A REVIEW PAPER ON NANO-EXPLOSIVE MATERIAL

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Abstract- New explosive materials (EMs) are the key to great advances in microscale energy-demanding systems as actuation part, igniter, propulsion unit, and power. Nanoscale explosive materials (nEMs) particularly offer the promise of much higher energy densities, faster rate of energy release, greater stability, and more security nEMs could therefore give response to microenergetics challenges. This paper provides a some review of current research activities in nEMs for microenergetics application.

Introduction- ENERGETIC MATERIALS (EMs) are substances that store Chemical energy. Old classical EMs can be classified into three Various classes, i.e. propellants, explosives, and pyrotechnics. Propellants and pyrotechnics release their energy through relatively Slow deflagration processes that last for several seconds Combustion process. Explosives release their energy in fast detonation Rate (microsecond timescale). Old classical Ems (composite) are relatively easy to prepare, and their performances can be predicted and tailored by adjusting the stoichiometry of the Chemical reactants. They have been widely used in military, mining, and demolition applications.

Significant efforts have been made to introduce metal powder with micro and nanosized particles into old classical EMs. Faster combustion velocity rate have been demonstrated .However, difficulties in handling such powders and their incorporation into existing formulations have also been reported.

First results demonstrated mainly empirically that the initiation and combustion properties of EMs are strongly influenced by their microscopical properties. They suggest that reducing the particle size to the nanoscale may result in reduction of the mass-transport rate and therefore would increase the burning rates making these nanoscale EMs (nEMs) attractive alternatives to monomolecular structures.

This paper presents a review of nEMs, a young but very active field of research. To begin, we introduce the recently synthesized nEMs and give the main performance reported by the authors. A section is dedicated to material: it is an important class of materials that combine excellent performances with interesting synthetic approaches for MEMS compatibility. While thermodynamic calculations of adiabatic flame temperature and reaction enthalpies are tools to help the choice of desirable EMs, they are not sufficient, in general, for the choice of good material for microscale application where thermal losses have to be taken into account.

REVIEW OF EMS FOR MICROSCALE APPLICATION

The first route explored by researchers was to used old classical EMs tomicroscale combustion by incorporating nanoparticles of Al into traditional propellants or explosives. Doping composite propellant with thermal conductive nanoscale particles has demonstrated a slight improvement in the reactivity of the mixture [1], [2]. Then, with the progress of nanoengineering, researchers preferred to combine or synthesize inorganic energetic nanocomposite composed of particles of oxidizer and fuel (mainly Al) to produce explosive material.

[A]. Nanoparticle-Doped Propellant

Nano-Al is the most widely used metallic doping particle forthe following reasons.

1) Al is a very common metal used in technology and is comparativelylow cost.
2) Al powder from spontaneous combustion rate and also improve VoD and heat of detonation
3) Al can be easily produced in nano size particles form (50–100 nm) and nano-Al is commercially easily available
4) Al enhances the reactive power of the material by increasingthe combustion velocity due to its high thermal conductivity of matrial.

