300 W picosecond laser machining of silicon nitride composite

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Advanced technical ceramics, such as silicon nitride, are vital engineering materials due to their excellent thermo-mechanical properties, chemical inertness, and high strength-to-weight ratio [1]. They are increasingly used in aviation, aerospace, electronics, semiconductor industries, and other fields.

Many applications of these advanced ceramics require machining to produce specific shapes and sizes at defined process quality. For instance, the machining of small-scale cantilever structures from ceramics is used for MEMS sensing applications [2], and the cutting and drilling of ceramic guide plates to manufacture probe cards for functionality testing of semiconductor devices. However, the low fracture toughness of advanced ceramics (due to high hardness and brittleness) makes conventional machining challenging due to chipping and cracking. This has led to an interest in non-conventional methods such as laser beam machining.

Research on the use of ultrashort pulsed lasers for machining advanced materials has highlighted advantages such as no tool wear, high precision, flexibility, and minimal thermal effects. Previous literature has focused on lower average power lasers (<50 W) with a maximum material removal rate of about 20 mm^3/min [3]. However, the increased industrial demand for machined advanced ceramics requires higher manufacturing throughput, which necessitates the use of high power lasers (>50 W).

Recently, high power ultrashort lasers have become available, presenting an opportunity to scale up the throughput of machining advanced ceramics. In this study, a state-of-the-art 300 W picosecond laser system operating at 1064 nm is used to investigate the influence of process parameters, such as total energy dose and dynamic pulse energy distribution on the ablation efficiency, material removal rate, heat-affected zone, and thermo-chemical reactions during laser interactions. The underlying material removal mechanism is presented and discussed, and finally, optimised process parameters are used to demonstrate high throughput cutting of silicon nitride while discussing the consequential effect on surface integrity.

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