Raster-scanned formation of vertically grown femtosecond laser-induced columnar structures on Al

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The fabrication of micro- and nanoscale surface structures using lasers, whether through conventional direct laser patterning or via self-organization driven by laser-matter interactions, predominantly relies on laser ablation [1]. Consequently, the resulting surface structures typically form beneath the untreated surface level. This inherent limitation can restrict the functional applicability of laser-textured surfaces, as the generated patterns are confined to a limited region and may not effectively interact at interfaces due to their depth. In 2024, we successfully demonstrated the formation of columnar structures (CSs) within the laser spot on ultra-pure Al plates, induced naturally by femtosecond (fs) laser pulse irradiation [2]. These structures, overlaid with nanostructures, exhibit atypical vertical growth extending above the original surface level following repeated fs pulse exposure. As a result, this fabrication approach effectively addresses the aforementioned limitations associated with laser-textured surfaces. However, the formation of fs-CSs is highly sensitive to the laser fluence, and making it challenging to achieve a uniformly structured area through raster scanning. In this work, we investigate the formation of fs-CSs on Al substrate via raster scanning under fs laser pulse irradiation, employing two distinct laser beam intensity profiles: Gaussian and flat-top. Our results reveal that only the flat-top beam intensity profile enables the formation of fs-CSs with controllable height through raster scanning. In contrast, when using a Gaussian beam, the height of the fs-CSs saturates at an early stage and does not increase with continued pulse exposure.

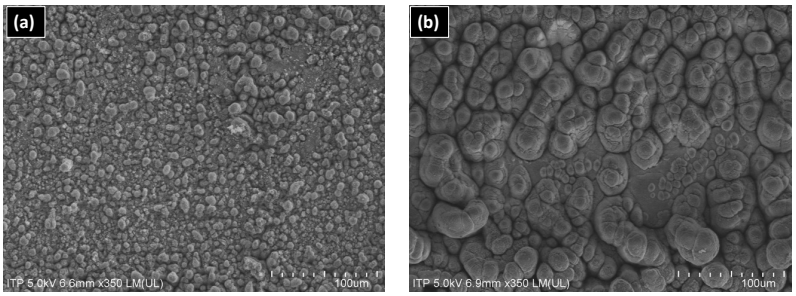

Figure 1. SEM images of fs-CSs formed via raster scanning with (a) a Gaussian beam and (b) a flat-top beam.

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References:

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