A CLEAN LASER MACHINING PROCESS
BY MICHAEL SCAGGS

For decades the laser has been thought of as the "ideal" machining tool. Yes, it does provide a means to machine an enormous variety of material and product that could not be machined in conventional ways. However, when one looks very close at the laser cut or treated surface, i.e., under a microscope, the euphoria of the laser being the panacea of a machining tool diminishes rapidly.

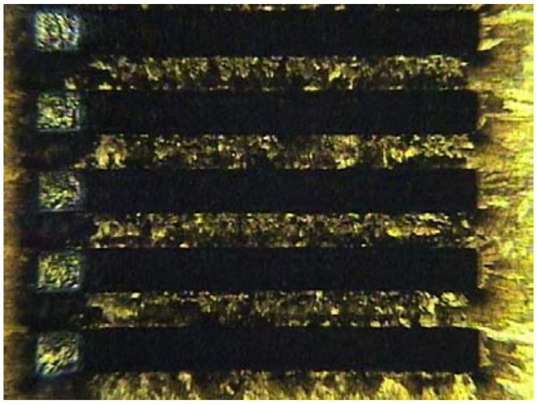

Figure 1: 200 micron features etched in SS using a KrF excimer laser at 6 J/cm^2. (Photo courtesy of Exitech)

The industry has a myriad of buzzwords to describe the aftermath of a laser treated material: heat-affected zone, slag, recast, redeposited-molten-debris, and oxidation, to name a few. Attend a laser conference or seminar and you will see beautiful micrographs of "perfect" holes or cuts. The clever, upon closer inspection, will discover that a sacrificial layer of material was first applied that required a secondary process to remove the sacrificial layer or a secondary operation was performed such as chemical etching, plasma etching or other processes or perhaps that a lot of time consuming motion/optical tricks or gimmicks were employed. Again the hope or promise of a "perfect" machining tool has been dashed because what looked promising is now too expensive or impractical to be put into production.

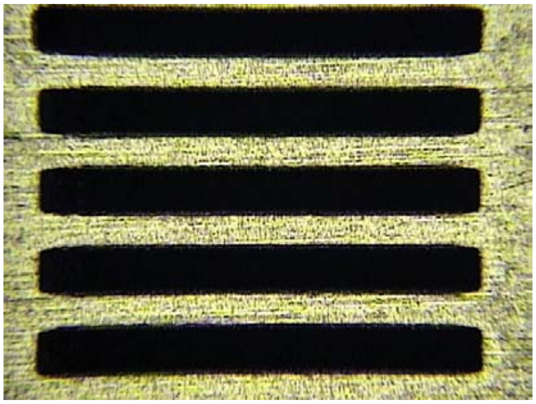

Figure 2: 200 micron wide features etched in SS using a KrF excimer laser at 6 J/cm^2 and the Clean Lase process. . (Photo courtesy of Exitech)

Those around the laser industry have heard countless times the phrase, "The laser is a great solution looking for a problem." Putting it in other words, laser technology isn't perfect and does have its share of caveats associated with the process. Hollywood, perhaps, is in part to blame or maybe the over aggressive marketing of a very competitive laser industry. Whatever is the reason, what is needed is a way to make laser processing technology more closely align the perception of those who are not "laser jocks".

There have been some promising techniques employed that have resulted in cleanly etched features. A process patented by Gupta et al has the material to be machined completely immersed in a liquid bath.[i] The vast majority of applications would not accommodate this level of complexity and cost. Another technique was closer to solving the problem, but fell a bit short of the optimum liquid level and flow of liquid.[ii] Other processes simply use capillary action from placing the liquid under a transparent optical material in close proximity to the

Copyright © 2003 by Neoteric Concepts, LLC

part being machined.[iii,iv,v] The problems associated with these techniques are obvious. There is simply improper or too deep a liquid level for any reasonable pulsing of the laser except at ver low repetition rates. Moreover, anything but a thin film (significantly < 1 mm thick) or mist of liquid creates bubbles from excessive sonic cavitation when higher energy densities are used and therefore deleterious refraction effects will dominate the process and create rough features. As a consequence it again would be too expensive or be impractical to incorporate such methods into an industrial setting.

