Fundamentals of layered nanoparticle covered pyramidal structures formed on nickel during femtosecond laser surface interactions

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Highlights

- We report a novel micro/nanostructure: nanoparticle-covered pyramids (NC-Pyramids).
- Stop-motion SEM videos detailing the formation process are presented.
- NC-Pyramids form via ablation with femtosecond laser pulses on metals.
- NC-Pyramids form through preferential ablation and redeposition of nanoparticles.
- NC-Pyramids have a solid core with a nanoparticle shell.

Abstract

The formation of nanoparticle covered pyramidal structures using femtosecond laser pulses with a fluence near the ablation threshold is reported for the first time. These unique structures form through combination of preferential ablation of flat regions around the pyramids and redeposition of nanoparticles created during the ablation process. The structures are demonstrated on nickel and stainless steel 316. When produced by rastering Gaussian pulses across the sample, layers of nanoparticles join together to sinter to form unique layered shells.

Keywords

Femtosecond phenomena; Laser processing; Microstructuring; Nanostructuring

1. Introduction

Femtosecond laser surface processing (FLSP) is a rapidly developing technology that can be utilized for creating specialized micro/nanostructures on the surface of various types of materials. The wide range and precise control over the surface morphologies enable precise tailoring for specific applications. A large variety of micro/nanostructured morphologies fabricated by FLSP have been reported in the literature, including pillars [1], [2], [3], [4] and [5], cones [6], [7], [8], [9], [10] and [11] and spikes [3], [12], [13] and [14] and mounds [15]. All of these surface morphologies share similar characteristics, namely microstructure with a height to width aspect ratio of at least 2:1, widths around 2–10 μm, and either nanoripples or nanoparticles covering the surface. In this work, we present for the first time a new surface morphology fabricated via FLSP that is referred to as nanoparticle covered pyramids (NC-pyramids). NC-pyramid have a pyramidal shape and are covered with a thick layer of nanoparticles (typically >2 μm thick). The NC-pyramids have an aspect ratio near 1:1 and can grow to be more than 50 μm in height and width. In a recent publication covering FLSP, we demonstrated that different values of the laser fluence lead to different formation processes for mound-shaped structure growth and therefore unique surface morphologies [15]. NC-pyramids are another unique surface morpholooy that result from using FLSP...