Excimer Lasers for Machining Optical Components

- For the fabrication of optical structures, excimer laser mask projection techniques have been demonstrated to be suitable, and in general result in smoother surfaces than can be obtained by focal point scanning using, for e.g. ps laser. In all cases, structuring results from the basic assumption that machined depth is proportional to accumulated shot dose.

- Glasses, including FS, can be machined at 193nm, but require high energy density (e.d.), resulting in rather slow processing rate, and, depending on glass type, some risk of cracking due to formation of color centres, induced internal stresses etc. By contrast polymers machine smoothly and efficiently by the process of ‘photoablative decompositon’. PMMA requires 193nm(ArF), Polycarbonate PC) machines very well at 248nm(KrF), with easier operating logistics.

- One of our customers has successfully used the technique summarized here to machine fibre coupling lenses in PMMA. In the example below, ROC=400µm.

With some limitations, the same technique can be extended to small arrays of features machined in parallel by using a mask with an array of defining apertures.

- An oblique view of structures which are small (100µm wide) rectangular wells which have an inclined floor of parabolic shape. The application is extraction mirrors for optical waveguides; the example here was done in Optec as a demo using 248nm in PC; a machine subsequently installed for the customer uses 193nm on polymer waveguide structures of proprietary composition. Single structures are made by using a dynamic mask which starts as a small vertical slit, gradually opening to the left in a programmed manner so that each part of the ramp accumulates the desired number of shots.
- Any shape which is not re-entrant can be machined by contour sectioning. As an example, the dynamic MRA (motorized Rectangular Aperture) is used as a mask with single shots fired for a wide range of opening of decreasing size, resulting in the pyramid shaped stepped crater, here in PC (248nm).

If the order of selecting motifs is reversed, starting with the smallest one and increasing in size, then successive shots smooth out the steps resulting from previous shots, and an optically smooth surface can result.

This technique is most commonly applied to arrays of features using SIS (Synchronized Image Scanning), in which all the motifs in the set are on the same mask plate, and at constant pitch. A large laser is used with a beam big enough to illuminate one or more complete lines containing the complete set of motifs, and the virgin part is translated at constant speed with PSO (Pulse Synchronized Output) firing of the laser ensuring that the images of successive motifs in the set fall on top on each other. In this way an indefinitely long line (lines) of finished motifs is produced in a single operation. (N.B. The ends of the line(s) contain elements of the array which have not ‘seen’ all the motifs in the set, and are thus incomplete)

Arrays generated in this way can contain millions of identical elements. Another example is of pyramid features, 60µm pitch, in PC. Feature regularity requires highly accurate placing of superimposed shots, typically with air bearing stages and massive granite structures; the machine below can generate arrays 150mm x 150mm. High end machines can cover several m².
• Another technique that can be used to generate arrays is Orthogonal Grooving (OG). Here a linear array of simple motifs is used in combination with part motion to generate a 1D array of grooves, normally identical though could be otherwise. In a second operation the same array is machined in the orthogonal direction. This example shows an array of identical concave lenslets, 50µm x 90µm, x 36µm deep with a well defined shape factor. Surface roughness was measured <15nm.

The two stages of array generation are shown, together with a view of a printed character through a completed array using binocular microscope.

• Both Si and Ge can be machined at 193nm. ZnSe can be machined at 248nm, and the example here is of a ‘moth’s eye’ absorbing structure in ZnSe (6µm pitch) generated by OG.

• Diffractive optics can also be manufactured using excimer laser; the examples below were made in Sol-Gel for replication as IR optics, at left a binary structure with 10µm cell size, at right a 4-level device with 25µm cell size.
Most of these structures can be produced as individual features or small arrays at R&D level by Optec MicroMaster with small excimer laser.

Production quality of larger area arrays, either by OG or SIS, requires a large laser and air bearing stages, some typical systems are shown; these systems are designed to meet customer specifications.

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