IKONICS®

ADVANCED MATERIAL SOLUTIONS

For **Precision** Composite Machining

Patent-pending breakthrough technology makes quick work of perforating and cutting composites, ranging from carbon-fiber to **Kevlar®** — and does it without de-lamination, burnishing or need for de-burring.

Composite Machining

Composites consist of various fiber-reinforced materials ranging from carbon fiber to Kevlar® with epoxy resins to provide a cohesive bond. Often, these epoxies contain particles to impart impact resistance and integral strength. Conventional machining of these materials is notoriously difficult. Most have a high propensity for burring/spurring, matrix de-cohesion, de-lamination and thermal damage.

Additionally, many conventional machining processes suffer from excessive tool wear which can contribute to multiple defects including dimensional changes with time. Of course, tool wear and replacement is also a financial consideration.

Composite materials are typically patterned, drilled, channeled, cut and otherwise machined to achieve the desired end product. For acoustic applications, multiple small holes are drilled to achieve a specific POA (Percent Open Area). Conventional machining of these holes can take hours, sometimes days to complete.

Machining Technologies

Traditionally, composites have been machined using conventional CNC drilling, punches, lasers, and abrasive water-jet technologies. Expensive, specially coated drills wear out quickly causing burnishing, tearing and changes in hole dimensions. Punches and other tooling eventually dull, bend and may break. Lasers can burn surfaces, and all of these methods can cause de-lamination. Even abrasive water-jet systems will cause de-lamination unless the process is well tuned. Further, abrasive water-jet systems cannot control depth for blind holes or cavities, and are a high cost investment.

While not a total replacement for any of these machining methods, Photo-Machining overcomes many of the issues indicated. This innovative process uses well-established technology...

It is excellent for producing perforations, blind holes, cavities, and other geometric features over large surface areas. This is particularly true for array patterns where multiple holes and/or other features are required. This process allows for such features to be produced simultaneously, with ultimate precision.

Photo-Machining

The Photo-Machining process was developed and introduced by the IKONICS Corporation several years ago. Photo-Machining uses a patent-pending photoresist and sand blasting to machine a variety of patterns, holes, slots, etc. into glass/silicon wafers, ceramics and other brittle materials. Applying this technology to composites required the development of a new self adhesive proprietary, patent-pending photoresist able to withstand the high (kinetic) impact of a more powerful sand blasting system.

The process therefore combines the precision of photo-lithography, similar to that used broadly in the electronics industry, with the kinetics of a dry abrasive sand blasting technology. Together, these technologies impart the precision and control needed to perforate and cut composites to produce the desired end product. Because the process is photographic, a maximum level of accuracy can be achieved repeatedly, such that design features or perforations are positioned and sized within microns.

"The key to the process is a unique and proprietary patent pending self-adhering photoresist film technology."

With resolution to 200µm (.008"), accuracy is easy to achieve. While industrial photoresists are familiar and well understood, particularly in the electronics industries, none, other than IKONICS's propriety photoresist, have the ability to survive a highly aggressive dry-abrasive sand blasting environment used to abrade composites. Figure 7 illustrates how the process works.

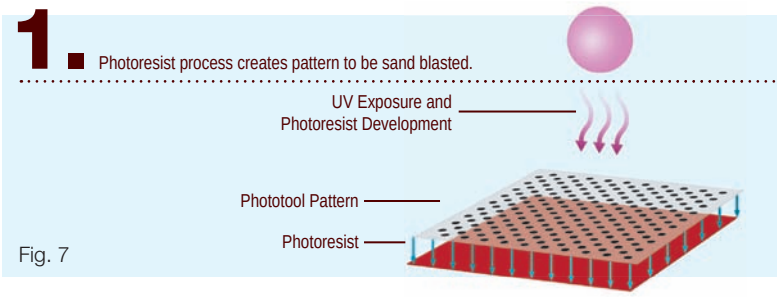


Fig. 7

features & benefits

"The development of a unique robust photo-sensitive masking system revolutionizes the way composite materials are perforated and cut into shapes."

