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Visual Modelling of Physical Processes

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Abstract

The development of information technology has also opened new perspectives in modeling and simulation of processes used in electronics packaging technology. In September of 1999 an IEEE/NSF supported Project has been launched for the creation of Virtual Laboratory (http://www.ett.bme.hu/vlab or http://www.ewh.ieee.org/mm/cpmt/vlab) environment to present and study equipment, and to promote process modeling and simulation developments. An important additional goal of the project is to support electronics packaging education in order to prepare engineers for the needs of the 21st century.

The current step of the work is the development of simulations and models for laser processing like via drilling and patterning of pure and metal finished copper layers on polymeric substrates, e.g. epoxy, polyimide and aramid, mainly that are commonly used for laminated interconnect substrates.[1]

The paper will describe the virtualized facility of our Department and the results of physical model creation efforts and 3D visualization tool developments for laser processing with the application of CO_2 and frequency multiplied Nd:YAG lasers, using all five wavelengths, i.e. 10600, 1064, 532, 355 and 266 nm.

INTRODUCTION

CO_2 and Nd:YAG lasers are the most commonly used equipment for laser processing applications. The differences between the beam properties and quality of the two laser types and the various material interactions strongly determine their applicability fields. The wavelength of the beam produced by a CO_2 laser is about 10 μm, which is absorbed well by plastics, wood, paper and organics, and the glass is opaque at this wavelength as well. Apart from the fact that metals nearly act like mirrors and absorb only a few percent of the medium-IR beam, sheetmetal cutting and welding is the largest market for CO_2 laser processing systems. This is thanks to the high continuous (average) output power of CO_2 lasers. The low average power of Nd:YAG lasers working in pulsed mode gives low cutting and welding speed, but it still has a significant advantage; their high energy pulses can overcome the surface reflectance of most materials, thus providing effective drilling, engraving and other processes.

CO_2 laser cutting has the same virtues as the general laser processing. Minimal kerf and superior laser-cut edges are significant advantages of the laser over most other cutting processes. CO_2 lasers are convenient tools for drilling and surface marking as well. The laser process is non-contact, thus eliminating part distortion and the need of frequent maintenance. Intricate patterns can be cut under the control of a computer, also prototypes can be quickly and easily created and modified.

CO_2 LASER PROCESSING SYSTEM FOR VIA GENERATION

The processing system of the Department is based on a 25 W CO_2 laser manufactured by the Synrad Company. The beam emitted by this laser is focused in a 200 μm spot. The power density in this spot is not enough to enable metal cutting, but it is sufficient for cutting and drilling plastics, plexiglass, of course paper, different types of plastic foils and many other materials.

The laser is controlled by a PWM (pulse width modulated) TTL signal, that contains the information of the required output power. The smaller the duty cycle, the less power the laser will emit. The designed PC card can produce this signal and also supports some processing technologies, e.g. controlling the

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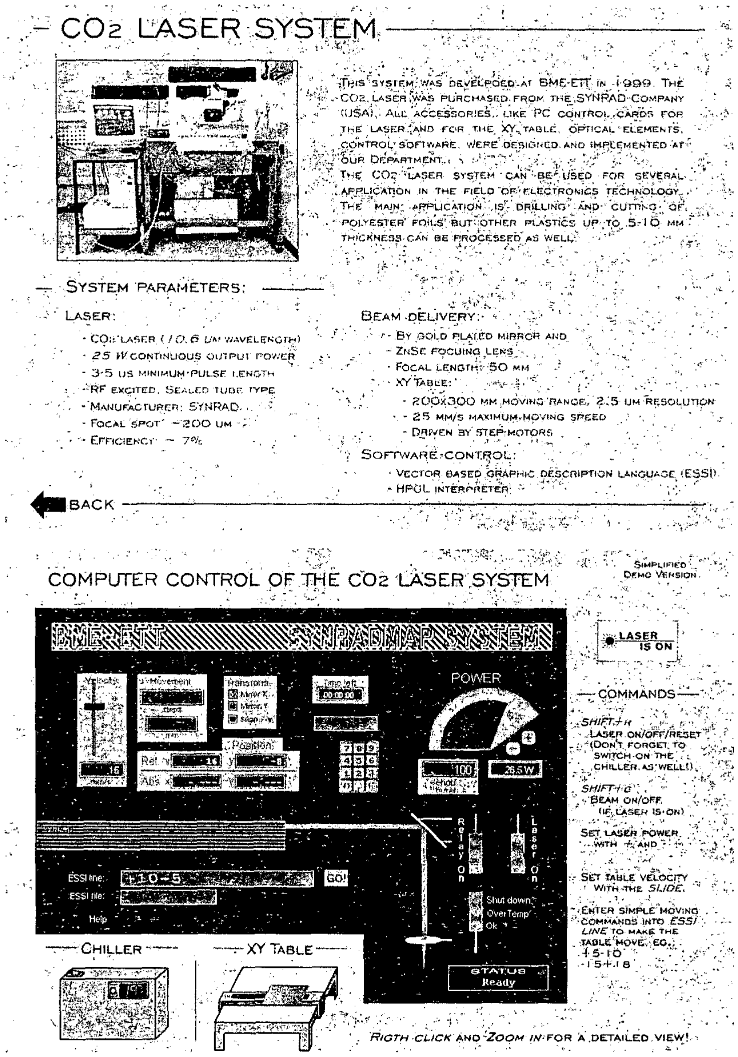

