ALT`22

INTERNATIONAL CONFERENCE

Advanced Laser Technologies

BOOK OF ABSTRACTS

September 11-16, 2022

MOSCOW, RUSSIA

УДК 535.21; 535.23; 535. 33; 535.37
ББК 22.343.4; 22.344; 22.345

Abstracts of the 29th International Conference on Advanced Laser Technologies – 2022. – 224 с.

The book contains abstracts of ALT`22 conference reports devoted to fundamental and applied aspects of innovative laser technologies, laser-matter interaction, biomedical photonics, laser systems and materials, laser diagnostics and spectroscopy, nonlinear and terahertz photonics. The book contains abstracts of plenary, invited, oral and poster presentations. The official language of the conference is English.

ALT`22 Conference Book of Abstracts are on the conference website
https://altconference.org/proceedings

ISBN 978-5-6045474-6-5

Designing Two-Dimensional Temperature Profiles with Arrays of Tunable TiON:Si Nanostructures

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Optical heat generation and control at the nanoscale play a key role in many applications, including photocatalysis, sensing, thermotics, etc [1]. The heating temperature of a nanostructure is determined by several contributions: the intensity of the incident radiation, the absorption cross section, the heat capacity, and the rate of heat exchange with the thermostat. Tuning the heating temperature can be easily achieved by changing the intensity of the incident light. However, to the best of our knowledge, precise tailoring of the heating temperature at a fixed light intensity is still of no practical implementation. Here, we propose tunable optical nanoheater consisting of titanium oxynitride (TiON) nanocylinder placed on top of Si pillar. The TiON nanostructure acts as a plasmonic antenna that absorbs the incident light. The Si pillar is used to reduce the heat flow from the heated nanostructure to the thermostat (substrate). The designed structure allows for *in situ* adjusting the photoheating temperature at a fixed light intensity. We show, experimentally, that the temperature of TiON:Si nanostructure can be tuned within a broad range 100-700 ^{o}C at the modest incident intensity of 5 MW/cm^2. The temperature is remotely measured using Raman thermometry. Our approach is based on the photoheating-induced oxidation of TiN on air, which leads to formation of a TiON. Typically, preparation of TiON from TiN is not straightforward since the oxidation of TiN quickly leads to the formation of titanium oxide (TiO_2) [2]. We observed a gradual transition from TiN to TiON and then to TiO_2 upon heating at a temperature of 350 ^{o}C. This allowed us to precisely tune the permittivity of TiON. Using this procedure, the absorption cross-section of the TiON nanoantenna can be modified to achieve a desired heating temperature. The proposed TiON:Si nanostructure were used for designing heating surfaces with nonuniform temperature profiles. The heating surface represents a two dimensional array of identical TiON:Si voxels – a three dimensional analogue of pixels. Under uniform illumination all voxels are heated to the same temperature. In order to create a non-uniform temperature profile, we tuned the heating temperature of each voxel through the photoheating-induced oxidation. The results of this study open up new possibilities in photocatalysis and sensing. In particular, the developed TiN:Si nanostructures were used in our recent works for realization of optical sensors for measuring the phase transition temperature of nanosized materials [3, 4].

This paper has been supported by the Kazan Federal University Strategic Academic Leadership Program (PRIORITY-2030).

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