- No hole burrs/spurs to remove (Fig. 1).
- Minimal tooling and setup costs. Rapid turnaround and flexibility for design or pattern changes with little cost or lost time.
- No degradation in quality from part to part.
- No burning or delamination of layers during perforating or cutting (Fig. 2).
- Precision depth control for blind holes or cavities to within 25µm.
- Thru-holes or features with size accuracy and repeatability to within +/- 10µm.
- Precision positioning +/- 25µm over entire area being perforated.
- Excellent for perforating large area hole array patterns simultaneously (not one hole at a time) and removing large amounts of material quickly (Fig. 3).

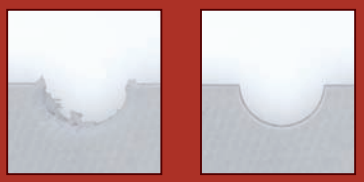


Fig. 1

¼" hole in Fiberglass composite
Left – Burrs/spurs after drilling
Right – Clean holes new process

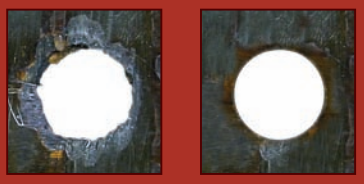


Fig. 2

¼" hole in Carbon Fiber composite
Left – Delamination after drilling
Right – Clean holes new process

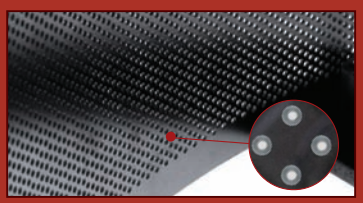
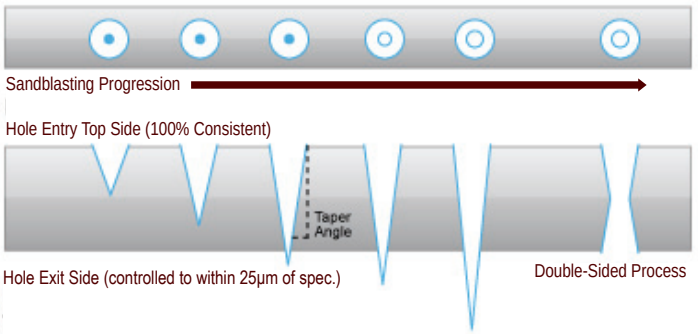


Fig. 3

Large perforation array with 1mm to 1.5mm holes used to attenuate sound in Thrust Reversers.

Properties and Limitations

The inherent nature of sand blasting produces a taper angle of about 15°, which for some applications, i.e.: sound attenuation, is a distinct advantage. Because of the taper, the process is limited to a maximum of a 2:1 thickness to hole diameter ratio. The result is the entry hole opening will be larger than the exit hole opening. This can be mitigated by sand blasting from both sides. The graphic below illustrates this phenomenon:



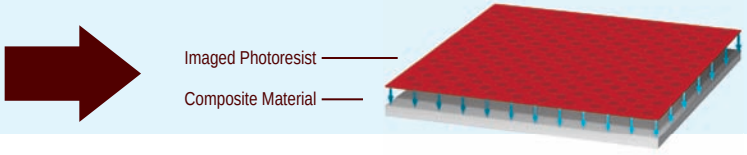
The photoresist mask has a finite life before degradation occurs, limiting the depth of machining. This limitation can also be affected by the composite materials used, the type of epoxy-resins used, and the feature being machined. In sum, this process is well suited to thinner composites (up to 5mm).

