Full Paper

Nanoenergetic Composites of CuO Nanorods, Nanowires, and Al-Nanoparticles

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Abstract

This paper reports on the synthesis of the nanoenergetic composites containing CuO nanorods and nanowires, and Al-nanoparticles. Nanorods and nanowires were synthesized using poly(ethylene glycol) templating method and combined with Al-nanoparticles using ultrasonic mixing and self-assembly methods. Poly(4-vinylpyridine) was used for the self-assembly of Al-nanoparticles around the nanorods. At the optimized values of equivalence ratio, sonication time, and Al-particle size, the combustion wave speed of 1650 m s^{-1} was obtained for the nanorods-based energetics. For the composite of nanowires and Al-nanoparticles the speed was increased to 1900 m s^{-1}. The maximum combustion wave speed of 2400 m s^{-1} was achieved for the self-assembled composite, which is the highest known so far among the nanoenergetic materials. It is possible that in the self-assembled composites, the interfacial contact between the oxidizer and fuel is higher and resistance to overall diffusional process is lower, thus enhancing the performance.

Keywords: Al-Nanoparticles, Combustion Wave Velocity, CuO Nanorods/Nanowires, Poly(4-Vinyl Pyridine), Self-Assembly

1 Introduction

Traditional preparation of nanoenergetics or metastable intermolecular composite involves physical mixing of oxidizer and fuel. If they are mixed in stoichiometric proportions, the energy density of a mixture can be maximized, but the kinetically controlled ignition may still require well-homogenized mixing of the two components. Thus, it is expected that the arrangement of oxidizer and fuel is critical to the propagation rate of combustion wave front or energy release. A thermite reaction being a solid state diffusion controlled reaction, the maximum interfacial contact area between the oxidizer and the fuel is desired to achieve higher energy release rates [1]. The composites synthesized via physical mixing [2], sol – gel synthesis [3], etc. possess a randomized distribution of oxidizer and fuel and thus lower interfacial contact area and hence combustion wave speeds. Therefore, by homogenizing the distribution of a fuel around an oxidizer, the rate of energy release or propagation of combustion wave front can be substantially enhanced due to an increase in the contacting area. This can be achieved by ultrasonic mixing or self-assembly processes [4, 5]. During ultrasonic mixing, however, there could be a danger of particle disintegration and sintering of nanoparticles. In the self-assembly approach, fuel nanoparticles can be arranged in an orderly manner around oxidizers and such composites can assume maximum hot spot density due to its ordered composition resulting in higher rate of energy release.

When spherical nanoparticle morphology is selected, self-organization may restrict assembling of few small nanoparticles on larger ones against a cylindrical (rod-like) morphology, where a relatively larger number of nanoparticles can be assembled. The rod-like nanoparticles (nanorods) are synthesized using solid templates like mesoporous silica [6], nanoporous alumina thin films [7], polymeric systems [8], arc discharge methods [9], and laser ablation [10]. They are also synthesized by an inorganic condensation method following a sequential route of olation and oxolation reactions in an aqueous solution [11]. Among these methods, the wet chemical approach of inorganic condensation [12] is attractive for the nanorods synthesis because this method has better control over the size and aspect ratio of the nanorods. In this method [12], copper chloride and sodium hydroxide are mixed together in the presence of a poly(ethylene glycol) (PEG) surfactant. This

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