Use of nanoparticles in gas generating and energetic materials (review)

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As is written in Springer Handbook of Nanotechnology [1], the nanoparticles are aggregates of atoms bonded together with a radius between 1 and 100 nm. The properties of materials at the nanoscale can be very different from those corresponding to a bulk material. Depending on the nature of substance it occurs mainly upon diminishing the size below 100 nm.

In the scope of this review the objects of interest are the particles of energetic materials (EMs), metals and their oxides as well as composite particles. The main feature of nanoparticles is their great specific surface that makes strong effect on the material reaction activity. In addition, in the case of metal the thickness of oxide surface layer on nanoparticles can be lesser than in the case of micron sized particles that also leads to enhanced reactivity of the material. These almost evident properties of nano sized materials provide the perspectives of their use aimed at increasing the heat release rate and thus improving ignitability and burning rate of energetic materials. It is believed, however, that more detailed investigation of the properties of nanostructured materials will lead to discovery of new fields of their use and new possibilities of improving the features of existing EMs. Some of examples of new features of nanostructured EMs are given in the review.

The mixture of oxidizer and fuel with particle sizes in the nanometer range can be considered as a simple example of nanocomposites called in the literature as Metastable Intermolecular Composite (MIC). The detailed studies were conducted [2] aimed at developing a better understanding of ignition and combustion of MIC materials. Ignition by impact has been studied using a laboratory gas gun using nano-aluminum (Al) and nano-tantalum (Ta) as the reducing agent and bismuth (III) oxide (Bi_2O_3) as the oxidant. Another sort of nanocomposite is based on carbon nanotubes serving as a support for filling agents like transition metal oxides Fe_2O_3, NiO and Co_3O_4. It was found [3] that the catalytic performance of composite nanoparticles in thermal decomposition was better than corresponding single component, showing positive synergetic effect. Of all catalysts, the Co_3O_4/CNTs composite particles exhibited the best catalytic performance. The attempt of using the carbon nanotubes as support for nanoparticles of polynitrogen (N_8), which possesses giant heat of formation, was made in [4]. Using evaporation/condensation technique the content of N_8 about 5-8 mass% has been reached that gives some promise for the future research. New information about the effect of nanosized TiO_2 (anatase form) on the burning law of nitramine based propellants is reported in [5]. It was found that with increase in specific surface of catalysts up to 100 m^2/g the pressure exponent can be reduced. Such effect was never obtained with the number of different catalytic materials.

It is interesting to note that the use of materials in nano sized form opens new possibilities in exploring the mechanism of solid/solid reactions. The role of metal oxide oxygen release in the ignition of nanothermies was studied in [6] using T-Jump/TOF mass spectrometer at heating rates in the range of ~10^5 K/s. The reactions in Al/CuO, Al/Fe_2O_3 and Al/ZnO systems were investigated. Mass spectrometric analysis indicated that metal oxide particles released molecular oxygen very fast to initiate the reaction. A clear correlation was observed between the capability of oxygen release from oxidizing particles, and the overall reactivity of the nanocomposite.

Another example of unique properties of nano structured EMs is described recently in [7]. It was demonstrated that self-propagating reactive waves moving faster than 2 m/s can be realized using a 7-nm cyclotrimethylene trinitramine (RDX) annular shell around a multiwalled carbon nanotube. This burning rate exceeds more than 10^3 times the bulk value for RDX at atmospheric pressure. The reaction also evolves an anisotropic pressure wave of high total impulse per mass (300 Ns /kg) and produces a concomitant electrical pulse of disproportionately high specific power, as large as 7 kW/kg. Such waves of high power density may find uses as unique energy sources. However, there exist great problems with scaling of discovered effects because with larger system size they become much less and special efforts have to be undertaken in order to provide practical feasibility of new phenomenon.

In the review, the brief description of the production methods and properties of nanoparticles of different nature are reported along with discussion of novel effects and applications of nanostructured gas generating and energetic materials.

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