BORON-HYBRID FUELS FOR PROPULSION

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The performance benefits of metal fuels are well known for propulsion systems. Boron, which at lean mixtures gives better theoretical specific impulse for airbreathing propulsion systems than do hydrocarbons, can release more than three times the energy of kerosene on a volume basis. To boost the energy content of conventional liquid or solid fuels, boron particles can be added. Unfortunately, the widespread use of boron in propulsion systems has been discouraged by the difficulty in achieving high combustion efficiencies. Many years ago, organo-borane molecules were studied in the hopes of producing high efficiency, high energy fuels containing boron, but they suffered from handling and toxicity issues.

Metal particles used in fuels and propellants are typically larger than a micrometre in diameter. The last decade has witnessed the increased use of ultrafine metal particles in the nanometre size range (nanoparticles). With specific surface areas on the order of 100 m^2/g, the greatly enhanced reaction rates of nanoparticles can lead to faster and more efficient combustion. However, this high reactivity also means that these nanoparticles can age quickly through environmental oxidation, reducing their energetic content and making them less reactive. Agglomeration of the nanoparticles is an additional problem, not only for dispersion in a liquid or solid fuel, but during ignition and combustion.

One possibility to address the aging problem is to combine the boron with another metal, such as titanium or zirconium, to form a metastable compound. A second possibility is to physically coat the boron nanoparticles with a polymer. After having successfully produced thin coatings of polyethylene and polypropylene on aluminum nanoparticles with a surface-initiated Ziegler-Natta polymerization process, we were able to able to coat boron nanoparticles with polyethylene, albeit with some difficulties in controlling coating thickness. Additional benefits for efficient combustion could also result by coating with an energetic or fluoropolymer. The latter was recently achieved on aluminum nanoparticles from the in-situ polymerization of polyvinylidene fluoride in supercritical carbon dioxide. Unfortunately, neither of these possibilities solves the agglomeration problem.

A third possibility is to chemically bond or "cap" the boron nanoparticles with a polymer. Relying on a modified direct chemical synthesis approach recently published in open literature, we prepared a boron-hybrid energetic binder where boron atoms are directly incorporated in the polymer structure. The resulting organo-boron compound was an oily product that can be mixed with a liquid fuel or, in our case, mixed, dispersed, and co-polymerized within a polyurethane-based polymer binder to produce a solid fuel. We have since succeeded in casting a small amount of this fuel with promising mechanical properties, and characterized its burn rate and energetic content.

Future work will include scaling-up the synthesis and raising the boron content to 20% by mass. We are also looking at other combinations of metals and polymers. Aluminum is a fuel commonly used for rockets, so we are investigating aluminum-hybrid fuels for use in both hybrid and solid propellant rockets. Nanoparticles may also enable the use of metallized fuels for applications such as microcombustors and microthrusters where larger metal particles would not burn efficiently or could block nozzles and passages.