Localized Transient Electrons Dynamics Control in Femtosecond Laser Micro/Nanofabrication: from Fundamentals to Applications

Dr. Lan Jiang
Laser Micro/Nano Fabrication Laboratory
School of Mechanical Engineering
Beijing Institute of Technology, Beijing

Abstract

An ultrafast (attosecond/femtosecond) laser pulse duration is shorter than many physical/chemical characteristic times, which makes it possible to manipulate/adjust/interfere with electron dynamics, such as excitation, ionization, density, and temperature of electrons. This study proposes to control localized transient electrons dynamics by temporally/spatially shaping femtosecond pulses and then to control the subsequent processes by adjusting laser-electron interactions. A multiscale model is developed, which shows that it is feasible to control electron dynamics to adjust localized transient material properties, phase changes, and micro/nanostructures. Based on our theoretical predictions, the proposed fabrication methods are validated experimentally. We propose to: i) control the localized transient electron density to induce resonance absorption, by which microchannel processing efficiency is increased by 56 times and the maximum aspect ratio is extended by 3 times; ii) adjust the phase change mechanism by changing photon-electron interactions, which reduces the recast layer thickness by 60%; iii) adjust electron generation on fabricated material surface, by which the periods, orientations and structures of the surface ripples can be effectively adjusted; and iv) control electron density and its distribution, which obtains controllable micro/nano hierarchical structures on material surfaces and enhancement factors up to 2.2×108 of surface-enhanced Raman scattering. Also, our proposed methods are applied to fabricate some novel fiber sensors and key structures.

Dr. Lan Jiang is the Changjiang Distinguished Professor of Mechanical Engineering at the Beijing Institute of Technology. His research activities are focused on laser micro-/nano-fabrication. He received National Outstanding Young-Scientist Award, National Natural Science Foundation of China in 2010; Beijing Medal of May 4, Beijing Metropolis Government in 2010; and the First Award of Natural Sciences, Ministry of Education, China in 2014. He was elected the NationalLeading Researcher for S&T Innovations in 2013; and the Leader of Innovation Group, Ministry of Education, China in 2013. Dr. Jiang served as the Panel Chair for the 5-10 Years Strategic Planning of “High Energy Density Beam and Nontraditional Energy Field Manufacturing,” National Natural Science Foundation of China (2009-2010); Chief Scientist, National Basic Research Program (973 Project), Ministry of Science and Technology of China (2011-present); and the Panelist of National High-Tech R&D Program (863 Project), Ministry of Science and Technology of China (2012-present). Dr. Jiang has authored 137 papers in international journals and 33 patents. He has delivered 46 keynote/plenary/invited talks in international conferences.

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