The Virtual Cleanroom – a new way of teaching high technologies

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Abstract – **Education in high technologies is often characterized by a high degree of complexity, large economic efforts and very limited access to training locations. Industry, in contrast, requires qualified engineers with substantial practical experience backed by profound theoretical know how. We have developed a new concept, the "Virtual Technology Laboratory", to cope with this discrepancy in the field of microsystems technology. The "virtual machines" resemble the actual cleanroom facilities at Zweibrücken as close as possible. Students can train many aspects of the operation of the machines before ever visiting the real cleanroom. First tests show the learning success of subsequent hands-on-laboratory courses to be significantly improved. This blended learning concept, i.e. the combination of virtual and real training, might be very attractive for the collaboration of educational institutions, as well as for further education and on-the-job training of engineers.**

I. INTRODUCTION

Most of the equipment used for the fabrication of microsystems is complex, very expensive and available at only a few universities. Therefore most often students are not allowed to operate such equipment on their own. However, students can not fully grasp the complexity and the special problems related to the manufacturing of microsystems without a thorough hands-on experience in a microsystems technology cleanroom. Conventional approaches, like e.g. written materials and lectures might be effective means of teaching theoretical knowledge but are not capable in effectively imparting laboratory skills. In order to use the precious cleanroom time as effectively as possible and to ensure the best possible preparation of the students we use a novel combination of multi-media based training and compact cleanroom courses.

II. CONCEPT OF THE VIRTUAL CLEANROOM

University education in high technology fields like micro-system technology (MST) is not complete without intensive laboratory sessions. Students can not fully grasp the complexity and the special problems related to the manufacturing of microsystems without a thorough hands-on experience in a MST cleanroom. However, installation, operation, and maintenance of a state-of-the-art manu-facturing line for educational purposes require substantial financial efforts not affordable at every university site.

The department of microsystems technology of the Kaisers-lautern University of Applied Sciences at Zweibrücken has a fully equipped cleanroom accessible for educational purposes. Students should come to the cleanroom with the best possible preparation in order to use the precious cleanroom time as effectively as possible and to minimize any damage or bodily injury due to maloperations. However, conventional approaches like e.g. written materials might be effective means of teaching theoretical knowledge but are not capable in effectively imparting practical laboratory skills.

Within the INGMEDIA project in the framework of the German BMBF program "Neue Medien in der Bildung" the problem of suitable preparation of the students has been tackled by developing a new multi-media based approach, the "virtual cleanroom". It consists of a series of computer simulations of MST production machines or measurement equipment, such as a high temperature oxidation and diffusion oven, a sputter coater, a mask aligner or a film thickness probe.

Contrary to other e-learning approaches in MST, the simulations, i.e. the "virtual machines", are not just a schematic presentation of the basic functional principles of some abstract equipment but resemble the actual cleanroom facilities accessible within our collaboration as close as possible.

Like pilots train to steer a new type of airplane in a flight simulator before actually flying it, the students can train many aspects of the operation of the machines before ever entering the cleanroom at the campus of Zweibrücken. The virtual machines also include documentation on the real equipment such as hyper-linked manuals, as well as multi-media materials like videos and interactive animations, which help the students in better understanding the functional principles of the related processes and operations.

As an examples you may compare the virtual mask aligner and its real model, a SUSS MA6/BA6 in fig. 1.

Fig. 2 shows another example. The film thickness probe, FTP 500, has a virtual counterpart which has a nearly identical graphical user interface for the computer assisted film thickness measurements. In addition, an interactive computer animation helps in better understanding the measurement principle.

Concepts are developed to link the different virtual machines by virtual wafers, such that processing results from one machine can be used as input for a following machine. Therefore the students not only learn the operation of the individual machines, but also get to know about the subtle dependencies within a complete MST manufacturing process.

Fig. 1 The real mask aligner MA6 (top) and its virtual pendant, the computer based training tool (bottom)

As pointed out before, the "virtual cleanroom" is not thought to replace the real laboratory experiences. The virtual training of the students is an essential prerequisite for the successful implementation of very compact, yet complete practical courses as offered by the education network *pro-mst.*

In particular, the compact format allows performing the hands-on training in the framework of a one- week excursion to the campus at Zweibrücken. The virtual training should be performed at the site of the sending university or company before coming to Zweibrücken. The training programme could even be installed at the students' personal computer at his home.

