Anomalous increase in the spectral reflectance of columnar surface structures on Al with femtosecond laser irradiation

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Over the past few decades, the formation of intricate nanoscale and microscale surface patterns via femtosecond (fs) laser pulse irradiation has been extensively acknowledged as an efficient means to diminish metal surface reflectance through various fundamental processes [1]. These include multiple reflections, optical matching, and the excitation of surface plasmon polaritons at the nanostructured surface, which collectively enhance the absorptance of light at the metal surface [1]. By fine-tuning laser processing parameters such as laser fluence and the number of applied pulses, the size, shape, and density of these surface structures have been engineered, and it has been experimentally verified that the optical reflectance of metallic surfaces can be considerably reduced across a broad spectral domain [1].

Recently, we successfully fabricated columnar structures (CSs) on ultra-pure Al substrates, which were naturally induced via fs laser pulse irradiation. These vertically growing structures, covered with nanoscale features, exhibit out-of-plane growth beyond the original surface level upon repeated fs laser exposure [2]. Previous research has consistently reported a monotonic decrease in reflectance with an increasing number of laser pulses attributed to the evolution of complex morphologies and enhanced surface roughness that promote light trapping and absorption [1]. However, our observation reveals a contrasting behavior that fs laser-induced CSs (fs-CSs) on Al led to an increase in spectral reflectance across the entire visible wavelength range under more pulses of irradiation, as shown in Fig. 1.

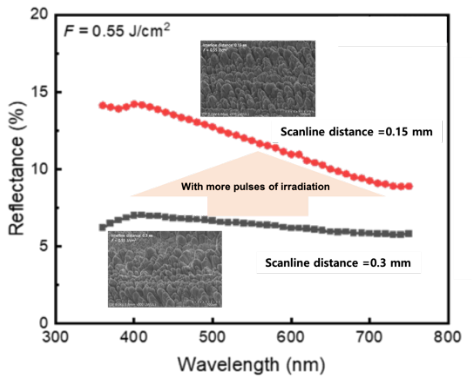

Fig. 1. Spectral reflectance of fs-CSs increasing with the number of irradiating pulses.

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References:

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