論文の内容の要旨

氏　名　　Pham Xuan Khai

The fabrication of microholes with a high-aspect ratio is required in various industrial devices, such as fuel injection nozzles, turbine blade cooling, or wire drawing mold. Mold materials with a high hardness, such as cemented tungsten carbide (WC-Co), are difficult to machine by classical chip-removal techniques and they are mainly fabricated by electrical discharge machining (EDM). Even though the accuracy of EDM is fairly high, it has several drawbacks such as low machining rate and additional time and cost needed for polishing and finishing processes. Therefore, laser machining processes of hard but brittle materials have been intensively studied. This thesis presents a research on microhole drilling on WC-Co using femtosecond laser pulses at a wavelength of 800 nm. Microholes of 100 to 300 μm in diameters were drilled on WC-Co plates of 0.5 and 1 mm thicknesses by means of laser trepanning drilling technique using a galvano-scanner with an f-θ lens of 80 mm focal length in air. The effects of the machining conditions, such as the focus position of the laser beam relative to the sample surface, scan speed of the laser beam, and laser polarization on drilling speed, the shape of drilled holes and characteristics of the sidewall surface were investigated. It was found that focus on the surface produced a less tapered hole and a higher machining speed than focus 0.5 mm away from the surface in either direction. A low scan speed of the laser beam of 0.035 mm/s produced straighter, less tapered and more symmetric holes than a high scan speed of 15 mm/s. However, the high scan speed resulted in a higher machining speed. A circular polarized beam resulted in round holes, whereas a linearly polarized beam produced distortions in the shape of the holes. It was also found that laser-induced periodic surface structures (LIPSSs) were formed on the entire sidewall surface of drilled holes and LIPSS formation was dependent on the laser polarization. For a circularly polarized beam, LIPSSs were formed at a period of 300 nm and oriented perpendicularly to the plane of incidence on the sidewall. For a linearly polarized beam, LIPSS formation was dependent on the relative angle α between the direction of the laser polarization and the plane of incidence on the sidewall. For relative angles α from 0° to 70° and from 110° to 180°, LIPSS spacing was 300 nm. However, there were two types of LIPSSs coexisting from 70° to 110°. One had a spacing of 120 nm and the other had a spacing that varied from 500 to 760 nm depending on α. The orientation angle of LIPSSs measured between the LIPSS orientation and the plane of incidence had a nonlinear dependence on α. To understand this dependence, a model was proposed in which LIPSSs are assumed to align perpendicularly to the direction of the absorbed electric field lying in the tangent plane of the sidewall of a drilled hole. The calculated results from this model showed good agreement with the experimental results.