Abstract

High energy, high-density fuels have remained attractive since long for volume-limited propulsion systems. Increase in energy content and density of liquid hydrocarbon fuels by synthesis route is somewhat challenging. On the other hand, the use of metal/metalloid energetic particles with high volumetric heating value has received significant attention. In this context, boron is considered as potential fuel additive for liquid fuels due to its exceptional energetic content. The introduction of liquid fuel into combustion chamber is typically in the form of sprays of fine droplets, where the droplets signify the sub-set level component of a spray. Therefore, understanding the combustion characteristics of boron laden isolated droplets is an essential requirement in order to address the complex mechanisms in a spray. In present dissertation, combustion characteristics of Jet A-1 droplets loaded with boron and boron-based materials have been examined experimentally using a time-resolved high-speed photography system. Initially, the boron and in-house synthesized boron-based materials were characterized thoroughly in terms of particle size, morphology, surface chemistry, ignition temperature, and oxidation behaviour using standard material characterization techniques.

The droplet combustion study starts with the investigation of morphological effect of boron particles (amorphous and crystalline) in the aggregation process and its effect on the structure, and nature (permeability) of the agglomerate shell formed inside the burning droplet. It was observed that the morphology of the particle (crystallinity) is responsible for different burning behaviour of fuel droplets. A porous, permeable agglomerate shell forms in case of amorphous boron loaded droplet whereas a densely packed, impermeable agglomerate shell forms in case of crystalline boron loaded droplets.

The surface modification of sub-micron boron particles with octadecyltrimethoxysilane (a silane compound) was performed in order to improve the dispersion stability of boron particles in liquid fuel. The capping of OTMS on boron surface makes the particle stable against air oxidation. The dispersion stability of OTMS-capped boron in Jet A-1 at particle loading of 1%, 5% and 10% are found out to be 20 hours, 18 hours and 2 hours respectively. Ignition and combustion characteristics of as-received and silane-coated boron particles loaded in Jet A-1 at desired concentrations have been analyzed to understand the effect of silane coating. The burning process of OTMS-capped boron is slightly affected compared to as-received boron.

In the last part of the dissertation, a new route has been explored to decorate metal (aluminum or magnesium) additive on boron surface using photo-reduction method (UV irradiation) in order to improve the ignition and combustion of boron. This technique was employed for the first time to decorate Al/Mg on boron surface. The overall burning characteristics of metal decorated boron (B-Al or B-Mg) relative to as-received boron loaded in Jet A-1 droplets have been examined. The results show better burning characteristics for B-Al and B-Mg compared to as-received boron. The overall evaporation rate of liquid fuel (Jet A-1) was observed to be enhanced significantly with the addition of metal decorated boron.

Keywords: Droplet combustion; Jet A-1; Boron; Amorphous; Crystalline; Aluminum; Magnesium; Agglomerate shell; Silane; Surface functionalization; Photo-reduction