OR0501

Simulation of high-rate Plasma Jet Machining

Johannes Meister[1], Thomas Arnold[1]

[1]IOM Leipzig, Leipzig, Germany

johannes.meister@iom-leipzig.de

Plasma Jet Machining (PJM) - a local dry-etching process using fluorine-based atmospheric plasma jets is a promising technology for deterministic ultra-precision machining of optical components made of fused silica and other silicon-based materials. Using a high-power microwave plasma jet large removal rates can be achieved, as required for the aspherization.
The plasma jet source utilized for PJM consists of a coaxial waveguide system and a gas nozzle fed by a mixture of inert and reactive gases such as argon, helium, oxygen, and CF_4. In the proximity of the nozzle the gas is excited by 2.45 GHz microwave energy to form a stable rotationally symmetric jet discharge in atmospheric pressure. Furthermore an outer ring-shaped nozzle for nitrogen shields the jet from the surrounding environment. Inside the plasma jet a large current density of long-living highly reactive fluorine radicals are created that locally interacts with the workpiece surface.
However, due to a plasma gas temperature of more than 1000 K a significant amount of heat is introduction into the workpiece. This leads to a nonlinear etching behaviour of the purely chemical material removal process, which reduces the convergence of the machining process considerably.
Therefore, a method has been developed which determines the heat input of the jet with a high spatial and temporal resolution using infrared thermography. The temporal temperature distribution of the workpiece during a machining process has been extrapolated by a FEM heat transfer model. Furthermore, a temperature-dependent removal function has been determined on the basis of well-defined test etchings and accompanying simulations. The combination of both the spatio-temporal temperature distribution and a temperature dependent local etching rate makes it possible to predict the actual anticipated material removal.
That way, typical thermally induced surface figure errors can be reproduced. With this information, the accuracy of the machining results can be significantly improved.

Keywords
plasma jet machining
optical manufacturing
temperature dependency
plasma etching
dwell time method