Tailoring optical, photothermal and electronic properties of semiconductors and dielectrics by Laser-Induced Surface Nanotexturing

Cold processing of refractory metals, wide-band-gap semiconductors, and hard ceramic surfaces has been achieved through the fabrication of Laser-Induced Periodic Surface Structures (LIPSS) via ultrashort laser pulse irradiation. LIPSS are nanoscale patterns that appear on the material surface during the interaction with ultra-short laser pulses and facilitates surface modifications with remarkable control on spatial resolution, surpassing the limitations of traditional optical technologies.

The application of this innovative nanomachining technique facilitated precise control over the size, periodicity, orientation, and geometry of the fabricated structures by adjusting laser parameters such as pulse energy, repetition rate, and scanning speed. This control was demonstrated across a diverse range of materials, including refractory metals (e.g., molybdenum), semiconductors (e.g., SiC, InP), and refractory ceramics (e.g., LaB6). Additionally, employing beam shaping techniques, such as spatial and temporal modulation, allows for even finer control over the generated nanostructures. By optimizing these parameters, it is possible to achieve precision in shaping the LIPSS morphology, ensuring that the resulting patterns meet specific requirements for diverse applications.

The induced structural alterations directly influenced and enhanced solar absorptance by leveraging the light-trapping capabilities of laser-induced nanotexturing. This process increases the surface area and augments photon-matter interactions, resulting in improved performance in optoelectronic applications. Moreover, in the domain of energy conversion, LIPSS show promise for applications such as Photon Enhanced Thermionic Emission (PETE), where the tailored surface structures can facilitate the conversion of sunlight into electrical energy by promoting the efficient emission of photoexcited electrons.