Figure 1 and 2 The virtual CO_2 laser in the Virtual Laboratory

drilling time by hardware with the built-in micro-controllers.

Designing the optical system of a CO_2 laser processing unit poses special problems as well. The about 10 μm wavelength beam can not be "conducted" through fiber-optic cables, because up till now no suitable material has been found for that. Therefore, a CO_2 laser beam can only be delivered by a system of mirrors and lenses. To eliminate the power loss and the overheating of the optical units, the lenses must be transparent at the 10.6 μm wavelength. There is not a wide variety of these materials, ZnSe (Zinc Selenide) and Germanium are used generally. Finding the proper material for the mirrors is less of a problem. Since gold, silver and copper reflect the most of the 10.6 μm beam, they can be used as cover layer on any type of a carrier plate. We used gilded glass for this function, because it was easy to produce with the Department's vacuum evaporating unit.[2]

Figure 1 and 2 show the CO_2 laser in the Virtual Laboratory. The users will find a photograph of the system, the description of its application and the most important parameters of it (Figure 1). The next figure is a screenshot of the animation of the control software. On this page of the CO_2 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 inter-preted 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.[3]

VIA GENERATION IN FR4 LAMINATES IN THE VIRTUAL LABORATORY

The Nd:YAG UV laser with 355 nm wavelength was used to punch through-board vias into single-sided copper clad glass fiber reinforced (FR4) board.[5] The laminate was 0.25 mm thick including the 35 μm thick copper layer on its upper surface. Although the SEM photos (Figure 3) were prepared of different holes made by increasing number of laser shots, the sequence characterizes the hole formation mechanism as the function of time.[4] A Flash movie in the Virtual Laboratory, accessible among the results of the Laser Laboratory, visualizes the process by making the pictures flow one to another. On the basis of the visualization we can conclude that each laser shot melts a small volume of copper and it explodes from the crater in the form of small droplets. It can be supposed that epoxy also melts but ablates, while glass is broken into small particles and pushed out together with the melt.[6]

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Figure 4 shows a screenshot of the process animation.

The aim of the visualization is to follow all steps of the physical model where material movement takes place, i.e. the crater formation mechanism through material drift, droplet formation, launching and resolidification. Flash technology is used to present the quasi 3D pictures dynamically as in a movie, where the presentations can be slowed down and made fast, as well as, zoomed in and zoomed out.

