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Fast plasma figuring technology for the correction of meter-scale optical surfaces

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The next generation of meter scale optical surfaces will require sub-aperture surface figuring processes for the form correction at nanometer level. Due to the limitations of current numerically controlled polishing and other machining techniques, numerous optical surfaces will be corrected using energy beams. The work presented in this paper focuses on an advanced optical fabrication process called Plasma Figuring. The process utilizes an inductively coupled plasma (ICP) torch to dry etch silicone based materials using a dwell time method. The plasma figuring (Fig. 1) process enables the correction of flat and spherical surfaces down to lambda by 20 (i.e. 30 nm rms). The process is used for removing low and mid spatial frequencies shorter than 1/5 mm-1. Surfaces processed by plasma figuring are easy to polish through flash polishing also named buffering. Thus, average surface roughness better than Sa 3 nm rms can be reached. Plasma figuring does not induce sub-surface damages even when hundreds of nanometers of material are removed. Plasma figuring is carried out at atmospheric pressure using a dedicated CNC machine. A three axis Fanuc 30i series is used for ensuring that dwell time patterns are applied and satisfy the deconvolution result. The machine motion system is designed to process meter-scale optical components in a raster scan manner. Plasma figuring process is enhanced by an advanced tool path algorithm that enables a robust thermal management of the plasma jet. Indeed, the result of a tool path strategy underpins the figuring result and secures a reduced number of iterations. Results show that a dedicated tool path enables to reduce the effects of the nonlinear term introduced by the temperature of the plasma jet. The investigation of the power dissipation of the plasma torch reveals the true efficiency. The investigation is carried out through both temperature and flow measurements of the coolant that runs through two key components: nozzle and coil. Two results are obtained. The first set of experiments is carried out in capacitively dominated plasma mode (i.e. E mode). Results show that the amount of power dissipated into both the torch coil and nozzle. In fact, 15.4% and 33.3% are dissipated by nozzle and coil coolant channels respectively. The second set of experiments is carried out in inductively dominated plasma (i.e. H mode). The results reveal an increase of energy efficiency of the torch.

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