A new, innovative, patent pending process may offer hope for reaching expectations of engineers looking for lasers to solve their machining problems. This new technique is called, Clean Lase™. Clean Lase is an acronym formed from **C**avitated **L**iquid **E**tching **A**ssist i**N**novative **LASE**r machining.

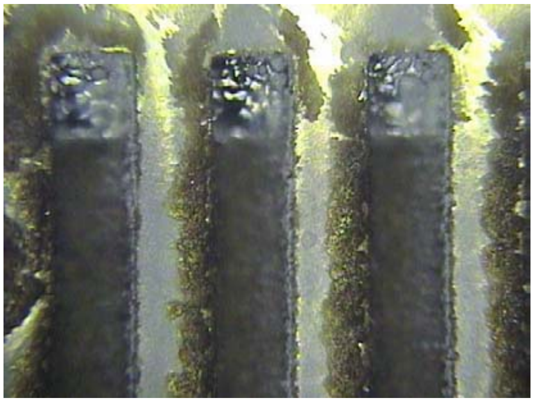

Figure 3: 200 micron slots cut into a 670 micron thick silicon with a 248 nm excimer with no assist. (Photo courtesy of Exitech, Inc.)

The Clean Lase process works best in conjunction with a pulsed, ultraviolet laser. The process works with any laser type so long as the liquid being used as the assist is not strongly absorbed by the laser in use. How the process works is quite simple. A uniquely designed spray nozzle atomizes the liquid into the laser interaction zone. A thin, laminar flow of liquid blankets the laser interaction zone. This blanket of liquid completely removes the presence of oxygen (a primary catalyst of unwanted debris). As there is now a barrier between an oxygen environment and the material being machined, plasma is greatly reduced and more energy can be efficiently coupled into the material. The laser now coupled into the material begins to melt and vaporize the exposed region. Localized sonic cavitation takes place and micro bubbles begin to implode during the lasing process. This sonic cavitation ejects the molten material from the machined area. The liquid blanket sweeps away the solidified, molten droplets from the laser machined area. The resulting feature has no slag or debris buildup. Further, the strong agitation of the sonic cavitation leads to no burr or recast formation on the edges of the exposed area. What is left is as close to a perfect cut as has been presently possible through direct laser machining.

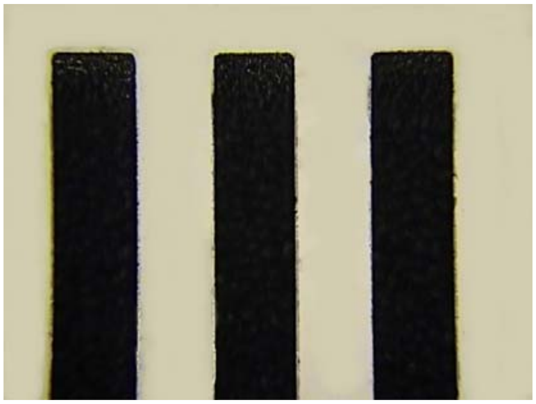

Figure 4: 200 micron slots cut into a 670 micron thick silicon with a 248 nm excimer with Clean Lase assist process. (Photo courtesy of Exitech, Inc.)

All materials tested to date have benefited from the Clean Lase technique. Figure 1 shows a piece of stainless steel irradiated with a 248 nm excimer laser. The depth of the each slot is 9 µm. Figure 2 shows the same piece of stainless steel processed under identical conditions except the Clean Lase assist was applied. Figure 2 is as machined, i.e., no post processing took place after the

Copyright © 2003 by Neoteric Concepts, LLC

laser treatment. The depth of the slots increased to 37 µm – a 4 times improvement in cutting speed with the Clean Lase applied. Close inspection of the two photos show that in the unassisted sample there is a large debris field of oxidized material and the edges of the feature have a large lip of recast and burr formation (and have burrs extending in excess of 42 µm). On the other hand, the Clean Lase treated feature shows no indication of oxidation, recast or burr.

