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Formation of microcrystals under the influence of femtosecond laser radiation on carbon samples in liquid nitrogen

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Abstract. In this paper, we present the results of an experimental study of the carbon microcrystals formation by direct laser action on the carbon target surface at temperature of liquid nitrogen. It is demonstrated that the formation of microcrystals occurs in the subsurface layer and is caused by the achievement of critical temperature and pressure.

1 Introduction

Pulsed laser action in liquids contributes to the creation of a wide range of nanomaterials, including metal particles, metal oxides, semiconductors, as well as to the production of carbon materials with unique chemical structures, different shapes and sizes [1]. In addition to the wide variety of allotropic carbon and composite structures that have been characterized experimentally, there are many that have been predicted to exist (especially at high pressures) and are expected to have unusual properties and excellent potential applications [2-3].

The features of interaction of ultrashort laser radiation with solid targets in a limited volume of liquid are more complex than with a solid target in vacuum or in a gas environment. Laser-induced plasma expands adiabatically at supersonic speed, creating a shock wave limited by liquid, absorbing the remaining part of the laser pulse and obtaining a constant supply of vaporized matter [4-6].

2 Experiments and results

The laser system with the following parameters was used as a laser radiation source in the experiments: λ=800 nm, τ=50 fs, f=1 kHz, P_{av}=500 mW. The diameter of the focused laser spot on the sample surface was about 80 µm. The power density of the laser pulse reached $2 \cdot 10^{14}$ W/cm2 with Gaussian distribution. The output laser radiation through the periscope was filed in galvanoscanner enabling the processing of the sample surface at a set rate. For mounting the carbon sample and the subsequent cooling was collected open cryostat, allowing to fix the sample [7].

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Processes, accompanied by a rapid increase in temperature and pressure, as well as their rapid decrease, are highly unsteady. In this case, it is difficult to talk about the traditional carbon phase diagram, which makes sense only for equilibrium States. Under the modes of action accompanied by an additional laser-induced mechanism – subsurface overheating of the substance, the formation of an intermediate metastable state is possible. In this case, it is possible to form a local metastable layer of carbon at high pressure, which allows the synthesis of crystalline carbon structures. The subsurface heating up to several thousand degrees and the achievement of critical pressure values during the action of a sequence of laser pulses make it possible to create nonequilibrium conditions that initiate a phase explosion accompanied by the formation of single-crystal carbon micro-and nanostructures [8-9].

The registered structures have dimensions of about 1÷10 μm (Fig.1). Verification of the elemental composition of crystals using energy dispersive x-ray microanalysis (EDAX, which is part of the scanning electron microscope Quanta 200 3D) showed the absence of any other elements except carbon.

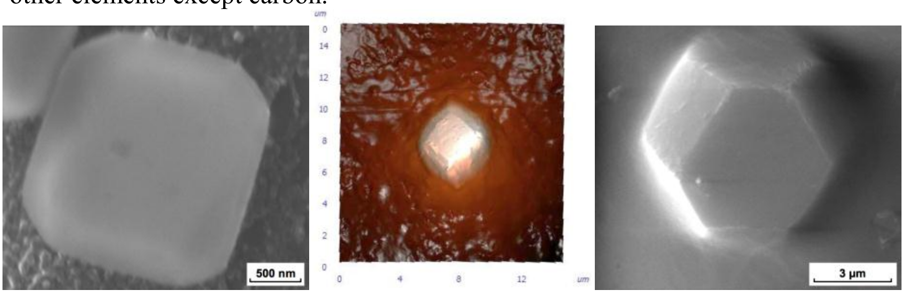

Fig. 1. SEM and AFM images of obtained single crystals of carbon.

3 Conclusion

The crystal structures registered after laser-induced splitting of the surface layer of glass carbon also have comparable dimensions. This is much larger than the size of nanodiamonds. Nevertheless, it can be assumed that the synthesis of both nanodiamonds and larger crystals is based on General principles. First of all, it provides the necessary temperature and pressure.

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