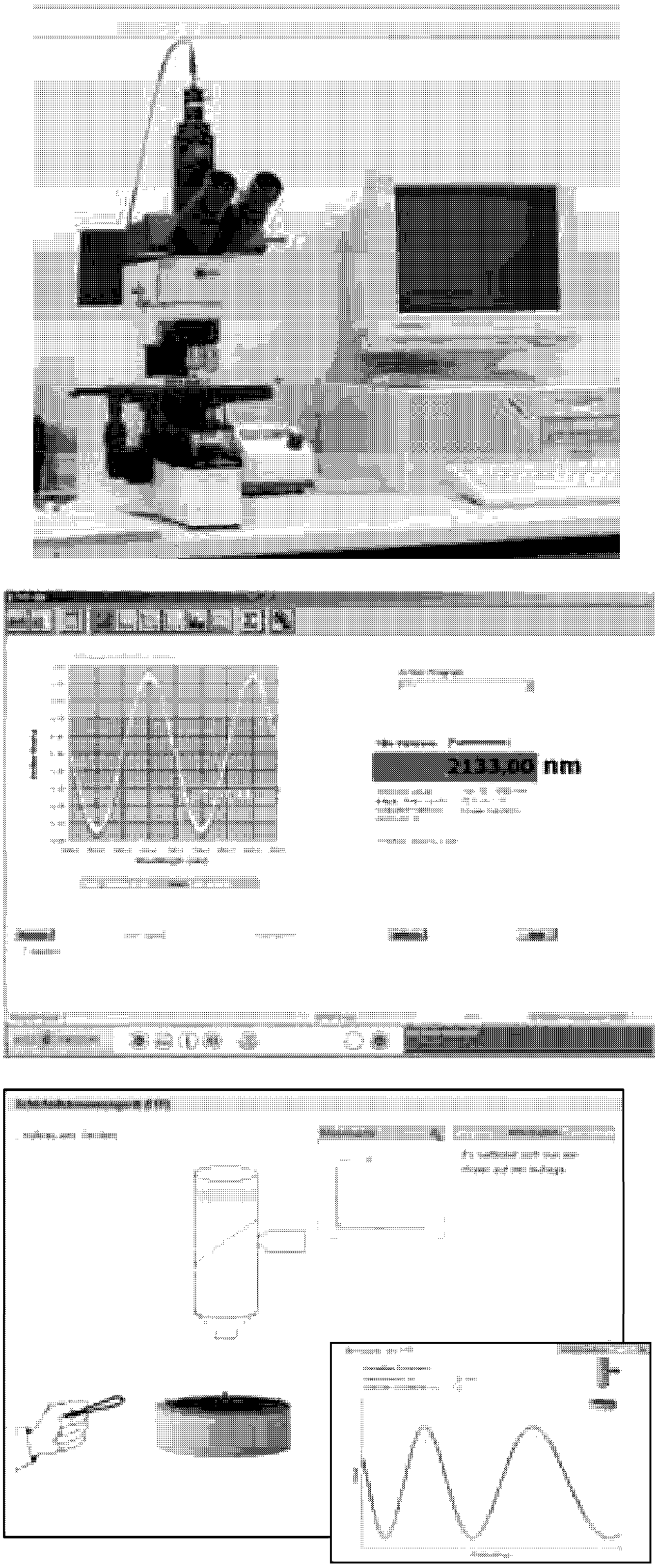

Fig. 2 Film thickness probe. Picture of the real computer controlled FTP (top), Graphical Use Interface of the virtual FTP (middle), Interactive computer animation (bottom)

III. FIRST RESULTS AND CONCLUSIONS

Testing this concept with different groups of students from different universities we found that virtually pre-trained students were much better prepared compared to others and could start to work much more on their own after only a very short introduction to the actual machines. The virtual training helped the students to act more carefully and independently in the laboratory and gain much deeper insight into the individual processes and the complete production line.

As an example, Fig. 3 shows the result of the recent lab-course of students from the university of applied science Aachen held in February 2004. All necessary manufacturing steps were performed by the students themselves. Within only one week of intense lab-work, they finally succeeded in making a simple but fully operational bulk micromachined piezoresistive pressure sensor. When they left Zweibrücken, they took with them not only their own silicon pressure sensor, die and wire bonded on a ceramic substrate, but also a deep impression about the chances and difficulties of manufacturing in a cleanroom environment.

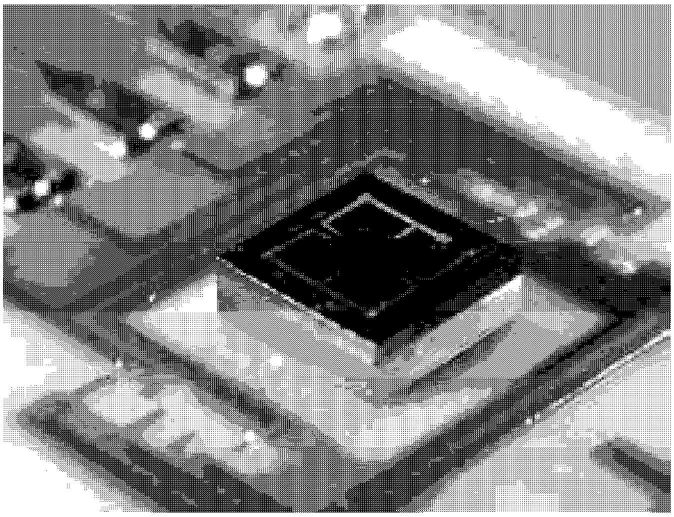

Fig.3 A fully operational silicon pressure sensor made by a virtually pre-trained student group from Aachen within a one week laboratory excursion to Zweibrücken.

We believe that blended learning concepts like the combination of a virtual pre-training with a compact hands-on course are very promising educational approaches in general. This holds true especially for such cost intensive subjects like education in microsystems process technologies.

This blended learning concept provides exceptional chances for a high value but cost saving educational scheme by sharing high quality teaching facilities and their costs within a network of different collaborating educational institutions.

In addition, the compact but intense practical courses in combination with preparatory computer based training will be very attractive for further education and on-the-job training of engineers or technicians new to this field of technology.

Further information may be found at www.ingmedia.de and www.pro-mst.de.

IV. ACKNOWLEDGMENT

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