Figuring of Large Optical Surfaces Using Reactive Atom Plasma (RAP) Processing

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Abstract

This paper presents an investigation into the capability of reactive atom plasma (RAP) processing for figuring of large optical surfaces. Following identification and optimization of the main processing parameters, 500 nanometre deep spherical surfaces were etched into nominally flat 200x200mm fused silica substrates. The RAP processing time was optimised down to 12 minutes duration whilst achieving surface figure error levels of 31nm RMS.

Introduction:

This paper presents a major development step towards an overall aim of establishing a rapid final figuring method for large optical surfaces of 1 metre within a processing time of 10 hours using reactive atom plasma (RAP) processing. Form corrections to 100mm diameter surface regions of Lithosil synthetic fused silica substrates have been undertaken using the RAP Helios 1200 machine. This RAP machine is designed to process 1.2metre optical components [1]. The RAP process is a chemical etching process combining an Inductively Coupled Plasma torch with a large scale computer numerical controlled motion system. To figure large optical components, the tool (plasma torch) moves along a raster scanning path at a speed dictated by a dwell time map which results from a Fast Fourier Transform (FFT) analysis of a surface error topography. This surface figuring approach requires three process inputs: the initial surface figure error map, the tool removal function and machine kinematic configuration. Linking as it does with grinding and polishing processes the aim is to integrate RAP machining into a rapid fabrication chain to feed a steadily growing worldwide demand for large scale ultra precise surfaces.

Experimental work

Two tasks were carried out: firstly, the RAP processing parameters were optimised and secondly, a Lucy-Richardson deconvolution algorithm was applied to measured surfaces against demanded spherical form surfaces creating necessary tool paths to perform a rapid surface figuring operation.

An experimental design was carried out to establish the optimum levels for key processing variables. Accordingly, surfaces were exposed to a moving RAP plume travelling at constant speed. Trench depth was used as an experimental output to assess the action and interaction of the selected parameters. Experimental tests were carried out both at low (1m/min) and high velocity (3m/min) to reflect the necessary processing conditions while undertaking a rapid surface figuring operation. This first experiment enabled optimum RAP processing conditions to be determined.

The second task included the central 100 mm diameter regions of 200 x 200mm fused silica samples being measured using a phase shifting interferometer. These surface measurements permitted precise surface removal maps to be created. The measurement map was modified to enable surface deconvolution and the creation of dwell-time and tool velocity maps. CNC code was generated by interpolation of the measurement matrix values along both the XX and YY directions used by the FANUC 30i series CNC system.

Results and discussion

The results of the design of experiments enabled a high performance torch to be obtained. An effective high material removal rate of 1.5mm^3/min was established. The achieved dynamic range of the process, in regards depth of trenches, was found to be 5 – 150 nanometres. Of priority significance, with notable inter-actions at low speeds, was the employed power levels and the torch stand-off distance.

The form accuracy result of the optimised RAP figuring process is shown in figure 1. Processed and theoretical spherical shapes were compared and the residual figure error was found to be ~31 nm rms (λ/20). This achievement was consequent on two iterations. Surface figuring tests were repeated to ensure an effective repeatable process had been established. The output of the initial figuring iteration was used as the input for the second (final) figuring iteration. Each surface figuring iteration took

~ 6 min. A convergence ratio of approximately 78% was achieved. Also the surface roughness was 1.8nm rms before RAP processing and it became 6nm rms. Apparent edge effect is dealt using other energy beam technologies. The detail of overall time taken for each figuring experiment is given in Table 1.

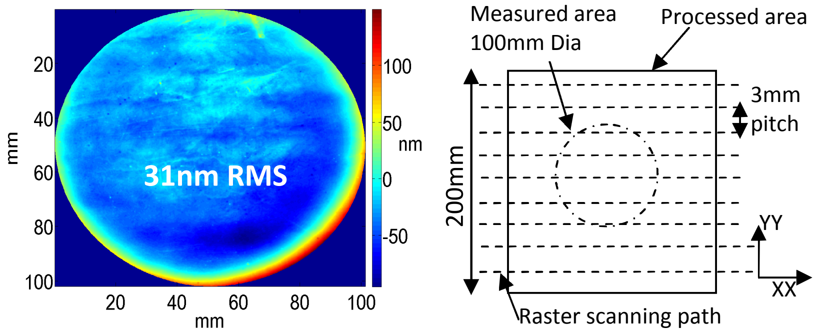

Figure 1. Surface figure error of a RAP processed 100mm diameter surface

Measurement [min.]	Computational [min.]	Torch startup- [min.]	Sample loading [min.]	Figuring [min.]
30	20	3	5	6

Table 1. Duration of the operations comprising a single figuring step

Conclusion

A statistical experimental analysis has been successfully applied to the RAP process. RAP processing parameters were optimized to obtain a very high material removal rate while reducing dwell time and heat transfer effects during figuring. A fast figuring capability for the RAP technology over a 100mm diameter area has been demonstrated and a surface figures accuracies of 31nm RMS achieved.

References

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