Pulsed laser induced photo ablation of diamond

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Abstract

Laser processing of diamond is governed by metastability of its crystal structure. When heated up to T_g~2000K diamond lattice tends to rearrange globally showing so called graphitization. Several regimes of short-pulsed laser graphitization of diamond are observed. If laser fluence exceeds a certain threshold E_g then multi-photon absorption in diamond can lead to material heating up to T_g and formation of permanent graphitic layer. After that pulse energy can be easily absorbed (absorbtion in graphite is many orders of magnitude higher than that of diamond). This results in graphitic layer heating and vaporization (ablation) at the sample surface. For $E<E_g$ so called accumulation effect takes place: diamond graphitization (blackening) requires a number N pulses, N increasing for smaller E. This effect is explained as a two – step process. Initially graphitic nano (micro) regions are formed. Diamond lattice rearrangement starts at tiny graphitic inclusions. Then thermal growth of graphitic regions size from pulse to pulse results in phase transformation of adjacent diamond layers.

Further removal of thus formed graphitic layer can be realized either by its vaporization or chemical etching if irradiation takes place in reactive atmosphere, e.g. air. In the latter case, photoinduced phenomena can play an important role. This regime was called laser nanoablation and takes place at $E<<E_g$. Its first step is diamond ionization. Each act of ionization contributes to lattice rearrangement and activation of a number of top-layer carbon atoms which can react more easily with oxygen. This process is threshold free, that is pure photolytic. The number of exited and correspondingly oxidized carbon atoms grows with concentration of charge carriers.

Diamond ablation rates, photoionization and surface graphitization in air were investigated for femtosecond (λ=800, 400 and 266 nm) and nanosecond (λ=193 nm) laser pulses. Depending on multiple-pulsed irradiation conditions ablation rates ranging from 10^{-7}nm (reactive etching of exited surface carbon atoms) to 100 nm/pulse (laser graphitized surface vaporization) were observed at fluence $0,1<E<10$ J/cm^2. The examples of fine diamond micro and nanostructuring will be presented.