

Progress in Electronics Packaging Virtual Laboratory Development

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Abstract

The development of information technology has opened new perspectives in electronics packaging education to prepare engineers for the needs of the 21st century. The Department of Electronics Technology has been working on the improvement of the education in this respect for many years. It has obtained an IEEE/NSF grant in 1999 to create the Virtual Laboratory, a solution of the educational support with the newest and high-quality Web-technology. This paper gives a summary of the results of the one-year long practical development.

Introduction

The Department of Electronics Technology at the Technical University of Budapest has been playing a significant role in the education, research and development of electronics technology in Hungary for more than 35 years. Electronics technology is the area of technology associated with or applied to the realization of electronic circuits and systems. Considering that today's electronics is microelectronics, in the last decade the Department has directed its energies towards the study of packaging and interconnection, printed wiring technology, thin and thick films, multichip modules, laser technology, sensors, actuators and displays, quality control and reliability, computer aided design and manufacturing, computer integrated manufacturing and production control among others. [1]

In the hierarchy of the University the Department of Electronics Technology belongs to the Faculty of Electrical Engineering and Informatics. The Faculty graduates electrical and information engineers on the master level, offers postgraduate programs and awards Ph.D. degrees for the scientists working in the related areas.

In the Electrical Engineering Branch there are obligatory core subjects to study for all the students in the first six semesters. Since the knowledge of technology is necessary for all electrical engineers, there is a core subject with the title Microelectronics and Technology in the fifth semester, which allows the students (about 450 every year) to get acquainted at the basic level with the realization technology of electronic products and develops their ability to communicate with the specialists of other fields. Complementary to the lectures the students have to take part in a set of laboratory exercises to study manufacturing processes such as printed wiring technology, thick film technology, surface mounting, vacuum technique, thin film processing, photolithography, laser material processing, packaging, quality control etc. [2] These processes are grouped into three main laboratory exercises:

- Processing technologies of printed wiring boards

- Thin film deposition and patterning by photolithography and laser engraving
- Thick film technology and surface mounting

In the second part of the curriculum students are offered a range of two-year long degree programs. The Department of Electronics Technology is responsible for those degree programs that aim at teaching material science aspects, the physical design, fabrication processes and manufacturing systems of electronic components, circuit modules and units. These programs are Microsystems and Circuit Modules (about 50 students/year), Computer Integrated Manufacturing (ca. 30 students/year), Design and Manufacturing of Electronic Equipment (about 20 students/year). Complementary to the lecture courses each program contains a large set of laboratory experiments as well.

Project Outlines

The rapid development of packaging technology is accompanied by the dramatic change in the knowledge required from engineers, researchers and scientists working in this field. Microelectronics packaging education for both undergraduate students and working engineers has increasing importance. It is, however, at a much lower level than electronics and microelectronics education in general. A possible reason for this is the high cost that is necessary to carry out hands-on experiments. [3]

An interactive virtual microelectronics packaging laboratory environment can provide a new tool in practical education both for students and instructors. Interactive multimedia web-based training programs gain greater effectiveness from this medium. This way of learning allows the user to enter into a world that attempts to imitate situations of real life, providing immediate, real-time responses to the user's input. The use of graphics, animations, sounds make the virtual environment more realistic and the training more effective and enjoyable.

The main reason the Department has begun developing the Virtual Laboratory was to be able to support the existing microelectronic packaging education at Technical University of Budapest. Several papers have been published in the past few years on the Electronic Components and Technology Conferences and other forums to provide reports on the current status and plans of education and to obtain grants for the further development.

The targeted audience, as mentioned above, includes the large group of students of the Electrical Engineering Branch, who attend the lectures of Microelectronics and Technology. In addition, it involves those who take part in any of the degree programs of the Department, a smaller group of undergraduate students and Ph.D. scholars who would like to perform research in the real laboratories and have to determine

the processing parameters prior to the real experiments. But the Virtual Laboratory is open for everybody who wants to take part in distance learning courses on packaging technology, thus students from other universities are welcome, just as are practicing engineers. The Virtual Laboratory can be accessed from the homepage of the Department of Electronics Technology: <http://www.ett.bme.hu>.

The language of the Virtual Laboratory is English. This is acceptable for the Hungarian students as well, since they have to take a technical foreign language examination parallel to their engineering study before the end of the fifth semester. 90-95 % of the students choose English as foreign language.

