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The Virtual Clean Room - a new tool in teaching MST process technologies

University education in high-technology fields like MST is not complete without intensive laboratory sessions. Students cannot fully grasp the complexity and the special problems related to the manufacturing of microsystems without a thorough hands-on experience in a MST clean room. However, installation, operation, and maintenance of a state-of-the-art manufacturing line for educational purposes require substantial financial efforts not affordable at every site. Students have to come to the clean room with the best possible preparation to use the precious clean room time as effectively as possible and to minimize any damage due to maloperation. However, conventional approaches like e.g. written materials are effective means of teaching theoretical knowledge but are not capable of effectively imparting practical laboratory skills.
The INGMEDIA project, funded by the Federal Ministry of Education and Research, tackles this problem by a new multi-media based approach, the "virtual clean room." It consists of a series of computer simulations of MST production machines, such as a high temperature oxidation and

Figure 3: The real mask aligner MA6 and its virtual pendant, i.e. the computer-based training tool.

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. our "virtual machines," are not just a schematic presentation of the basic functional principles of some abstract equipment but resemble the actual clean-room facilities accessible within our collaboration as close as possible.

As an example, you may compare the virtual mask aligner and its real model, a SUSS MA6 in Fig.1.
Thus students can train most aspects of the operation of the machines before ever visiting the clean room at the campus of Zweibrücken, like pilots train to steer a new type of airplane in a flight simulator before actually flying it. The virtual machines also include documentation on the real equipment such as hyper-linked manuals, as well as multi-media materials like interactive animations, which help the students in understanding the functional principles of the related processes and operations. The different virtual machines are linked by virtual wafers, such that processing results from one machine can be used as input in a following machine. Therefore the students not only learn the operation of the individual machines, but also get to know the subtle dependencies within a complete MST manufacturing process.

The virtual training is followed by a hands-on laboratory session in the clean room of the University of Applied Science in Zweibrücken. Within one week of clean room work, for example, the students themselves perform all manufacturing steps necessary to end up with working bulk micromachined piezoresistive pressure sensors. During this week they get an in-depth view of the opportunities and problems of manufacturing in a clean-room environment. We found that due to the virtual training the students come to the clean room much better prepared and can start to work on their own after only a very short introduction to the actual machines.

The virtual training of the students is an essential prerequisite for such compact, yet complete laboratory courses. In particular, the compact format allows performing the hands-on training with external, virtually pre-trained groups of students. In the future this might provide possibilities to share costs and teaching facilities within the framework of 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 of engineers and on-the-job training.

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