In 1997, Brown et al. [3] found the influence of the Related to micronized Sb particles into $KMnO_4$ and found that reducing particle size from 14 to 2 µm enhancement the burning rate by a factor of 4.
Ivanov and Tepper [4] reported that by addition of aluminum nano particles in a propellant mixture formulation, the mixture burning rate could be improvment by a factor of 5–10.
Chiaverini et al. [5] presented result of an increase of 70% in burning rate of HTPB-based solid propellant doped with 20% of nano particles of Aluminum.
Armstrong et al. [6] found that the burning rate of the AP-based propellants increases when old classical Al powder is replaced by nano-Alumium. The burning rate increases magically from 1 to more than 100 mm/s when the aluminum particle size decreases from 10 µm to 100 nm. This tendencyvof material has been confirmed for different types of propellants (HTPB/AP, GAP/AP, and GAP/AN) by numbers of authors and Study reorts [7], [8]–[9]. The ignition time of composite material is also reduced when the propellant is doped with Aluminium nanoparticles [10]. However, for explosives, the use of metallic nanopowder has not proven to be effective [9].
In result we found that, doping propellant with Al nanoparticles improves slightly its reactivity and ignition capability; the maximum burning enhancement seems to be reached when the Al content represents 20% of the propellant mass.
However recent studies present that the homogeneous mixing of of nanosized metal particles into propellants does not increase the reaction temperature
and burning rate sufficiently to compensate the thermal losses occurring in microscale devices. These nano-Al doped propellants suit mesoscale applications but are not applicable for microscale applications. The quenching diameter is around
the mm, and the combustion is unstable in the centimeter scale. Furthermore, some authors have reported [8] that an AP based propellant mixing with pure nano-Al has unstable and non reproducible
combustion because of the difficulty to uniformlymix the ultrafine Al particles into the propellant. Other methods have been therefore considered. One is the homogeneous mixture of carbon nanotubes (CNT), having very high thermal conductivity, into traditional propellant, and the other is developed by
Pivkina et al. to produce nanopowder of AN and RDX. Very recently
Manaa et al. [11] presented a study of ignition and combustion rate of explosive-nanotube mixture. They incorporated single-wall CNT produced by Carbon Nanotechnologies, Inc. inside a PETN EM and demonstrated that the mixture , can burn rapidly with local temperature estimated between 1500 ◦ C–2000 ◦ C. Shock wave with an average speed of
6.8 km/s has been measured.
An interesting vacuum code position technique was presented by Pivkina et al. to synthesize nanostructure AN, RDX, and AN/RDX composites [12], [13]. The typical process of Synthesizing nano-RDX and AN/RDX consists of realizing nanopowder of the constituent (AN, RDX) by vacuum condensation of evaporated pure bulk substrates onto the cooled Substrates to obtain AN and RDX powder with 50 nm in diameter. Old classical AN and RDX powder with 200 and 50 µm in diameter, respectively, have been compared with nano-AN and RDX powder with 50 nm in diameter.
Accordingto the results, the burning rate can increased for nanoscale RDX: 15.1 mm/s for the conventional RDX and 30 mm/s for the nanoscale one. Pure AN could not have a sustained combustion;
only thermal analysis has been performed and showed that the temperature of max heat release for AN nanopowder is less than that for old classical one.
Vasylkiv et al. [14], [15] proposed nonreactors produced by nanoblasts impregnated with particles of $C_3H_6N_6O_6$. The described technique opens the door to the synthesis of a wide range of multimetal oxide ceramic and metal-ceramic composite nanopowders with precise stoichiometries and uniform morphologies.

[B] Nanoscale Thermite Material

Thermite reaction is a highly exothermic reaction that consist a metal reacting with a metallic or a nonmetallic oxide to form a stable oxide and the respective metal or nonmetal of the reactant oxide [46]. This is a form of oxidation–reduction reaction that can be written as

$$M + AO \rightarrow MO + A + \Delta H$$

Where M is a metal or an alloy, A is either a metal or a nonmetal, MO and AO are their respective oxides, and ΔH is the heat of reaction. The thermite reactions exhibit fast reaction rates that make their use highly energy efficient. Nano-Al is most widely used as the fuel for the reasons detailed plus additional advantages for thermite reactions.
1) Al has low vapor pressure: Al, unlike calcium or magnesium, does not require a pressure-tight reaction vessel for the reaction.
2) Al melting temperature is low (approximately 660 ◦ C)resulting in a low ignition temperature.
Among a large number of possible oxidizers [16], only a few have been investigated by different teams: Fe_2O_3, MoO_3, $KMnO_4$, CuO, NiO, MnO_2, WO_3, SnO_2, and SiO_2
In 1995, Aumann et al. [17] make MoO_3/Al MIC being 20–50 nm in diameter. When the mixture is stoichiometric, the energy density reached 16 kJ/cm^3, and the mixture can burn 1000 times faster than macro scale termite material.
Bockmon et al. [18] compared different samples of Al/MoO_3 material fabricated using ultrasonic mixing where nano-Al was used. The measured average combustion velocity increases from approximately 685 to 990 m/s when the Al particle size is decreased from 121 to 44 nm. As a comparison, micrometer
scale Al/MoO_3 burns at 10 mm/s [3]. Authors also note that the reaction rate becomes independent of Al particle diameter below a critical diameter, which is 40 nm in their case. This could be explained , when the Al particle diameter decreases, the proportion of Al_2O_3 over Al

increases resulting in a reduction in the volume of active material and possible inhibition of the thermite reaction.

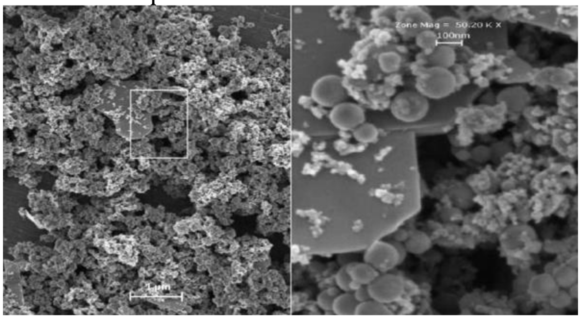

Fig. 1: SEM images of 80-nm Al particles mixed with MoO3 particles.[19].