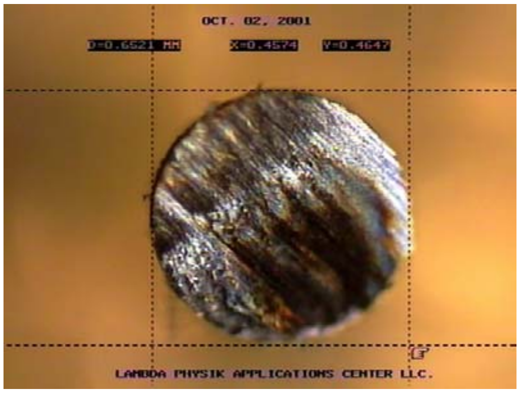

Figure 5: Beryllium/copper pin angle cut with 355 nm Nd:YAG laser. (Photo courtesy of Lambda Physik)

Figure 3 shows a piece of silicon etched by a excimer laser with a wavelength of 248 nm. The buildup of slag and debris is quite extensive. Figure 4 shows silicon etched with the Clean Lase process. Again, no post processing took place after the laser treatment. The silicon processed was not a very clean piece and had the collateral defects on the sample prior to machining. Nevertheless, not only did the Clean Lase produce a cleaner cut, the time to cut through the material decreased by more than a factor of 3. In another case a Nd:YAG laser was used to cut 670 µm thick silicon (3 watts of power @ 355 nm, 15 nsec pulses, 10 kHz repetition rate). The fastest cutting speed of the silicon without the Clean Lase process was 8 mm/minute. In contrast, the speed increased to > 20 mm/minute with the Clean Lase technique, nearly a 3 times improvement.

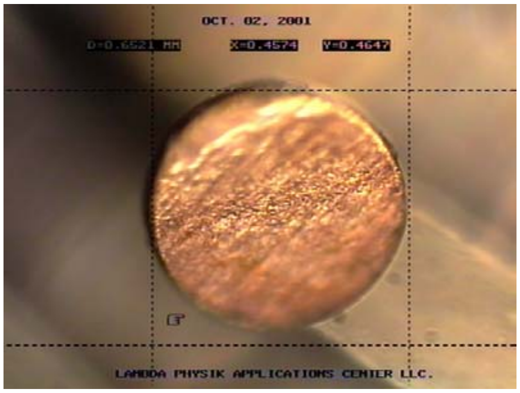

Figure 6: Beryllium/copper pin angle cut by 355 nm Nd:YAG laser with Clean Lase process. . (Photo courtesy of Lambda Physik)

Figure 5 shows a beryllium copper pin that was angle cut by a 355 nm Nd:YAG laser. The picture shows the end of the cut. Clearly the slag and oxidation affects are significant. Figure 6 shows the same material cut using the Clean Lase technique. In this photo there is absolutely no sign of recast or oxidation. The cut simply looks as if it were cut mechanically, but with no burr.

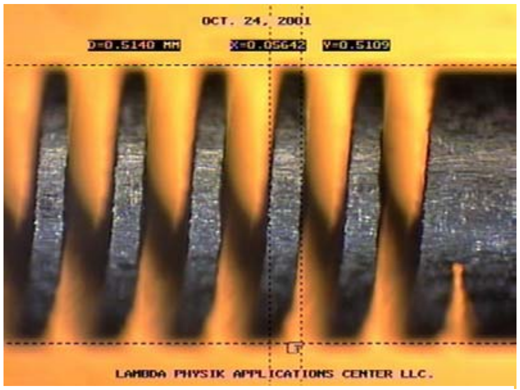

Figure 7: 0.5 mm OD & 0.25 mm ID stainless steel tube spiral cut using a 355 nm Nd:YAG and the Clean Lase process. The width of each turn is about 56 microns wide. . (Photo courtesy of Lambda Physik)

