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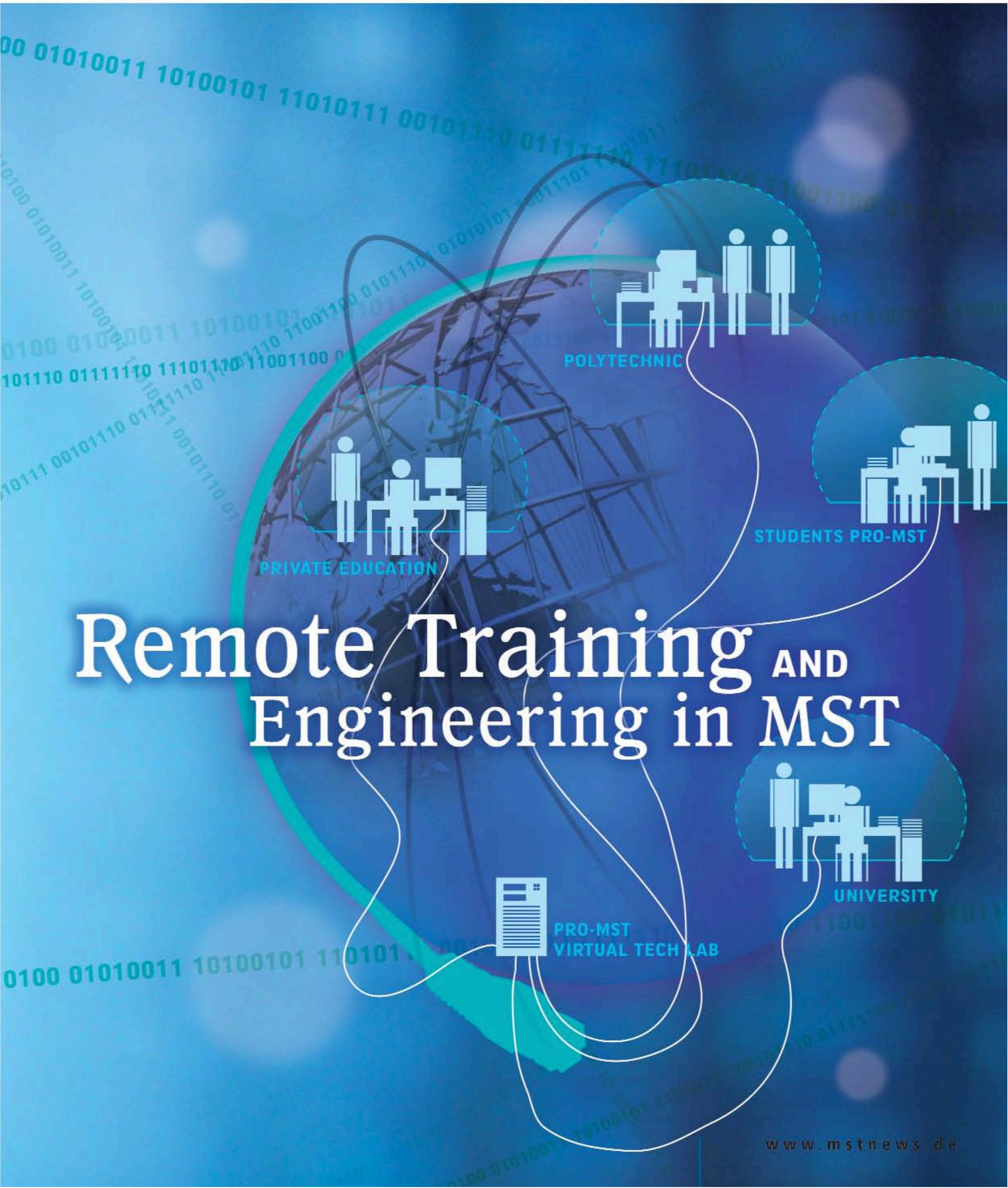

Remote Training AND Engineering in MST

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Adopting the Foundry Concept of Semiconductor Fabrication on Educational Schemes and the Virtual Technology Lab (VTL)

A. Picard, P. Kämper, A. Schütze, D. Wallach and Th. Walter

Teaching high technologies like MNT or other modern topics as e.g. bioengineering has to tackle such frequent problems as the high cost of state-of-the-art lab infrastructure and equipment. In general, hands-on training with appropriate tools is limited to very few examples. Moreover, even if state-of-the-art lab equipment were available, the complexity of modern equipment would not allow students the freedom of real experimental experiences. Instead, students have to follow rather restricted operating instructions without any possibility of exploring the features of the fabrication tools. The training and educational foundry pro-mst has developed a highly efficient blended learning system that addresses the above problems of high-tech education: pro-mst offers other educational institutions access to MST training facilities at moderate costs with state-of-the-art equipment in a clean room. This is complemented with an efficient method of preparatory training with the Virtual Technology Lab (VTL).

