Nanoenergetics and Combustion

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Abstract

In the nanotechnology community, there has been tremendous progress in the molecular sciences toward the total command of chemistry at all length scales. This progress has been inspired primarily by advances in the structural determination of biological systems. Similar advancements in assembly of molecular and nanoscale elements have been made in the pharmaceutical and microelectronics fields as well. These developments make it clear that in the foreseeable future it will be possible to synthesize any desired macroscopic structure with precise location of every atom. Functional nanomaterials are currently being produced by many different types of fabrication methodologies including self-assembly and supramolecular chemistry, additive manufacturing, and combustion synthesis. While such techniques have had widespread usage for non-reactive materials, considerably less attention has been given to reactive systems. However, many areas of combustion have the potential to be influenced by nanotechnology as a result of future fuels, propellants, pyrotechnics, explosives, and reactive materials having nanoscale features. In combustion applications, much of the highly desirable traits of nanosized materials can be attributed to their high specific surface area (high reactivity) and potential ability to store energy in surfaces. The ability to control the nanoscale structure and organization of energetic and reactive materials offers an unprecedented level of control over reaction and response characteristics of such materials. Surface functionalization may also make it possible to produce smart fuels and propellants, and fabrication of addressable energetic materials may enable a reaction to be switched on or off, or enable a deflagration to transition to a detonation or a homogeneous explosion on command. Assembled energetic particles and rods, nanolayered reactants, and porous substrates offer the potential to store high energy and insensitive materials in small volumes with reaction and quench length scales not achievable in the past. Such nanoenergetic materials offer long shelf life and nanosecond response times to produce localized heat, ultra high pressure bursts, and desired gas products. Various reactive and energetic materials are being investigated; examples include nanothermites and intermetallics, functionalized graphene sheets, and nanoporous silicon. Graphene sheets, because of their large surface areas, are excellent carriers of nanoparticles that may be functionalized to act as energetic materials or catalysts. Nanoporous silicon, again because of its high surface area and well-studied chemistries, allows for controllable feature design and organization to study the influence of multiscale characteristics on the ignition and propagation of reactive materials. This paper reviews the design, reactivity, and applications of several functional nanomaterials to combustion systems, particularly high speed propagating systems, and concludes by considering future research directions in the combustion and nanotechnology fields.

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