The Clean Lase process even works on 3-dimensional surfaces. Figure 7 shows a spiral cut in a 0.5 mm outer diameter and

Copyright © 2003 by Neoteric Concepts, LLC

0.25 mm inner diameter stainless steel tube. This part is shown as machined, with no secondary clean up process. This part almost looks as if it were cut on a screw machine.

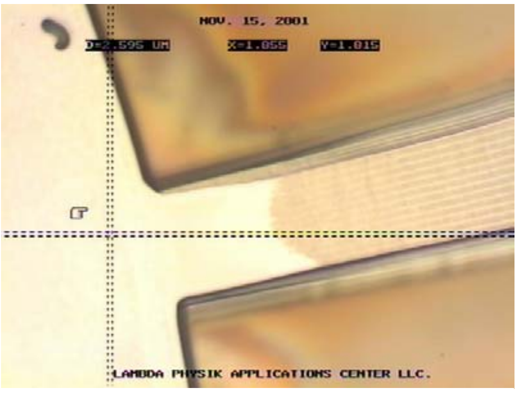

Figure 8: Polymer material etched by KrF excimer laser and Helium assist with ~ 290 mJ/cm^2. . (Photo courtesy of Lambda Physik)

The obvious benefit of the Clean Lase process to metals has been shown in the preceding text and photos. How does the Clean Lase process work on polymers? Figures 8 and 9 illustrate the answer to this question. Figure 8 shows a thin polymer film used for optical waveguide that has been etched with a 248 nm excimer laser and a blanket of helium gas over the laser interaction region. Helium is a common choice of assist gas for ultraviolet laser processing.[vi,vii] Yet even with the helium cover gas, the debris (mostly carbon) generated is still excessive and undesirable, not to mention that the fine features are not resolved. Figure 9 shows the same material etched under identical laser parameters but with the Clean Lase process applied. The features in figure 9 are resolved to better than 2 microns. The difference between the two photos is clear: not only is the soot reduced, but the optical resolution has been enhanced as well. The Clean Lase process further reduces the heat-affected zone that would otherwise add to the distortion of the edge of the feature.

A simply to employ and use process is now available to laser users that will further aid in the advancement and acceptance of laser technology in the machine tool industry. Applications that will benefit are wide. Any current process that has unacceptable levels of recast, burring, heat-affected zone, oxidation, soot or whatever name you want to give as negative side effect to laser processing can possibly profit from this technique.

Figure 9: Polymer waveguide material etched by KrF excimer laser and Clean Lase process with ~ 290 mJ/cm^2. Features of less than 2 micron wide are resolved. . (Photo courtesy of Lambda Physik)

---

[i] A. Gupta et al, Unites States Patent Number :5,057,184 (1991)

[ii] S. Roth, M. Geiger, Specific Surface Treatment by Laser Irradiation Under Liquid Films, ICALEO 2000

[iii] A. Dupont, P. Caminat, and P. Bournot, J. Appl. Phys. **78**, 2022 (1995)

[iv] D. Kim, H. Lee, J. Appl. Phys. 89, 5703 (2001)

[v] S. Zhu, Y. F. Lu, M. H. Hong, Appl. Phys. Lett. 79, 1396 (2001)

[vi] U. Sowada, H.-J. Kahlert, D. Basting; E-MRS Spring meeting Strasbourg 29.5. –1.6. (1990)

[vii] U. Brinkmann, "Clean Holes in Polymers under Helium Stream", Lambda Physik Highlights **24**, 5 (1990)

Copyright © 2003 by Neoteric Concepts, LLC