Introduction

Micro- and Nanotechnologies (MNT) are regarded as key technologies and essential for the competitiveness of highly industrialized countries. MNT comprise rapidly developing high technologies, are very interdisciplinary and cover a wide variety of applications. “High tech” in an educational context also means that you have to deal with very expensive and complex machineries. The affix “rapidly developing” intensifies the difficulties in keeping educational equipment up-to-date. Multidisciplinarity and the variety of applications on the other hand imply that it is difficult to handle every aspect of MNT on every educational site. Educational institutions have to decide on a clear profile and to focus their resources on their individual strengths.

As an example, the number of educational institutions offering study courses in MST has been rapidly increasing since 1995, but only very few can offer appropriate hands-on courses on the fundamental process technologies within an up-to-date clean room environment. It is a simple fact that the enormous investment and running costs of a training clean room are beyond the budgets. Actually, in certain cases clean rooms for advanced R&D or production purposes are available – but clean room managers are very reluctant to give

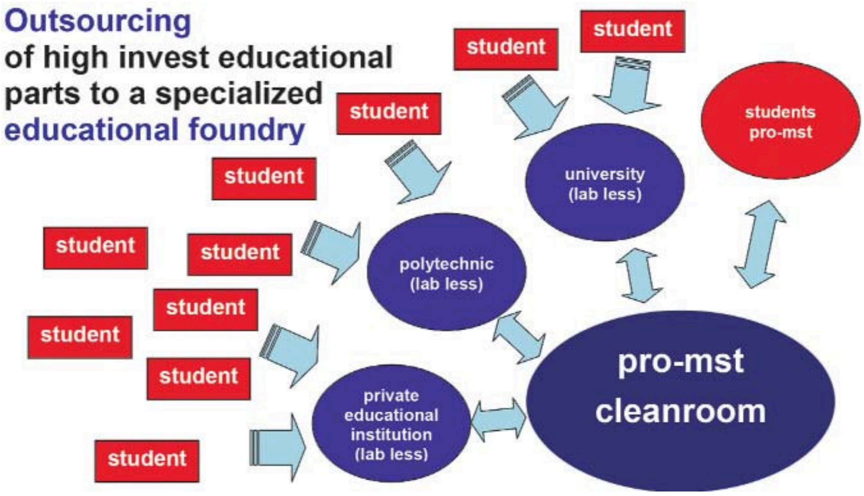

Figure 1: Adopted foundry concept within high-tech education.

access to inexperienced students. High-tech machineries and production lines are very sensitive to maloperation. Even a minor mistake within a process line can cause severe problems in yield or postpone the success of R&D projects for months.

Many other new fields like nanotechnology or bioengineering, but also classical disciplines like RF electronics or hydraulic engineering, face a similar key problem: up-to-date practical experience for students during their university education is very limited, resulting in suboptimal education results.

One way to address this situation is cost sharing within a scheme that we have termed education and training foundry.

An Education and Training Foundry: pro-mst

pro-mst is a network of several universities and partners from industry and R&D institutes as well. pro-mst acts as an education and training foundry while offering hands-on MST courses in a 300 m² training clean room at the campus Zweibrücken of the Kaiserslautern University of Applied Sciences. The fully equipped clean room, various measurement tools and a small assembly facility allow the fabrication of complete silicon sensors within a state-of-the-art semi-professional environment.

The concept of the training foundry resembles the very successful business concept of production foundries within microelectronics and MST fabrication. A foundry is specialized on fabrication processes and collects orders from different fab-less operating companies. This results in a very high degree of cost efficiency and productivity on both sides, i.e. foundry and orderer. The foundry can achieve an optimum rate of utilization (e.g. of a CMOS process line) and the orderer can concentrate on his specific profile and offers his own clients a lean but complete service (e.g. customer-specific ICs)

Fig. 1 shows how pro-mst adopted the foundry concept for high-tech MST education. Different “lab-less” educational institutions do offer cost-intensive educational study courses as MST to their clients, i.e. students. The part of the very expensive clean room training is sourced out to the training foundry. Lab-less, of course, only refers to a specific clean room lab for general educational purposes. It does not mean that there should be no laboratory at all. As an example, the University of Saarbrücken runs a very sophisticated clean room for advanced R&D projects, but they use the training facilities of pro-mst for the general practical education within the study course mechatronics/MST. Within only one week of intensive training students can build their own silicon sensor as shown in Fig. 2.