Considering the technical background of the Virtual Laboratory the basic idea of the specific developing tools was the use of a traditional, user-friendly HTML editor, e.g. Microsoft's FrontPage for the Web pages, Java and JavaScript for different interactive animations and simulations. At an early stage of the development we realized that there was a better software tool available for carrying out our objectives. This program is called Flash and it provides a new approach for the developers.

Macromedia's Flash – the basis for the Virtual Laboratory

Flash is a vector-based animation tool, invented especially for providing more colorful and "intelligent" Web pages – with less developing requirement on the part of the programmers.

As both drawn objects and characters are converted to vectors the resulting movie is resizable, thus allowing a high-quality playback on any type of computers with different settings. The embedded bitmap images are resized as well. Creating an interactive Flash animation is quite simple. Drawn, written or imported objects can be easily animated, can change their shape, color and their transparency. Calculation and string-related operations are also supported, just like sound, which are compressed to MP3 format. Flash content is published as a Flash Player (SWF) file that is optimized for Web delivery.

Another big difference compared to a traditional and bitmap based animation tool is that the objects do the mentioned actions simultaneously and independently of each other. Their behavior, however, can be made dependent on each other's as well as on the users' input. For example, advanced programmers of Flash can even simulate the operation of a complex system with all of its actions and reactions.

The vector-based feature of this software also results in much smaller file sizes than those of the standard browser-supported GIF animations. For example the size of a complete, interactive system-simulation without photos (bitmap pictures) won't exceed 100 kilobytes, and a professional menu-system carried out in Flash will only take a few kilobytes to download from the Internet. Photographs are stored as JPEGs in Flash movies, so the growth of the file size can be estimated when using them with a given compression factor.

Flash movies can start playing after downloading the first few kilobytes, so the users' attention can be focused during the entire process of downloading. This may be important in

case of movies that contain many photos and the time of downloading is relatively long, especially for modem-users.

The choice of Flash as the main developing tool is completely acceptable, as it is already widely used all over the world. In December 1999 about 86 % of the Internet browsers had the Flash Player plug-in installed, which means that nearly 200 millions of online users could enjoy Flash-spiced Web-sites (source: Macromedia's Homepage). This number is increasing rapidly. Those who don't have Flash plug-in on their computers or have an older version (Flash 4 is needed to use the Virtual Laboratory) will be prompted to launch the automatic downloading process from Macromedia's Web-site. The Flash plug-in is, however, pre-installed in the newest operating systems and Web-browsers.

As it is possible to publish Flash movies as executable (.exe) files, we can conclude that this software may open new perspectives in lecture presentations.

The Structure of the Virtual Laboratory

To provide support for most laboratory exercises held by the Department of Electronics Technology, we decided to retain the physical and logical structure of our laboratories. The selected laboratories were divided into 6 groups identified with the technology they represent. These laboratories are as follows:

- Printed Wiring Board Technology Laboratory
- Thin Film Technology Laboratory
- Thick Film Technology Laboratory
- Laser Technology Laboratory
- Surface Mount Technology and Assembling Laboratory
- Computer Integrated Manufacturing Technology.

A few of our laboratories (e.g. Sensors and Actuators Center, Electronic Noise Laboratory) were not included in the first round of the development, as they have less importance from the core education point of view. They have greater significance in the research and development activity of the Department. The realized basic structure will effectively support the real laboratory exercises both of the core subject Microelectronics and Technology and the degree program courses.

When we enter one of the virtual laboratories, we will be offered six possibilities to continue our browsing:

- Intro
- Equipment
- Process
- Results
- Test
- Tasks

Entering the Intro section we can participate in a short introduction of the laboratory, considering its history, aims and main projects. Also important material can be found here on the background of the technology. For example, in this section of the Laser Technology Laboratory the users are initiated into the principles of laser operation and designing laser processing systems. These demonstrations are based on interactive Flash animations. Interactivity here helps the better understanding of the material and makes it easier to follow the

process, as the actions of the demonstration following each other are triggered by the user and can be replayed.

