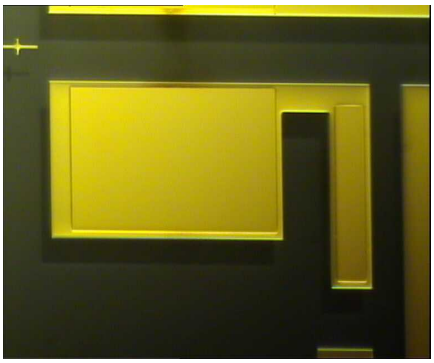
Debris Control in Excimer Laser Micromachining

Excimer laser micromachining of polymers proceeds by the phenomenon of photo-ablative decomposition, an effect discovered & so-named by Rangaswamy Srinivasan of IBM in 1981, using the remains of his Thanksgiving Day turkey!

During ablation, molecular fragments of reported size in the range 50-500 a.m.u. are ejected from the ablation zone with supersonic velocities, and form part of the audible shock wave and visible ablation plume in which further molecular disintegration takes place in the temporal tail of the laser pulse.

Momentum exchange with the surrounding atmosphere results in the redeposition of much of this material in a fine sooty-like deposit, mainly elemental carbon in the case of hydrocarbon polymers. The redeposit occurs generally adjacent to the ablation area, but the exact redeposition zone depends on energy density and its distribution over the ablation area. A circular ablation zone leads to a uniform halo, a square to the pattern shown here, and the symmetry of that redeposition pattern is an excellent test of the uniformity of energy density over the ablation zone.

Higher energy density spreads the deposit over a wider area. For obvious reasons, airflow near the ablation zone(as for e.g. with a gas jet or suction) can have very limited effect unless the airstream velocity approaches supersonic speed. Various alternative methods of eliminating the deposit have been used, including electrically charged wires and sacrificial films. However the most direct and obvious method is to avoid momentum exchange with the surrounding atmosphere by eliminating the atmosphere. Experiment confirms that vacuum ablation is deposit free, but somewhat impractical.

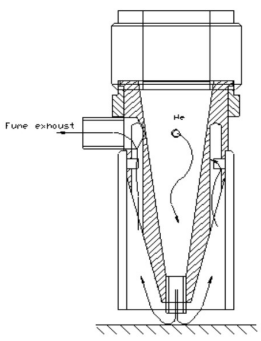


Using a lighter gas atmosphere is the next best option, and He the only practical safe solution, providing reasonably effective debris control. The photo at left indicates opening of contact areas to gold film; the width of the larger opened area here is approx. 1mm. Just a trace of redeposit can be seen between this zone and its neighbour above(out of the picture).

(N.B. For some polymers, oxygen has been used in place of He; the aim in this case is not to avoid momentum exchange but to ensure complete pyrolisys of ablation products)

Removal of He & debris from the ablation area is important. Not only does it remove potentially hazardous fumes to a filter unit, but it also removes the excess He. The refractive index of He is significantly different from air, so that careful control of He flow is required to avoid degradation of the UV optical image by infiltration of He/air mixture into the beam path. A typical coaxial gas nozzle construction is shown below. The inner tube carries a flow of He sufficient to prevent thermalized ablation products reaching the optical surface of process lens or protective window. Reproducible flow is obtained using flowmeter and ON/OFF stopcock in the He line, commonly controlled by the system software. An outer coaxial tube is used to flush away the used He including ablation products, some of which may be injurious to health; therefore fumes must be fed to factory exhaust or gas scrubber via suitable air blower used as extractor. Flush throughput must necessarily exceed He flow rate, exact flow rates to optimize redeposit elimination for minimum gas flow can only be determined by experiment in any particular case. It is important to understand that the aim is to bathe the ablation area in He, not blow debris away, whilst excessive exhaust flow sucks the He out of the critical zone. Optimum distances between inner & outer nozzles & part also depend some extent on the geometry of the part itself.

A similar principle has been successfully applied to larger gas nozzles with ablation area up to >25mm in diameter. In some cases the gas nozzle can be fixed directly to the process lens; in other cases an independent module with window is provided. Nozzles with independent mounts can also be equipped with pneumatic lift linked to process control.



Optec has also developed nozzles which also act as lightguides, & are compatible with TTL viewing & ring lighting, contact Optec to see how our innovative technology can help you.