Laser Ablation Synthesis of Energetic Graphitic Coated Aluminum Nanoparticles

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Abstract
Nanomaterials have gained widespread attention from an array of scientists and engineers for their unique physical and chemical properties that are believed to be a product of their high surface area to volume ratios, thus making them favorable for a wide variety of engineering applications. Specifically, here aluminum (Al) nanoparticles (NPs) are investigated for their energetic behaviors suitable for solid-state propellants. However, it is challenging and unsafe to preserve pristine Al NPs without any unwanted surface oxidation in ambient conditions, which in turn passivates and retards their energetic activities. To address these challenges, this poster presents a research initiative in collaboration with the US Army Research Lab (ARL) to synthesize graphitic-coated Al NPs as alternative and enhanced energetic materials via laser ablation in organic solutions.

Introduction and Motivation
- Al has large enthalpy of combustion (~1675 kJ/mol for bulk; ~2324 kJ/mol for single atom) -- smaller sizes equals more energy
- A facile technique is proposed to synthesize Al NPs encapsulated in graphitic shells to prevent any unwanted surface oxidation.
- Laser ablation synthesis in solution (LASSIS) offers a green, facile, and inexpensive way to synthesize these graphitic-Al shell-core NPs while offering a way to manipulate desired NP characteristics such as composition and size distribution.
- It was hypothesized that the carbon coatings would not only protect the Al NPs from surface oxidation but also enhance performance in such ways that it would retard the particle aggregation rates and allow for fine-tuning of energetic behaviors.

LASSIS Setup
- Q switched Nd:YAG pulsed laser
- 1064 nm
- 5 ns pulse width
- 10 Hz repetition rate
- 100 mJ/pulse (max)

Results
- Both show D- and G-band at ~1375 and 1585 cm⁻¹ respectively
- Nearly unimodal narrow spread at 2 min and a unimodal wide spread at 8 min
- 4 min and 6 min exhibit some bimodal behaviors
- Increasing ablation time decreases the bimodal peak differences and increases overall particle size

Effect of Laser Fluence
- Particle size distributions for ablation in acetone (top) and toluene (bottom) for two different fluences.
- Increasing fluence decreases modal sizes and standard deviations.
- Higher vapor pressure of acetone (32 kPa) vs toluene (3.8 kPa) results in earlier solvent and carbon coating pyrolysis for acetone

Conclusions
- Laser-induced air shock from energetic materials (LASEM) results for toluene and acetone at different laser fluences.
- Samples prepared in acetone at 2.2 and 2.6 J/cm² produce highest shock velocities.
- Compared to commercial Al nanoparticles, graphitic-coated Al NPs indicate higher velocities that can be attributed to the shells retarding the surface oxidation.
- Acetone’s higher vapor pressure than toluene → earlier pyrolysis → earlier shell formation → slower particle aggregation → smaller particles → faster reactivity.
- NPs synthesized in toluene exhibit exothermic properties while those in acetone exhibit explosive properties.
- Varying solvent, time, and laser fluence allows for fine-tuning of the NP properties

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