Granier and Pantoya [19], [20] observed that the burning rate of nano-Al/MoO3 MIC is increased by a factor of 10 when the average Al particle size decreases from 20 000 to 50 nm. Moreover, they noted that by decreasing the Al particle size from micrometer to nanometer scale in the composite decreases the ignition time by up to two orders of magnitude (from 6 s down to 20 ms) and increase the repeatability of the composite's response to ignition. The increased sensitivity to ignition may be explained by the reduction in melting temperature associated with nanoparticles. Sun et al. [50] studied the reactions of nano-Al with O2 with the

Moderate Al particle diameters ranging from 30 to 160 nm. It was shown that Al/O2 reacts below the Al melting temperature. The heat released by the reaction .

Bhattacharya et al. [21] found the burning rate of nanoscaled CuO/Al and Bi2O3/Al. The burning rate reaches the moderate values of 440 and 150 m/s for nanoscaled CuO/Al and Bi2O3/Al, respectively. Results of empirical studies shows that establish clearly that the initiation temperature, reaction properties, and propagation rate are strongly influenced by the microscopical properties of the EMs, including the size of constituents and intimacy of the contact.

Aluminum powder is a very common ingredient in Explosive materials. The aluminum is used to increase the energy and raise the flame temperature in rocket propellants system. It is also incorporated in Explosives to improve air blast, increase bubble energies in underwater weapons, raise reaction temperatures and create incendiary effects. In explosives, it is generally assumed that combustion of aluminum particles occurs behind the reaction front (during the expansion of the gaseous detonation products), so that the particles do not participate in the reaction zone, but rather act as inert ingredients. Nanometric aluminum has recently available in quantities large enough for introduction into energetic materials and small-scale performance testing. The powder exhibits unusual thermal behavior that was originally associated with "stored energy" due to defects in the crystal lattice. As this additional energy could contribute to enhance explosives performance, the concept of "stored energy" has created high expectations for these powders in explosive materials. Subsequent research, however, shows that any such stored energy in the aluminum nanopowders, if it occurs, is short-lived. The liberation of energy at low temperatures is because of instead to oxidation of the extremely small particles. Contradictory information was then published on other types of aluminum nano-powders

In explosives, it is not clear if the nanoparticles are small enough to react faster than micrometric particles and, therefore, to participate in the detonation reaction zone. There have been early claims of improvements using nanopowders in explosives. Other researchers subsequently have demonstrated some improvements in the velocity of detonation (VoD) of ADN/Al blends using nanometric aluminum13. Tulis et al.14 also measured an increase in the VoD of fuel-oxidizer mixture when Al was compared to aluminum flakes. However, there were other reports where nanometric aluminum showed either no improvement of performance or even a decrease of performance.

[C] Particle Sizes and Reactivity

An energetic material's particle size classically ranges from 1-100 μm [4]. As is known in general, smaller particles give higher reaction rates and this is no exception in explosive material materials. In general, the reaction rate of a nanoscale thermite material is several orders of magnitude larger than those on micron scales [4] and the much larger surface area can change the combustion behavior of material, as well as ignition behavior by increasing sensitivity [4]. The changes in properties are all associated with reduced diffusion distances and the associated surface area increases. The initial reactions in a dual fuel-oxidizer system such as a thermite reaction are assumed to be diffusion-limited solid-solid reactions [10, 11] As a result the rate of reaction and thereby the combustion velocity of material can be increased dramatically as the particle size decreases and particle contacts increase.

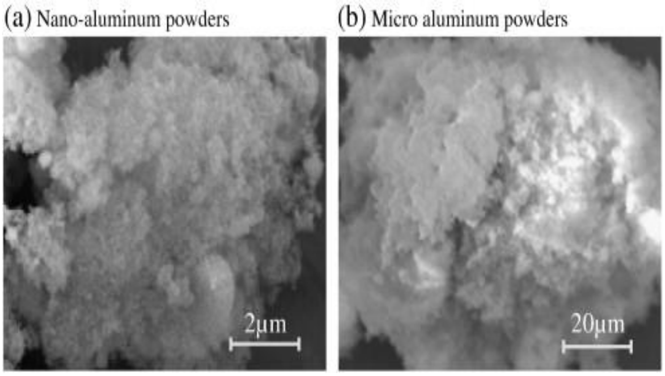

Fig. 2: Nano-aluminium powders and Micro aluminium powders [4]

Conclusion

The R&D of nano-explosive material is new field but it is very active, and promising results could lead to interesting breakthrough in the field of microenergetic devices. For years, different synthesis approaches to enhance the performances of explosive material have been investigated and reported in this review. The first approach consists of doping traditional explosive material (HTBP, PETN, RDX,) with nano particles of Al and, more recently, CNT.

Sorbital (sugar) as a fuel adding with potassium nitrate (KnO3) as a oxidizer and Iron oxide (red oxide Fe2O3) as a catalyst addition with nano aluminum powder (50-100 nm) will give best result in low cost .

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