Having chosen the Equipment section, the user will find the basis of our virtual laboratories. First of all the ground plan with the whole equipment of the real version of the current laboratory is shown. This enables the students to become acquainted with the structure of the real laboratory. The medium of the ground plan is an active Flash movie. All of the units of the technical equipment act like buttons. After clicking any of them a general data-sheet appears. Besides the image of the equipment the sheet gives information on the specific parameters of the system, the potential applications etc. From this sheet the user can navigate to other pages that contain even more information about the equipment, for example the schematics of the system and the description of the principles of operation. All of this is supported by animations. The simplified physical operation of the equipment is simulated by Flash, which also represents an important part of the Virtual Laboratory. Students can learn how to operate the system, can familiarize themselves with the build-up and the reactions of the system before they visit the laboratory and work with the equipment. For example, in the Laser Laboratory section even the different control software of the laser systems is implemented in Flash, with a reasonable fidelity. There are direct links to the Results section of the current Laboratory as well so that the user can have a look at what the equipment is practically applicable for.

If the student is interested in the technology itself, the Process section has to be chosen. The explanation of the physical/chemical principles and the steps of the processes can be found here. These include equations, illustrations, photographs and of course Flash animations. This section was founded upon the existing paper-based material, from which the students prepared for the obligatory laboratory exercises of their course. These sections of the virtual laboratories may substitute the out-of-date booklets, as the electronic publication format with the use of Flash enables the instructors to provide up-to-date and high quality information on the Internet. After further development of the Virtual Laboratory, users will have the possibility to carry out simulations and analyses on the processes by changing the parameters and perform virtual measurements and tests. The resulting virtual structures and products will be presented mainly by schematics and characteristics. (This will also require a higher-level programming tool besides Flash.)

In the Results section mainly photographs, photomontages, diagrams and their description represent the results of the educational research project of the Department.

The Test section provides the possibility of testing and evaluating the students' knowledge both for themselves and also for the instructors. A laboratory exercise always starts with asking the students questions to make sure they have done their preparation duty. This lasts more than half an hour sometimes. Excluding this action from the laboratory exercises by putting it on the Internet will leave more time for the demonstrations and experiments. When the student enters the Test area, he/she will be asked to answer a set of randomly selected test-question. The offered answers are randomized as well. After a successful completion of the test the student enters his/her student identity code and submits it to the web-server. The instructors can access the data collected by the web-server.

The Task section contains the detailed description of the experiments and tasks that has to be carried out and completed on the laboratory exercise.

The Virtual Laboratory – as it Appears on the Internet

An important viewpoint of developing the Virtual Laboratory was to provide an aesthetic, nice and convenient environment for the users with a simple and logical navigation possibility. Figure 1 shows the start page of the Virtual Laboratory. The navigation bar permanently stays in the left

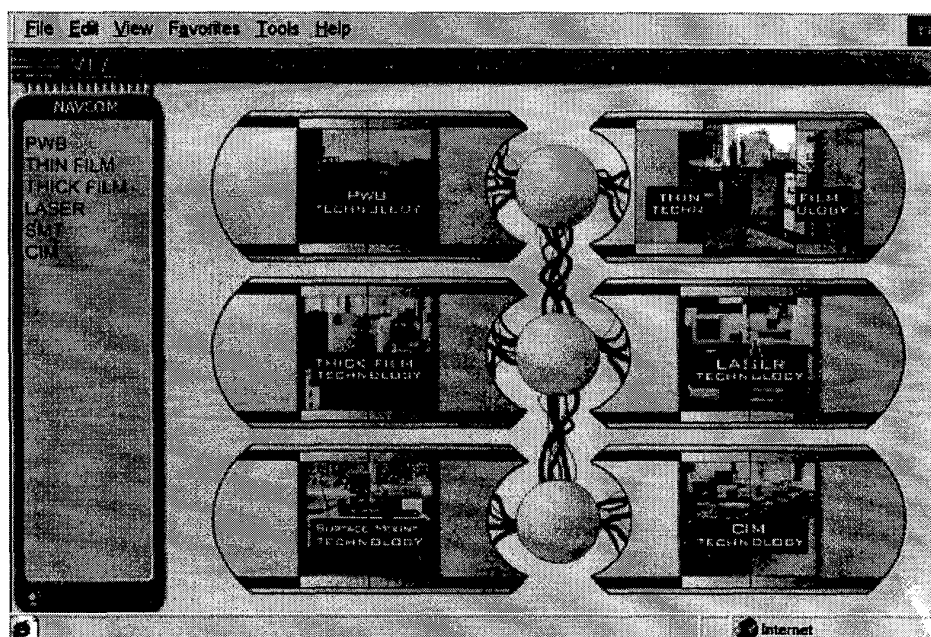


Figure 1. The start page of the Virtual Laboratory

side of the window thus allowing the users to find the required page independently of where they are actually. This menu has three levels, with the six laboratories on the top level. Each laboratory has six submenus, which come up when the name of the laboratory is clicked. These menu-points are already