Materials Compatibility

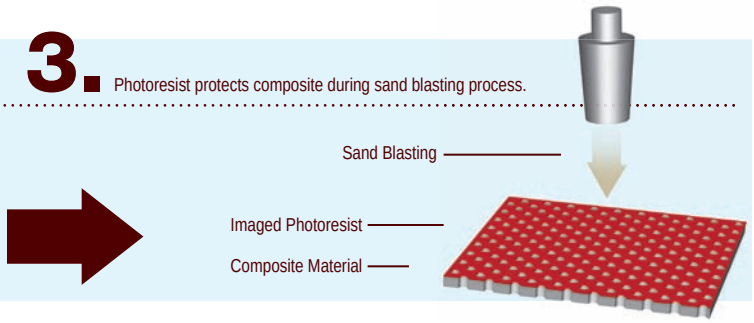
IKONICS Photo-Machining is best suited for non-ductile, brittle materials. The following is a partial list of materials compatible with Photo-Machining:

- Carbon Fiber
- Graphite
- Kevlar®
- Fiberglass
- Alumina
- Alumina Silicate
- Boron Nitride
- Ferrite
- Glass
- Ceramic Composites
- Many others

2. Imaged photoresist applied to carbon-fiber composite.



3. Photoresist protects composite during sand blasting process.



- Every hole/feature is present – no skips or dropouts due to punch breaks or drill misses.
- Fast, low-cost process: through-put not a function of the number of holes per part (Fig. 4).
- Controlled taper (cone shape) enhances sound attenuation for acoustic applications (Fig. 3).
- Process allows perforations to be made in laminated composite structures (composite applied to honeycomb core, Fig. 5).
- Any number, size or shaped hole or feature (including cutouts) are produced at the same time (Fig. 6).
- 100% Dry process - no water, slurries or solvents used.
- Process is easy to control; has broad latitude; and can be automated to reduce labor.
- Physical size is no challenge for Photo-Machining.

Fig. 4

Left: star & cutout; Right: over 2000 - 1.2mm holes, star and cutout. Both are 6" X 8". Both took same amount of time to process. (5 minutes)

Fig. 5

Perforations in pre-laminated structure without damage to the honeycomb core.

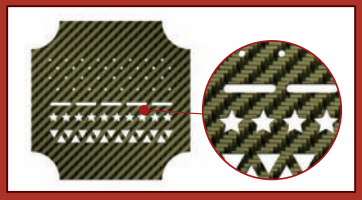


Fig. 6

Multiple holes, shapes & cutout produced at the same time on 5" X 5" Carbon Fiber Composite. (4 minutes).

Conclusions

Photo-Machining from IKONICS is a major breakthrough in machining composites. Conventional machining methods for perforating and cutouts on composite materials are challenging, at best, and often insufficient.

Compared to traditional machining methodologies, Photo-Machining is not only more user-friendly, but faster and ultimately lower in cost. Patent-pending photoresist technology coupled with high impact dry abrasive blasting delivers precision in feature size as well as positioning accuracy. Time to blast perforations and cutouts is significantly faster than other methods. Quality, feature reproduction and consistency are unmatched. With no burrs/spurs or other clean-up operation required, parts are ready to use immediately after machining. No de-lamination concerns assure part-to-part quality and high yields. Due to the photographic nature inherent to the process, every hole is exactly the same and all are present (none missing). Multiple holes, shapes, cutouts and/or cavities can be made simultaneously, and hole volume per piece is inconsequential to the process time.

Design changes can be made quickly with little down time or cost, making the entire process more flexible, diverse and versatile than traditional methods.

The process is completely dry and environmentally friendly. No water, slurries, or solvents are used. The process has wide process latitude which makes it easy to use and control.

While basic sand blasting is well understood, IKONICS's patent pending photoresist brings unsurpassed precision and control to the process.

About IKONICS® Corporation

IKONICS has served as an international leader in the development of imaging technologies for over 50 years. IKONICS proudly introduces products and process solutions for a diverse array of imaging markets.

At the core of IKONICS Corporation's success is the ability to quickly adapt its fundamental, commercial and technological competencies to the needs of image-consumers everywhere.

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4832 Grand Avenue, Duluth, MN 55807 USA | phone: (218) 628-2002 | toll free: (800) 643-1037 | fax: (218) 628-2064
www.ikonicsams.com | info@ikonicsams.com