



Atomization and combustion behavior of nanofuel droplets containing perovskite-type nanoparticles

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ABSTRACT

Metal and metal oxide nanoparticles (NPs) are promising agents for reducing energy consumption and pollution in applications where combustion power generation is provided. This study focuses on the production of new generation perovskite-type metal oxide NPs with enhanced catalytic activity customized for combustion and investigation of their catalytic performance for gasoline. The droplet scale combustion experiments were carried out at ambient temperature, atmospheric pressure and under normal gravity, the experimental processes were recorded with an optical system consisting of a high-speed camera and a thermal camera with a spectral range of 7.5–14 μm , and the combustion and atomization behavior of the nanofuel droplets were characterized. Perovskite-type NPs were produced by sol-gel technique in varying stoichiometric ratios (LaMnO_3 , $\text{La}_{1-x}\text{Nd}_x\text{MnO}_3$, $\text{La}_{1-x}\text{Ba}_x\text{MnO}_3$, $\text{Nd}_{1-x}\text{Ba}_x\text{MnO}_3$, $\text{La}_{0.5}\text{Nd}_{0.5-x}\text{Ba}_{0.5-x}\text{MnO}_3$, $x = 0, 0.3$) to confirm their catalytic activity's effect on gasoline droplets' combustion behavior. Structural characterization of the obtained five different NPs was carried out by SEM and XRD techniques. Chemical analysis, surface area measurements, and spectral properties of the samples were determined by XPS, BET, and UV-Vis spectroscopy, respectively. The results showed that all perovskite-type NPs have particle size range of 25–40 nm. $\text{La}_{0.7}\text{Nd}_{0.3}\text{MnO}_3$ NPs had the highest oxygen adsorption ability and $\text{La}_{0.5}\text{Nd}_{0.3}\text{Ba}_{0.2}\text{MnO}_3$ NPs had the largest surface area (393.4898 m^2/g). Perovskite type NPs tended to increase ignition delay and extinction times. The maximum flame temperature of fuel droplets loaded with $\text{La}_{0.5}\text{Nd}_{0.3}\text{Ba}_{0.2}\text{MnO}_3$ NPs was 469 °C. This temperature was 274 °C higher than the maximum flame temperature of the pure gasoline droplet. The outcomes demonstrated that, with the right catalyst design, perovskite-type NPs can perform better as powerful oxidizers and high energy combustion catalysts.

1. Introduction

Nanofuels are new generation fuels containing nano-sized functional agents that regulate the combustion, atomization, and emission behavior of the base fuel. Nanomaterials with improved physical properties can reduce the activation energy required for combustion reactions as a catalyst, facilitate hydrocarbon oxidation, and increase the volumetric and mass-energy density of the fuel depending on the calorific value of the components [1]. In addition, they can provide rich air-fuel mixtures by improving the atomization mechanism in liquid fuels [2]. NP additives, which function as combustion regulating and

improving agents (Al, Fe, B, MgO, Fe_2O_3 , Al_2O_3 , etc.) [3], can be produced by various methods such as solid-phase reactions [4], wet chemical synthesis [5], chemical precipitation [6], chemical vapor deposited (CVD) [7], hydrothermal reaction [8], sol-gel [9].

The ability to produce materials with targeted properties at the nanoscale, combined with recent advances in nanotechnology, has led to the discovery of a new class of high energy density fuels containing high energy density NP catalysts [10]. It is well known that the enhanced catalytic activity results from synergistic effects mediated by the materials' lattice structure defect (void), surface oxygen mobility, and the reduction-oxidation (redox) properties of catalysts. Perovskite-type NPs are among the most advanced materials of this class, with their low

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