

Laser-Induced Periodic Surface Structures on Hard Brittle Materials

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Thesis Abstract

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Thesis Title Laser-Induced Periodic Surface Structures on Hard Brittle Materials			
Thesis Summary Hard-brittle materials such as silicon carbide (SiC), gallium nitride (GaN), and diamond are appealing for functional micro/nanostructured surfaces, yet their extreme hardness and chemical inertness severely limit the use of conventional surface-processing methods. This study uses femtosecond laser irradiation to form laser-induced periodic surface structures (LIPSS) on reaction-bonded SiC, 4H- and 6H-SiC, GaN, and single-crystal diamond, and nanosecond pulsed laser irradiation to generate microcone structures on reaction-bonded SiC. The formation conditions of low- and high-spatial-frequency LIPSS (LSFL, HSFL), especially hybrid structures where HSFL form on LSFL via excitation of surface electromagnetic waves are clarified, and material-dependent trends across SiC, GaN, and diamond are explored and a unified formation mechanism is proposed. Chapter 1 provides a brief introduction to the materials and presents a literature review of surface structuring on SiC, GaN, and diamond. It identifies knowledge gaps and discusses the significance and objectives of this research. Chapter 2 presents the generation of microcones on reaction-bonded silicon carbide (rb-SiC) by nanosecond pulsed laser irradiation. The evolution of cone morphology with pulse fluence and the resulting superhydrophilic surface characteristics are described. Chapter 3 presents LIPSS formation on rb-SiC (SiC+Si composite). The relationship between laser parameters and development of different LIPSS on Si matrix and SiC grains is investigated. A preliminary mechanism for LSFL-HSFL hybrid LIPSS formations is discussed. Chapter 4 examines hybrid LIPSS formation on single-crystal 4H and 6H-SiC to validate and improve the proposed formation mechanism in Chapter 4. The influence of initial surface roughness and effect of bandgap on the LIPSS threshold are clarified, and a parameter map was constructed. Chapter 5 studies the influence of bandgap and optical properties on hybrid LIPSS formation on GaN, which is a wide bandgap, non-melting semiconductor. A process parameter map is constructed, and additional phenomena such as self-focusing, beam collapse leading to crack generation are analyzed. Chapter 6 presents an extension of the hybrid LIPSS study on single crystal diamond as an ultrawide bandgap material. Hybrid LIPSS formation conditions are identified and mapped. Laser-induced phase transformation of diamond into a thin amorphous/graphitic carbon layer is discussed in relation to the hybrid LIPSS formation mechanism. Chapter 7 presents the overall conclusions, and possible directions for future work are suggested.			