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Editorial

Metasurface Properties Obtained via Laser-Assisted Surface Technology

Haiying Song [1,2,*], Liang Wang [1,2] and Shibing Liu [1,2]

[1] Strong-Field and Ultrafast Photonics Lab, Faculty of Materials and Manufacturing, Beijing University of Technology, Beijing 100124, China
[2] Key Laboratory of Trans-Scale Laser Manufacturing Technology, Ministry of Education, Beijing University of Technology, Beijing 100124, China
* Correspondence: hysong@bjut.edu.cn

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Lasers as sources of heat or light energy have become a "universal tool" in the advanced manufacturing industry [1]. With the rapid development of high-precision mechanical manufacturing, high-performance surface devices are needed in many surface application fields. Laser-assisted surface technology (LAST, including coatings and modification) plays a vital role in several surface engineering fields [2–5]. LAST has been used to obtain many different surface properties on solid surfaces, such as super-hydrophobic, super-hydrophilic, super-interface, ultra-hydromechanical, ultra-tribological, and super-color characteristics [6–8]. Due to the higher performance requirements of structural parts in the high-end equipment manufacturing industry, single-surface technology cannot completely solve the problems of surface micro-defects and macro-deformation. Therefore, LAST combined with other surface engineering technologies has become more important and is receiving much attention.

Additive manufacturing-processed structures have an exemplary internal structure, excellent mechanical properties, and gradient materials. For example, by using laser-engineered net-shaping technology to deposit coatings on the surface of Ti-based implants, the wear resistance, corrosion resistance [9], and biocompatibility [10] have been improved significantly. A copolymer wire blended with carbon material was used as a raw material to construct a pyramid-shaped absorbing array, which achieved an absorption rate of more than 90% in the frequency range of 5.3–18 GHz [11]. Laser-based phase transformation hardening (LPTH) uses a high-energy laser to quickly scan a workpiece so that the surface temperature rapidly rises to the phase transition point. Subsequently, self-cooling quenching is carried out via rapid cooling, and the surface hardness of the workpiece is greatly improved. For example, Lesyk et al. [12] combined LPTH and ultrasonic impact hardening to treat medium-carbon steel AISI 1045, which rendered its surface wear 84 % lower than that of steel treated using a single technology (laser-ultrasonic composite surface treatment). Laser-shock processing uses a short-pulse high-power-density laser (>10^8 W/cm^2) to radiate the surface of the workpiece so that it rapidly vaporizes to produce a shock wave with a pressure of 10^4 Pa, resulting in robust and ductile deformation of the metal surface. Yang et al. [13] found that laser-shock hardening can significantly improve the corrosion resistance and wettability of a Ti-Cu alloy. Laser surface cladding involved the formation of a heterogeneous cladding layer with a certain thickness on the surface of an alloy using high-energy-laser rapid melting and solidification. Hu et al. [14] deposited nickel-based tungsten carbide composite powder on a tunnel-boring-machine cutter ring surface via laser cladding. The wear resistance of the coating with carbide particles was improved by about seven times. Arthanari et al. [15] deposited coatings sequentially on the surface of rare Earth magnesium alloy treated with laser melting cladding technology, and an excellent combination of hardness and corrosion resistance was obtained.

Laser molecular beam epitaxy (LMBE) is a thin-film deposition method that can precisely monitor the epitaxial growth of thin films at an atomic scale to prepare multi-element, high melting points and complex, layered structures. Krichevtsov et al. [16] prepared nano-sized magnetic NFO thin films using LMBE, which has an anti-spinel crystal structure and exhibits a magnetization reversal phenomenon. Laser chemical vapor deposition (LCVD) uses a focused laser beam to locally heat the substrate to drive the CVD reaction. The film exhibits excellent adhesion, conductivity, hardness, and smoothness [17]. Pulsed laser deposition (PLD) uses a high-power-density laser beam to ablate the target surface, with a high-speed plasma plume perpendicularly sputtering out on the target surface and forming high-performance thin films with complex compositions. Haroon et al. [18] used PLD to prepare a ZnO saturable absorber and coupled it to an erbium-doped fiber laser ring cavity. The peak power and pulse energy of the laser were significantly improved. Dong et al. [19] directly graphitized the surface of a Si substrate via femtosecond laser sputtering deposition, and multi-layer and layer-controlled graphene films were prepared on a Si substrate.

Laser surface micro-structuring uses the high-energy peak intensity and nonlinear absorption characteristics of lasers to prepare super-hydrophobic, super-hydrophilic, super-color, and antifriction micro-nano-scale structures on the surface of solid materials. Using laser ablation, Zhang et al. [20] formed a conical non-spherical microstructure on a metal surface, and a super-hydrophobic surface of a nano-pyramid structure with a contact angle of 160° was obtained. Li et al. [21] prepared composite nanostructures composed of random nanopores and nano-protrusions on the surface of GaAs/Ge solar cells using a liquid-phase femtosecond laser. The structure suppressed the surface reflectivity at 8.9% in the range of 300~1200 nm, and improved the battery surface's antireflection property. Meng et al. [22,23] prepared jungle-like black silicon structures using a femtosecond laser in an alkaline solution. The structures were able to reduce the average minimum reflectivity of the silicon surface in the whole visible light region to about 5.6%.

In summary, the protective layer and modified surface obtained via LAST can significantly improve the surface properties of solid materials. It can be widely used in fields such as aerospace, machinery manufacturing, petrochemical, shipbuilding, metallurgy, electronics, and information, and plays an increasingly important role in reducing weight, remanufacturing, energy saving, and environmental protection.

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