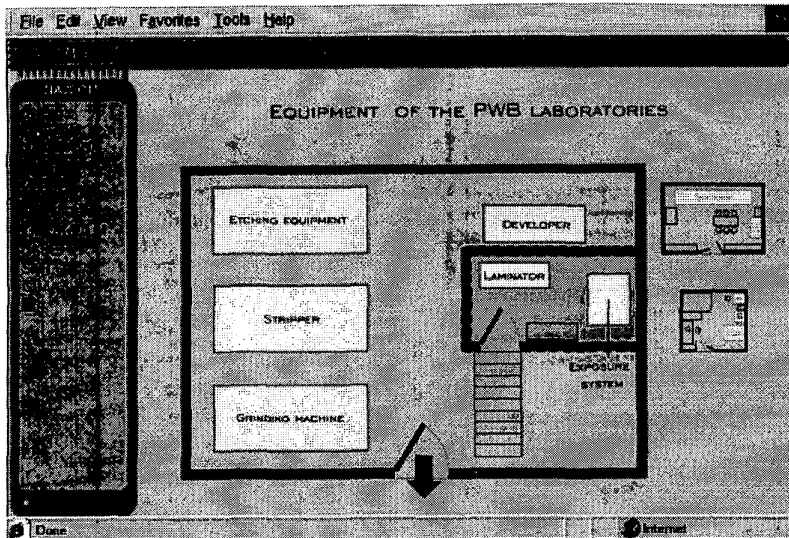


Figure 2. The Equipment section of the PWB Technology Laboratory

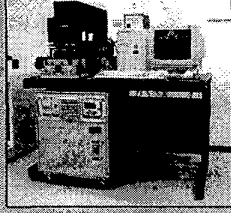
life, the virtualized version contains three ground planes as well. The small laboratory sketches act like buttons, pressing any of them will enlarge the desired room.

The light-colored areas represent the active equipment of the laboratory. A mouse-click over these areas will guide the user to the data-sheet of the chosen equipment.

Figure 3 shows some screenshots of the data-sheets. The first shot (Figure 3a) introduces the Gravidlaser system, which was developed at our Department. This is a Nd:YAG laser, capable of marking and

Figure 3b. The data-sheet of the CO₂ laser processing system

- GRAVILASER



THE GRAVILASER SYSTEM WAS DEVELOPED AT BME-ETT BETWEEN 1992 AND 93 IN ORDER TO BE ABLE TO ENGRAVE BITMAPS (EG. PORTRAITS) AND PRODUCE SURFACE MARKING ON DIFFERENT KIND OF MATERIALS. (THE SYSTEM WAS UNIQUE IN THE YEAR OF COMPLETION THANKS TO THE HIGH QUALITY LASER DESIGN AND IMAGE PROCESSING.) BEAM DELIVERY BY GALVANO-MOTOR ROTATED MIRROR SUPPORTS THE BITMAP ENGRAVING. PLASTICS, SELF-ADHESIVE ACRYLIC FOILS, METALLIZED PLASTICS, BRASS, ANODIZED ALUMINIUM, BLACK OXIDIZED COPPER AND STAINLESS STEEL ARE AMONG THE PROCESSABLE MATERIALS.


- SYSTEM PARAMETERS

<p>LASER:</p> <ul style="list-style-type: none"> • Nd:YAG / 1064 NM WAVELENGTH • 50 W CONTINUOUS OUTPUT POWER • PULSE POWER: > 50 kW • 150 300 NS PULSE LENGTH • MULTIMODE OPERATION • PUMPING SOURCE: KRYPTON ARC LAMP • Q-SWITCH: ACOUSTO-OPTIC (24 MHz) • FOCAL SPOT: 50-100 UM • LASER EFFICIENCY: ~ 1-2% 	<p>BEAM DELIVERY:</p> <ul style="list-style-type: none"> • THROUGH BEAM EXPANDER AND FLAT-FIELD OPTICS • FOCAL LENGTH: 110 MM • MIRROR ROTATED BY GALVANO-MOTOR IN Y DIRECTION (UP TO 100 MM/SEC) • XY TABLE <ul style="list-style-type: none"> • 50x50 MM MOVING RANGE, 5 UM RESOLUTION • 2.5 MM/S MAXIMUM MOVING SPEED <p>SOFTWARE CONTROL:</p> <ul style="list-style-type: none"> • VECTOR BASED GRAPHIC DESCRIPTION LANGUAGE (ESS) • WITH BITMAP ENGRAVING SUPPORT
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Figure 3a. The general data-sheet of Gravidlaser from the Equipment section of the Laser Technology Laboratory

