Saturable absorption in detonation nanodiamond films

R. Yu. Krivenkov[1], K. G. Mikheev[1], T. N. Mogileva[1], N. Nunn[2], O. A. Shenderova[2], G. M. Mikheev[1]
[1]*Institute of Mechanics, Udmurt Federal Research Center of the UB RAS, Izhevsk, Russia 426067*
[2]*Adámas Nanotechnologies, Inc., 8100 Brownleigh Dr, Suite 120, Raleigh, NC 27617, USA*
roman@udman.ru

The saturable absorption (SA) is a nonlinear phenomenon, which is characterized by a short-term increase of the optical medium transmittance at high incident light pulse intensity. In the last decade, SA has been intensively studied in single-walled carbon nanotubes (CNTs) and graphene due to the possibility of using these carbon nanomaterials to produce picosecond and femtosecond laser pulses [1–3]. Detonation nanodiamonds (DNDs) are another form of carbon nanomaterials, which are currently being considered as a promising material for various optical applications. Previously, we reported on the SA of DNDs in aqueous suspensions with an average aggregate sizes of ~5, 35, 50, and 110 nm upon excitation by femtosecond and nanosecond laser pulses [4, 5]. Here we report on observation of SA in DND films sedimented on a glass substrate.

DND suspensions with an average aggregate size of 30 nm were prepared according to the technology presented in our previous work [4]. The suspensions exhibited negative zeta potentials ($\zeta = -45$ mV) at neutral pH. DND films were obtained by the method of slow evaporation of a suspension filled into an optical cuvette. Thus, an optically homogeneous two-layer film was obtained covering the inner surface of the cuvette. The calculated surface density of DND was 11.9 μg/mm^2. The linear transmittance T_0 of a two-layer film at 1064 nm was 66%. The X-ray diffraction pattern of DNDs was acquired using 0.1541 nm CuK$_\alpha$ radiation on a D2 PHASER (Bruker) diffractometer. We observed the diamond reflections from the {111}, {220}, {311} planes at $2\theta = 43.9, 75.3, 91.5°$ respectively.

Experiments were carried out using an open aperture *z*-scan technique. Single-frequency radiation of the fundamental of the 1 Hz single-mode YAG:Nd^{3+}-laser served as the laser pump [6]. The duration τ_p of the laser pulses at $\lambda = 1064$ nm was 21.2 ns. Laser light was focused by a lens with a focal length of 150 mm, with the diameter $2w_0$ of the laser beam waist at 1064 nm being equal to 114 μm, and the Rayleigh length $z_0 = \pi w_0^2/\lambda$ being of 10 mm. The point $z = 0$ corresponds to the waist of the focused beam. The nonlinear transmittance T of the DND film was measured as a function of the film position z along the axis of the focused laser beam.

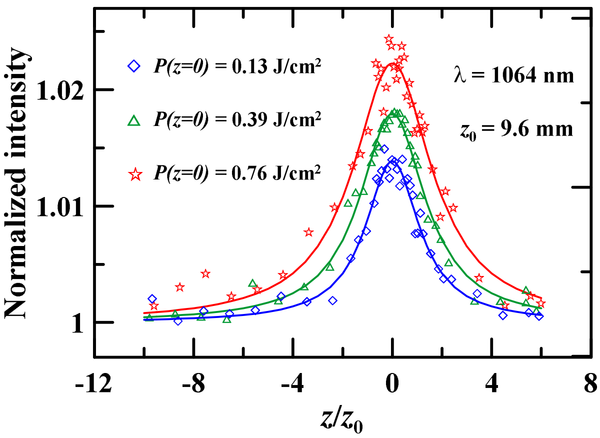

Figure 1 shows the normalized transmittance $T_n(z/z_0)$ of the DND film at 1064 nm for different incident fluences, where $T_n(z/z_0) = T(z/z_0)/T_0$. The obtained dependences $T_n(z/z_0)$ are symmetric relative to the point $z/z_0 = 0$ and that demonstrates SA in DND films at 1064 nm. The experimental dependences presented in Figure1 can be approximated using the expression $\alpha = \alpha_{ns}+\alpha_0/[1+I(z)/I_{sat}]$, where α is the absorption coefficient, characterizing SA; $I(z)$ is the incident beam intensity; α_{ns} is the linear absorption coefficient, which is not related to the SA; α_0 is the absorption coefficient, characterizing the SA at intensity $I(z)$ tending to zero; I_{sat} is the saturation intensity (coefficient determining the ability of a medium to exhibit self-bleaching). The fitted values of α_0 and I_{sat} were 0.19 cm^{-1} and 7.3 MW/cm^2, respectively.

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