A Thesis for the Degree of Ph.D. in Engineering

Material Removal Mechanism and Surface Integrity in Ultraprecision Cutting of Porous Materials

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Thesis Abstract

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Thesis Title

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Thesis Summary

Porous materials have received great interest not only in medical science but also in a variety of industrial applications due to the special properties of porous materials, such as high surface area, reduced volumetric density, and increased permeability. These materials are generally manufactured by powder metallurgy or chemical etching, however, to achieve the high performance of porous materials, precision processing of complex three-dimensional shapes is a necessary. During the machining of porous parts, surface integrity, mechanical properties, and porosity are significantly changed by the cutting process, which may influence their applications. Nevertheless, the researches carried out on the mechanical machining of porous materials are few especially in nanometer scale, thus, the machining mechanism has not been revealed. In this research, ultraprecision cutting in micrometer and nanometer scales for three types of porous materials, porous carbon, porous single crystal silicon, and porous titanium is performed with single crystal diamond tools. Microscopic material removal mechanism is investigated and machining conditions to improve surface integrity is discussed.

Chapter 1 provides the introduction and overview of the issues regarding research. The research significance and also the research objectives were included in this chapter.

Chapter 2 provides an introduction to ultraprecision cutting technology and an overview of the mechanism of cutting of hard brittle materials like ceramic and ductile materials like metallic materials, as well as past research works on the machining of porous materials.

Chapter 3 presents the results of the investigation on the fundamental mechanism of surface formation in the ultraprecision diamond turning of porous carbon. Influence on surface roughness by observed deformation, fracture, and rotation of carbon grains on a tool tip is revealed.

Chapter 4 contains the discussion of the fundamental mechanisms of material removal in the ultraprecision diamond turning of porous silicon. Influence of anisotropy and cutting stress field near the edge of a pore is investigated and cutting condition to accomplish flatness in nanometer scale is presented.

Chapter 5 presents the discussion of the fundamental mechanisms of material removal and surface integrity in ultraprecision cutting of porous titanium in comparison with pure titanium which has no pore. The transition of cutting chip shape, shear angle and machined surface hardness caused by the presence of pores are identified and evaluated.

Chapter 6 presents the general modeling for machining of the porous materials based on their material and mechanical characteristics which provides a guideline to decide cutting parameters.

Chapter 7 consists of the overall conclusion of the research. The future of this research area is also included.