- CO₂ LASER SYSTEM



THIS SYSTEM WAS DEVELOPED AT BME-ETT IN 1999. THE CO₂ LASER WAS PURCHASED FROM THE SYNRAD COMPANY (USA). ALL ACCESSORIES, LIKE PC CONTROL CARDS FOR THE LASER AND FOR THE XY TABLE, OPTICAL ELEMENTS, CONTROL SOFTWARE, WERE DESIGNED AND IMPLEMENTED AT OUR DEPARTMENT.

THE CO₂ LASER SYSTEM CAN BE USED FOR SEVERAL APPLICATION IN THE FIELD OF ELECTRONICS TECHNOLOGY. THE MAIN APPLICATION IS DRILLING AND CUTTING OF POLYESTER FOILS BUT OTHER PLASTICS UP TO 5-10 MM THICKNESS CAN BE PROCESSED AS WELL.

- SYSTEM PARAMETERS

<p>LASER:</p> <ul style="list-style-type: none"> • CO₂ LASER / 10.6 UM WAVELENGTH • 25 W CONTINUOUS OUTPUT POWER • 3-5 US MINIMUM PULSE LENGTH • RF EXCITED, SEALED TUBE TYPE • MANUFACTURER: SYNRAD • FOCAL SPOT: ~ 200 UM • EFFICIENCY: ~ 7% 	<p>BEAM DELIVERY:</p> <ul style="list-style-type: none"> • BY GOLD PLATED MIRROR AND ZNSe FOCUSING LENS • FOCAL LENGTH: 50 MM • XY TABLE <ul style="list-style-type: none"> • 200x300 MM MOVING RANGE, 2.5 UM RESOLUTION • 2.5 MM/S MAXIMUM MOVING SPEED • DRIVEN BY STEP-MOTORS <p>SOFTWARE CONTROL:</p> <ul style="list-style-type: none"> • VECTOR BASED GRAPHIC DESCRIPTION LANGUAGE (ESS) • HPGL INTERPRETER
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engraving different materials. This laser is used in the laboratory exercises of the Microelectronics and Technology course for engraving thin films. The next shot shows the CO₂ laser processing system. This was also designed and developed at our place. Researches on the drilling of polyester foils were completed by this system. The next shot presents the frequency multiplied laser of the Department. This laser can emit a laserbeam with wavelengths of 266, 355, 532 and 1064 nm, respectively. The workstation also supports 3D processing. The fourth shot shows our Alpha-Step 500 surface profiler

equipment. This system works with a stylus, which passes over the surface of the sample. The high-resolution profile data is then transmitted to the computer for further investigations.

Other equipment that were not presented here can be found in the Laboratory, like another Nd:YAG laser mainly for trimming application, optical microscopes with a high-resolution CCD camera, laserbeam profiler systems and other accessories related to a laser laboratory.

The equipment of the PWB laboratories consists of a CNC drilling machine, a fabrication line from dry film photoresist technology, an electroplating line for the

