Micro and nano-manufacturing of surface structures using structured tools

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Abstract

Local modification of surface with micro/nano-texture (arrays of geometric, non-geometric, nature-inspired patterns) provides an effectively way to change surface properties in desired area without altering the properties of bulk material. Owing to the promising and vast applications of those functional structured surfaces in optics and electronics, solar energy, cell biology, bioengineering and medical science, a variety of micro/nano-machining techniques, for example SPDT, micro milling, grinding, fast-tool-servo, fly cutting and ultrasonic assisted machining, have been continuously developed in recent years to meet the increasing requirements on both accuracy and complexity of micro/nano-structured surfaces. However, due to the inherent limitations such as machining errors induced by cutting tool wear and motion errors of machine tools, the scale-up fabrication of surface textures/patterns of sub-micro or tens of nanometers form deviation remains challenging, especially for the mass production of surface grooves/step/patches of large high-aspect ratio.

Micro/nano-machining using structured cutting tools provides an alternative way on mass production of functional surfaces. With the advance of FIB/Laser-assisted shaping of cutting tools, special designed micro- and nanostructures can be actually generated on cutting tool tips/wheels. Through surface scratching/grinding process, the structures pre-fabricated on a tool can be effectively replicated on material surfaces. This paper systematically reports the new research progress on surface structuring of functional structures using tools with various complex cross-sectional shapes. Periodic and non-periodic structures/patterns are generated through ultra-precision lathe turning (for soft metals) and grinding (for ceramics). The focuses are on the demonstration of the micro/nano-manufacturing capability of this technique and the exploration the achievable surface quality and dimensional accuracy of machined structures under different cutting conditions. The results show that owing to the unprecedented merits of high throughput, one-step, and highly flexible precision capabilities, this technique has led to the hope for breaking the technical bottleneck for the scale-up manufacturing micro/nano-structured surfaces.