Kinetics of formation of detonation nano-diamonds

V.M.Titov[1], B.P.Tolochko[2], K.A.Ten[1], L.A.Lukyanchikov[1]
[1] Lavrentev Institute for Hydrodynamics SB RAS, Novosibirsk, Russia, 630090.
[2] Institute for Solid State Chemistry and Mechanochemistry SB RAS, Novosibirsk, Russia, 630128.

Dynamics of nano-diamond particle growth at detonation of condensed explosives with a negative oxygen balance was investigated by the method of small-angle X-ray scattering (SAXS). The work has been done with the application of synchrotron radiation (SR) of the VEPP-3 accelerator at Budker Institute of Nuclear Physics. The radiation spectrum was from 10 to 20 kev and the beam was not monochromatic. The pulse duration was of the order of 1 ns and the pulse repetition rate was 250 nanoseconds.

Even the first experiments (detonation of ∅10 mm the trotyl-hexogen alloy) revealed that the SAXS signal amplitude is connected with the intensity of scattering on particles of larger density than that of the surrounding detonation products kept growing up to 1,75 - 2 microseconds (μs) [1], [2]. That differed significantly from the conventional model of the main nano-diamond formation in the zone of chemical reaction of the detonation wave, whose length does not exceed 0.7-2 mm (time of reaction 0,1 to 0,3 μs) [3].

This phenomenon may be caused by the "contrast" factor, since the SAXS signal value, if all other things being the same, depends on the squared difference in densities of scattering particles and detonation products around them. Then the signal value can grow at spread of the products [2]. Such an approach was estimated in [4].

In order to carry out more detailed investigation, the SR beamline #0-b VEPP-3 has been modernized. That allowed us to set experiments with explosive of 7 to 19 mm in diameter. The linear X-ray detector DIMEX with 256 strips and 0,1 mm resolution [5] was installed at beamline. It also was useful to apply flat explosives, where the line density in the beam axis normal to the plane of the explosive stays practically constant during the whole experiment.

It was ascertained that a delay of the SAXS signal maximum grows when the explosive diameter is increased. It indicates a connection of this effect with the zone of higher density and pressure in the detonation products that is bounded by the rarefaction waves – the so-called active zone with a length about two radiuses of a explosive, if a length is big. Experimental data shows that at a 7 mm diameter the main processes of the particle growth stop in a time of the order of 0,5 μs, and then their number and size do not changes much. SAXS data treatment shows a step-wise growth of the diamond's dimension in this time, up to 50 angstroms. Experiments with larger explosives shows a diamond's dimension growth during 2 - 3 μs.

So, a diamond nucleus has arisen in the chemical reaction zone and moves for some time in the high pressure zone (the active zone), where it may continue its growth and, possibly, acquires the carbon shell with the sp^2 - hybridization, and it can leaves this zone and move into rarefaction wave. It is rather complicated to separate these stages.

Literature.

1. A.N.Aleshaev, O.V.Evdokov, P.I.Zubkov et al. SR application in study of detonation and shock-wave processes// BINP preprint. 2000. #92, Novosibirsk. (in russian)
2. A.N.Aleshaev, P.I.Zubkov, G.N.Kulipanov et al. Application of Synchrotron Radiation for Studying Detonation and Shock-Wave Processes // Combustion, Explosion and Shock Waves. 2001. v.37, Issue 5, p. 585-593.
3. V.M.Titov, V.F.Anisichkin, I.Yu.Malkov. Study of the process of synthesis of the ultra dispersed diamond in detonation waves.// Physics of combustion and explosion. 1989. v.35, #3, p. 117-126.
4. A.P.Ershov. Simulation of synchrotron diagnostics of explosion// Letters to the Journal of Technical Physics. 2001. v.27, iss.19, p.90-94. (in russian)
5. V.Aulchenko, P.Papushev, S.Ponamarev, L.Shekhtman, V.Zhulanov. Development of a one-dimensional detector for the study of explosion with a synchrotron radiation beam. // J. Synchrotron Radiation. 2003. v. 10, p. 361-365.