Figure 3d. The data-sheet of the Alpha-Step 500 surface profiler

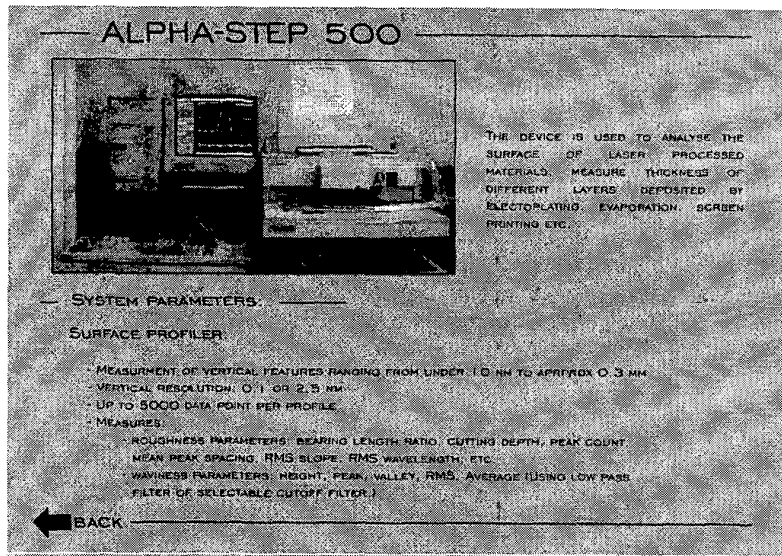


Figure 4 is a screenshot from the Equipment section of the Laser Technology Laboratory. On this page of the CO₂ laser processing system the users can try out nearly every service of the graphic user interface of control program. The main actions and reactions of the software and the monitored units controlled by the software are simulated. The user can also enter table-moving commands, which are interpreted and are executed by the sketchy XY table. They will also learn how to put the system in operation. For example, if the user has forgotten to switch on the chiller, the laser system will overheat and turn off itself within a few minutes, just like in the real life.

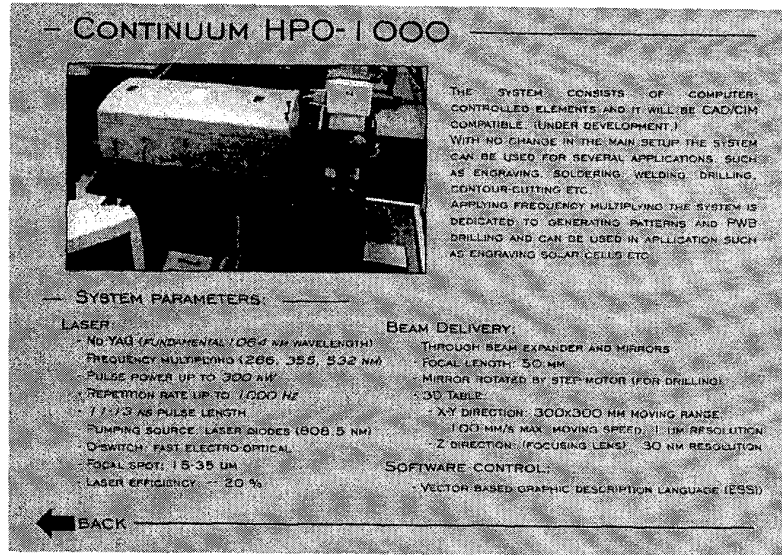
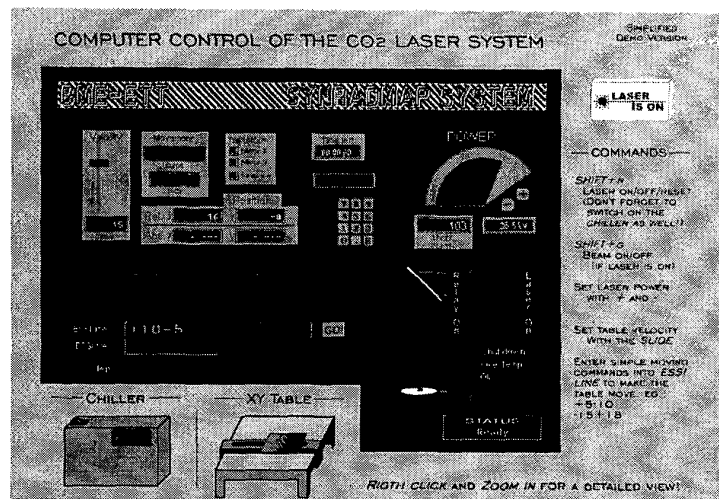


Figure 3c. The data-sheet of the Continuum laser

production of through-hole-plated printed wiring boards, an etching apparatus, an electroplating line for gold plating of direct connectors etc. The Thin Film Technology Laboratory includes the presentation of a vacuum evaporation unit, evaporation sources (electron beam and magnetron type sputtering sources) and the fabrication line for liquid photoresist technology. In the Thick Film Technology Laboratory a screen printer and firing ovens are described among others, while in the SMT Laboratory users can find manual and semiautomatic pick-and-place machines.