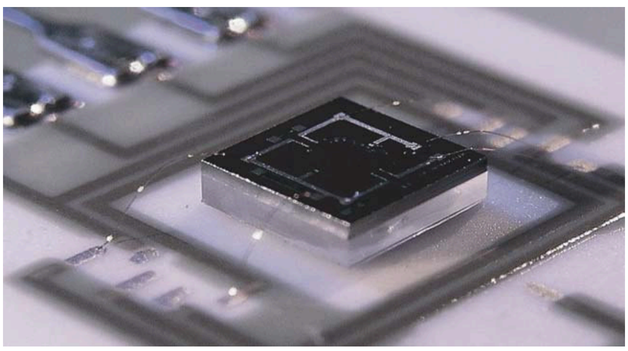

Figure 2: A simple, but fully operational silicon pressure sensor, manufactured by students from Aachen within a one-week excursion to the pro-mst clean room in Zweibrücken.

A proper preparation of the students is an indispensable prerequisite for such an intensive and ambitious lab course with real hands-on experience. Severe operating errors must be avoided since they might be dangerous for both the operator and the equipment. On the other hand, it would not be appropriate if the students just watched how professional operators handle the expensive equipment!

Moreover, in many cases modern high- tech equipment gives access to the processes only via computer panels, and the process itself is hidden in a closed process or vacuum chamber. This makes a direct experience of process fundamentals extremely difficult even if the students could operate the machinery by themselves.

pro-mst tackles the two problems of proper preparation and the “hidden processes” within modern equipment by a Virtual Technology Lab (VTL).

Virtual Technology Lab (VTL)

The Virtual Technology Lab is an essential part of the blended learning concept of pro-mst and comprises a set of interactive computer simulations, process animations, and illustrative videos.

- **Simulations** are employed for complex machines, which are controlled either by computer via a GUI or a machine control panel. The simulations resemble the user interface of the machines and respond interactively very much like their real counterparts at the training foundry
- **Animations** are used in those cases where only limited interaction occurs between the machine and the user. Animations are also advanta-

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geous to clarify the theoretical background or to illustrate hidden items (for example the optical pathway in the film thickness probe).
- **Videos** are used to show e.g. manual operating steps where simulations or animations would require too much effort for the desired effect. One example is the wafer handling for the mask aligner.

The machine behaviour, i.e. the result of the processes performed by the machine, is modelled, based on either a simplified physical model (e.g. the Deal-Grove model is used for the thermal oxidation of Si in the simulation of the high-temperature oven) or on a data field obtained from the real machine and interpolated by the software (e.g. the virtual sputter coater is based on the characteristics of the real sputter coater). In some cases, the data input by the user is simply checked for being within acceptable boundaries (e.g. the anodic bond simulation checks up on correct parameters for temperature, pressure, voltage etc.). It is important to note that for the desired effect, i.e. better understanding and preparation for the real lab course, the physical exactness is less important than the look and feel of the simulation.

Conclusion and Outlook
Three years of experience with the MST training foundry and evaluation of the Virtual Technology Lab has resulted in several clear indications for improving education in high-technology fields:
- While theoretical knowledge forms the basis, hands-on experience is important for an in-depth understanding of complex technological processes.
- Real hands-on clean room experience is achieved within a comparatively short time frame if students can concentrate on the content instead of learning basic machine operation due to proper preparation with the help of VTL.
- While the effort necessary to develop the simulation tools and user support for a virtual technology lab is quite extensive, this effort is justified if students from not one but several universities can profit from it. Moreover, comparing the costs of VTL with the investment and maintenance costs of a training clean room it becomes clear that the blended learning concept of VTL and educational foundry is an efficient way for providing high-quality practical experience in high-tech areas in general.

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E-learning Concepts for Electrical Engineers

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The advantages of the internet and the new media are supervision, accessibility and communication. Many obstacles such as price, time demand, and handling hinder the application of electronic courses. There is some hope that web 2 will remove some of these problems.

The Classical Approach
About a decade ago, together with many e-systems like e-mail, e-banking and e-commerce, e-learning became an interesting application of the new media. This approach was accompanied by many hopes – especially of the politicians – that education would become simpler and, even more important, less expensive. Especially university costs were expected to be reduced drastically. One thought of standardized courses that would be distributed by a single person replacing a whole faculty staff. The students would get them on-line at any location in the world. Examinations would be held by videoconferences. Again the student would have no need to appear at the university. In summary, the e-learning concepts at the time strongly reflected the ideals of a distance teaching university.

This hype is over now. For a demonstration let us have a closer look at the University of Hagen, the government-based and controlled German distance teaching institution. It has experienced all the hopes, changes and obstacles of e-learning. In the

Figure 1: Logistics centre of 1978