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An investigation on pulsed microwave-driven plasma jet etching for borosilicate glass

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Reactive plasma jet etching is an alternative surface machining technique for the generation and correction of highly precise optical surfaces such as lenses and mirrors. For this technique a multi-component non-thermal chemically reactive plasma is employed. The active particles, which are created by pulsed microwave power, can react with the solid surface and form volatile compounds, and then the surface will be successfully etched. Etching processes have been tested so far mostly for quartz and silica-based glasses using fluorine-based chemistry (e.g. using CF_4 as precursor gas), as most of fluoride-silicon compounds are volatile. However, the borosilicate glass contains metal elements which produce non-volatile fluorides such that the dry etching of surfaces in the room temperature under the atmospheric pressure is a difficult task. On the other hand, the fabrication of a range of optical components requires the etching of borosilicate glass. It is expected that by the development of sufficient control on etching processes, novel fabrication processes in optical elements will be facilitated. Therefore, the development of a practical plasma etching process for borosilicate glasses is highly demanding in practice.

The applicability of reactive plasma etching for a difficult-to-etch borosilicate glass (e.g. N-BK7) requires expanding the choices of reactive etching gases and widening the temperature range under a vacuum condition. For this purpose, we develop a plasma jet that contains different reactive halogenated compounds as well as some non-halogenated etching gases such as oxygen which are admixed to inert plasma gases like argon and helium. Reactive atoms chemically react with the borosilicate glass exposed to the plasma and form volatile fluoride-silicon compounds and non-volatile metal fluorides. We perform experiments to optimize the relevant phenomena and process parameters in order to achieve etching of surface by removing non-volatile deposited fluoride residues. Subsequently, we establish a fundamental understanding of the chemical mechanisms and kinetics of etch product formation.

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