Figure 4. Simulation of the PC control software of the CO₂ laser processing system



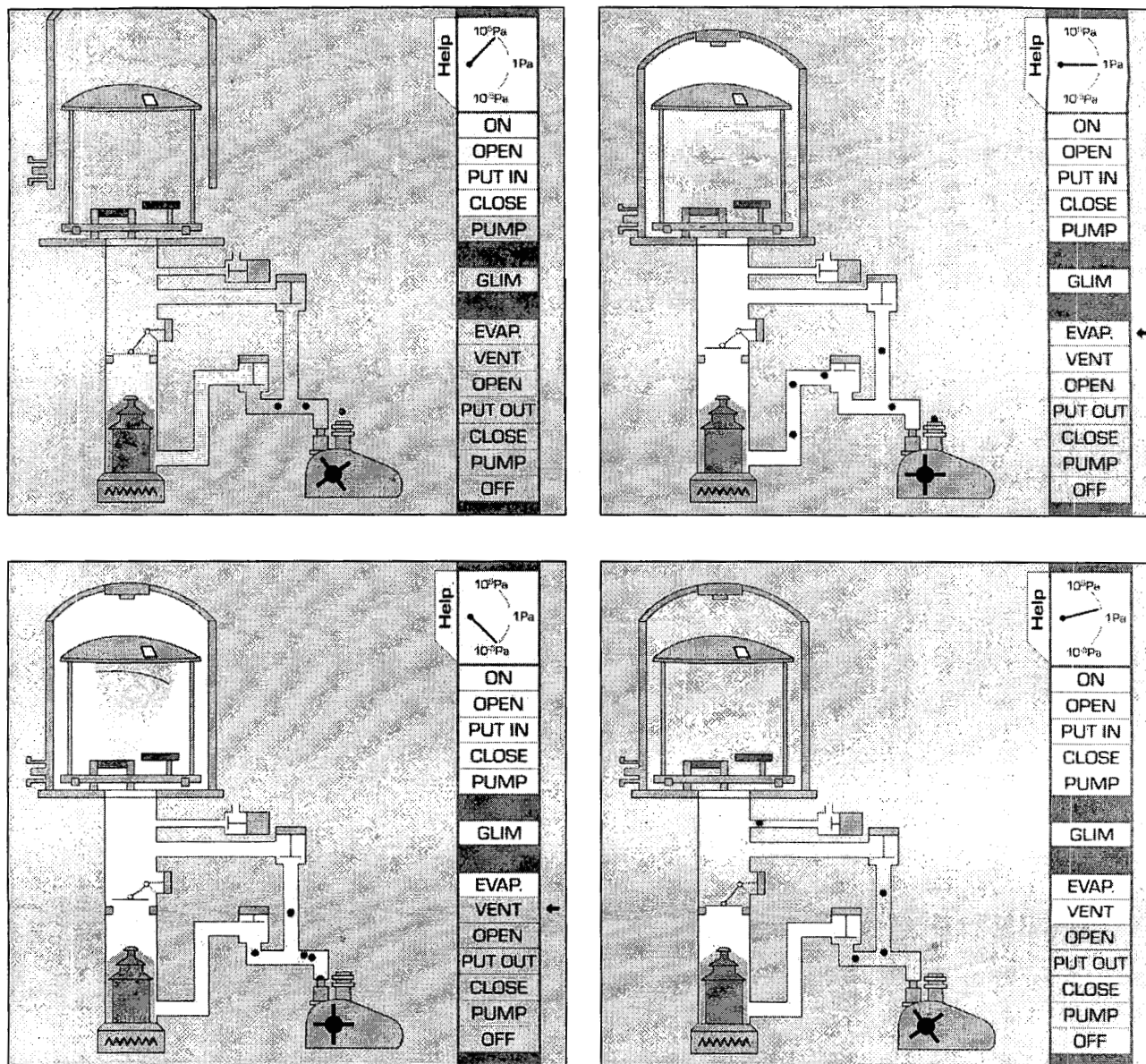


Figure 5. A series of screenshots of the interactive demonstration of the vacuum evaporating system in the Thin Film Technology Laboratory, Equipment section

Figure 5 shows a few screenshots of the demonstration process of the vacuum evaporating system. The first shot was taken while the bell jar was closing, after the insertion of the thin film substrate. The status of the vacuum valves and the vacuum gauge can also be inspected. The second shot was taken during the gas discharge process. The lighter and darker areas in the vacuum system represent the vacuum level. The color of the control buttons indicates if the step in question has been completed. The third shot shows the evaporating process and the last one shows the ventillation of the vacuum space.