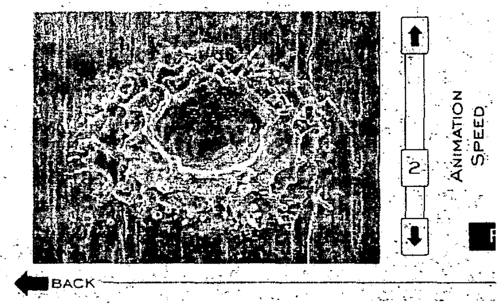

Figure 4 Screenshot of process animation

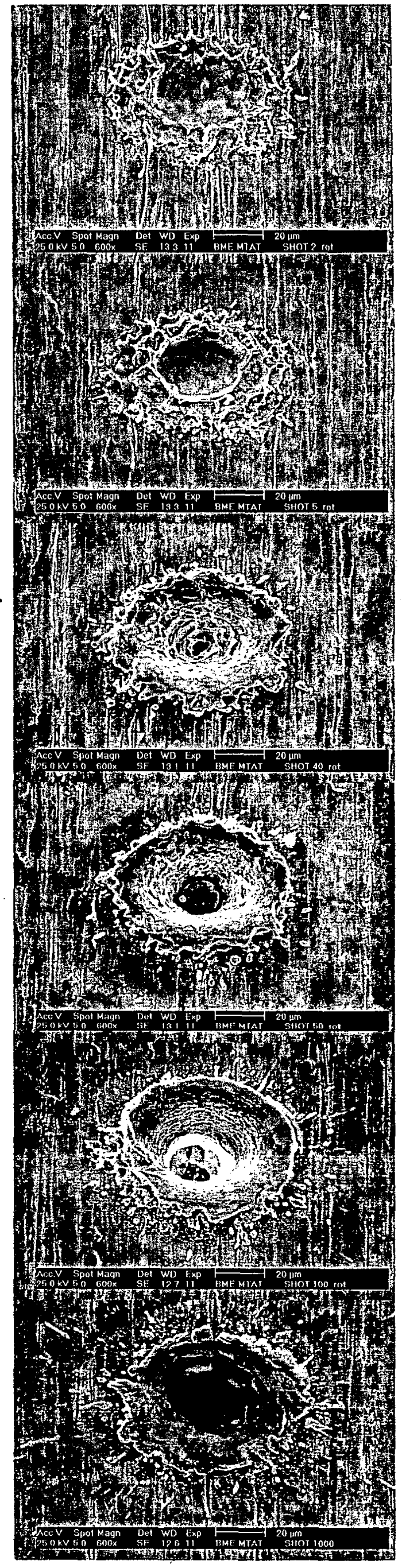

Figure 3 Drilling process of single-sided FR4 laminate

VIA GENERATION IN POLYESTER FOILS

Through-hole vias can be generated by either laser punching or laser trepanning. Laser punching is a process in which the laser spot is positioned to the center of the machined hole, and the laser punches through the material thickness using multiple pulses. The diameter is determined by the spot size of the focused laser beam. The diameter as well as the via wall angle can be controlled by changing the focal plane of the laser beam.

The basic material of our research was polyester foil with a thickness of 125 μm. In general, it is used as a circuit carrier, and certain electrical elements are printed on it with polymer thick-film technology. Experiments aimed at the optimization of hole drilling for through-hole contacting. We tried to minimize the hole diameter and the burr height. Too high burrs can impede the through-hole contacting process.

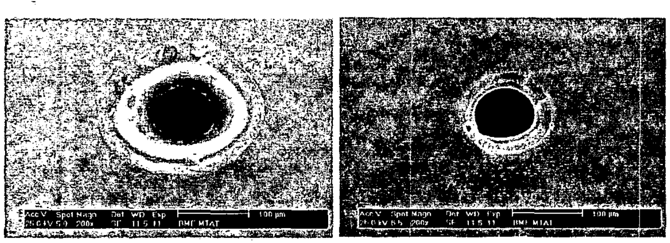

Figure 5 Entrance and exit holes in polyester foil drilled by CO_2 laser

Both sides of the samples were examined by Alpha-Step surface profiler. It uses a conical stylus ending in a globe with a radius of 12.5 μm, which passes over the surface. Some holes were also inspected and captured by a Philips XL30 Scanning Electron Microscope.[2]

Figure 5 shows the two sides of the hole that was drilled under special circumstances in order to reduce the burr height. Previous experiments proved that simple drilling methods result in unacceptable mass of burr. (Refer to Figure 8) The relatively long drilling time enabled the molten material to travel to the rims of the hole determined by the surface tension and settle. The use of covering sheets on both sides of the foil eliminated the burr formation. This can be seen in Figure 5 and in Figure 6, which shows the cross-section of the hole.

