evaluations and tests, templates have been created to make sure that storyboards and e-learning modules are checked in the same way. This is because a lot of different people are involved in the review process. Fig. 2 shows how the review procedure for the learning modules works.

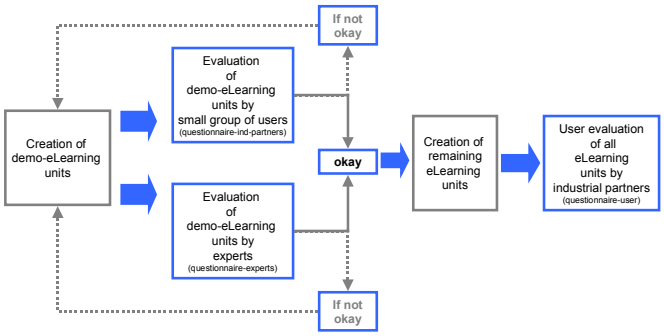

Fig. 2 Creation and evaluation process for e-learning modules

Software and Systems

It was planned from the beginning of the project that the modules from the four areas must have the "same look and feel" even if they are created by a number of different people. Therefore, we used the same authoring tool providing the capability to export all modules as SCORM-compliant e-learning units. Standardized learning units are extremely important to make sure that the modules can be implemented on every learning platform supporting the SCORM standard.

For the use of a learning management system, the following strategy have been applied: There will be a joint server running especially during the time for review and check of the modules. This is necessary as creation of the modules is an important phase of the project. The joint server can also be used after the end of the project. In parallel or after the end of the project, partners can run their own learning management system, integrate the learning units created into the joint project and also add own content, for example company-specific and confidential material.

The decision concerning the question of which learning management system will be used in the project was accompanied by a comprehensive evaluation process. In the beginning, the definition of user requirements by giving examples and the consortium's needs were collected. Based on the requirements, a detailed comparison and evaluation process of five systems were performed. Finally, the consortium decided to work with two different LMSs: "s.mart by s.team" and "JCollege by T-Systems".

Available e-learning units

Within the framework of the project, about 250 e-learning modules (corresponding to about 100 hours) will be created. The modules will provide material partly of a basic and intermediate level. The modules make intensive use of multimedia technology and heavily support user interaction. Due to these properties, the learning and training material strongly differentiates from conventional text books. The combination of e-learning modules from different areas will be used to create user-specific learning courses with high flexibility. These courses will be adjusted to the needs and backgrounds of the staff to be trained and educated.

SUMMARY

The paper reported on a project concerning the creation of e-learning material for semiconductor manufacturing. It was started in June 2002 and will end in May 2005. The overall project objectives are the creation, set-up and demonstration of new modules and courses for education, learning and training in semiconductor manufacturing for the following target groups: operators, technicians, engineers and managers. Training material of two different levels will be available. The emphasis of the content is on industry-driven requirements adjusted to the daily work in a factory.

The e-learning modules will be platform-independent due to the application of the SCORM standard. The creation of the e-learning modules follows a multi-step approach starting with content definition, storyboard creation, didactical and formal check, expert review, e-learning module creation, expert review and user test. Between all steps of the procedure, rework might be performed. Special emphasis is put on didactics, suitable media mix, interaction with the learner, a person-related language, and the inclusion of multimedia. At the end of the project, about 250 e-learning units will be available for training and education of staff.

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