Figure 6 shows a typical sample from the Results section. This picture contains a montage of the measured parameters of

a CO₂ laser drilled hole. The hole was drilled in polyester foil, which was 125 μm thick, and it was inspected and captured by two different measuring systems. A Philips XL30 Scanning Electron Microscope was used to take detailed photos of the hole and the Alpha-Step 500 surface profiler served the line-diagram of the cross section of it. Both sides of the hole was examined with the mentioned tools and the results were put on the shown figure, thus completing each other and providing all the important information of the hole. (The description of these measuring tools can also be found in the Virtual Laboratory.)

Figure 7 presents a few steps of the manufacturing process of PWBs from the Process section of the PWB Technology Laboratory. The demonstration is controlled by the user by clicking the button of the desired step. When the user drives the cursor over the camera, photos of the current status of the laminate will appear. Doing so with the book-sign, detailed information on the step of the process will be provided. The first shot shows the drilling of a PWB packet. The next one demonstrates the exposing process and the last shot shows the final result of the manufacturing with a photo.

and Béla Szikora for the high-level consultation in the different topics.

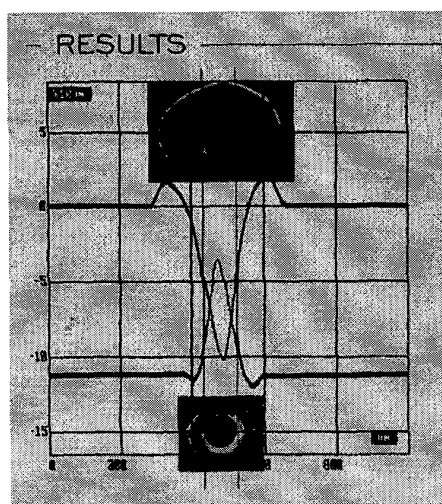


Figure 6. A cropped screenshot from the Result section of the Laser Technology Laboratory

Conclusion

The first big step in the development of the Virtual Laboratory was completed, which is already accessible through the Internet. It fulfills the principal main purposes, students and engineers can improve their knowledge of microelectronics packaging by studying manufacturing equipment, processes and products. It also provides an excellent possibility for students to make preparations for their hands-on experiments. All of this is placed into an environment that attracts users and helps keeping them longer.

The next step of the improvement is to realize simulation tools in the Virtual Laboratory so that the users will be able to carry out virtual measurements and tests prior to the real experiments.

Acknowledgements

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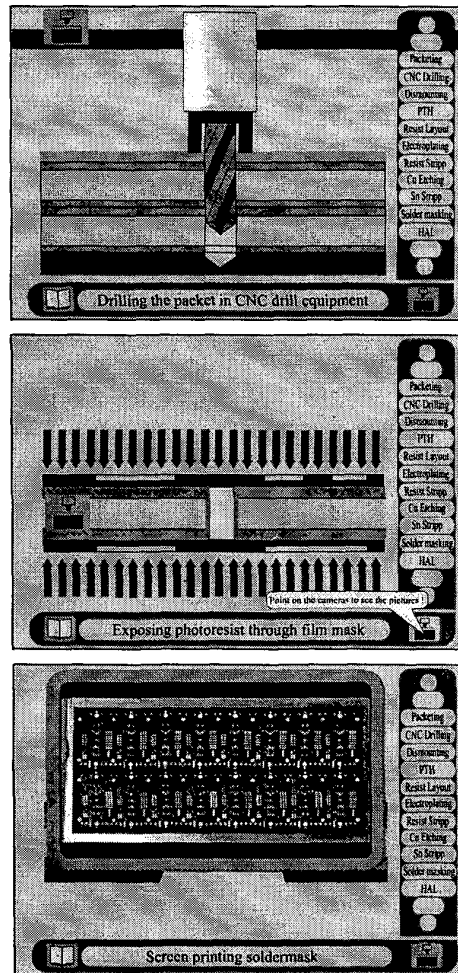


Figure 7. A few screenshots from the demonstration of the manufacturing process of PWBs

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