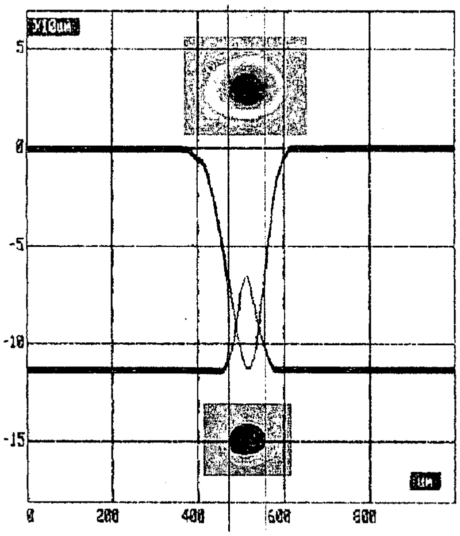

Figure 6 Mounted Alpha-Step and SEM results of CO_2 laser drilled hole

Figure 7 shows two screenshots of the animation that presents how the mentioned stylus of the surface profiler unit contacts the material and measures the shape of it. When the stylus hits a steeper wall it will produce a profile curve that differs from the real one because the cone angle of the stylus is 90°. This effect can also be inspected in the animation (2nd screenshot).

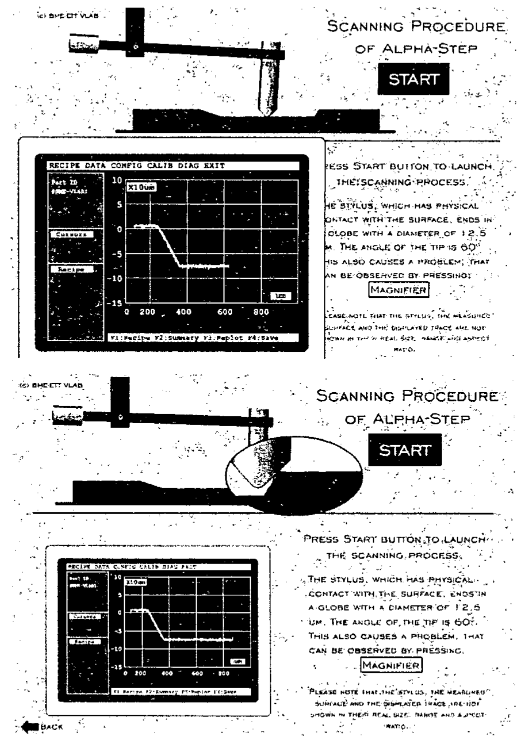

Figure 7 Presentation of operation of Alpha-Step 500 surface profiler

For comparison, similar experiments were made applying CO_2 laser with 10600 nm and Nd:YAG laser with 355 nm wavelengths. Figure 8 shows two montages of the results provided by different measuring methods. The curves were presented by Alpha-Step 500 and have been mounted together with a graphics editor.

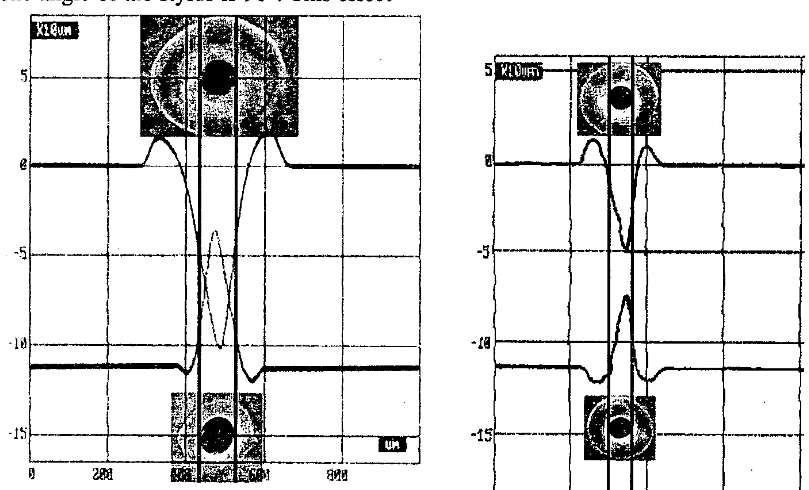

Figure 8 Holes drilled into polyester foil by (a) infrared (10600 nm) and (b) UV (355 nm) lasers

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CONCLUSIONS

The Virtual Laboratory proved to be an efficient medium for the visualization of laser material processing, as far as the processing equipment and the results are concerned. After physical modeling of the interaction of laser beam and the material visual models are planned to be prepared in the Virtual Laboratory, thus making the process more comprehensible and spectacular.

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