Title

Microwave controlled ignition, combustion and extinguishment characteristics of ADN-based ionic liquid propellant in single mode resonator

Authors

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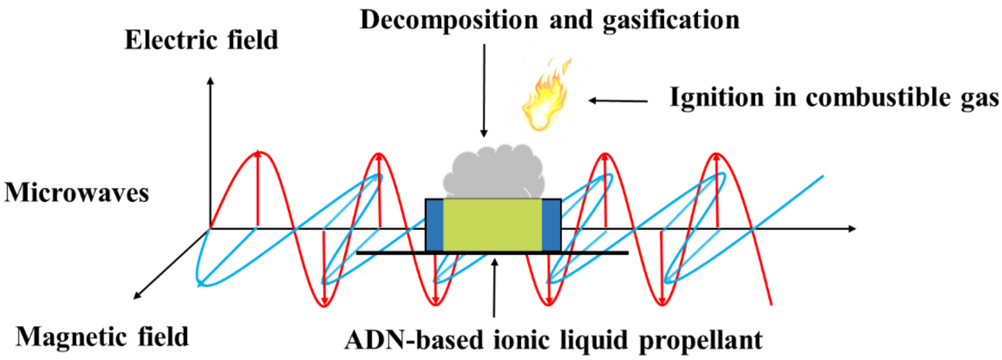
Abstract

With increasing concern on environment and human safety, hydrazine has gradually failed to meet the requirements of green liquid propellant due to its low specific thrust, high toxicity and inflammability [1-2]. At present, the Ionic liquid (IL) propellant is regarded as the most promising fuel to replace hydrazine. IL is a kind of salt composed of organic cations and inorganic anions or organic anions, which possesses the advantages of low vapor, strong polarity, good solubility, good stability, and so on [3-4]. Among them, ADN-based liquid propellants have attracted wide attention for its high performance, low toxicity, low cost and so on [5-6]. Meanwhile, the continuous progress of space exploration also puts forward higher requirements for liquid propellant ignition methods. At present, catalytic combustion is mainly used in ADN-based liquid space motors. However, the working process of the ADN-based liquid space engine heavily depends on the catalytic decomposition process of the propellant in the preheated catalytic bed. To avoid the deactivation of catalyst due to high temperature during combustion, the electric ignition is used to ignite ADN-based liquid propellant [7-8]. Microwave ignition has received much attention in recent years and is promising to solve the problem of storing fuel and oxidizer separately in liquid motors. Different with traditional ignition methods, microwave radiation could interact with the material as a whole by penetrating the material. To date, research focuses on the microwave ignition of solid energetic material, mainly nanothermite [9-11]. Compared with solid materials, liquid materials (especially ionic liquids) are natural microwave receptors on account of excellent molecule polarity, which could rotate hundreds of millions of times per second at typical microwave frequency (2.45GHz) [12-13]. Microwave can directly activate ionic structure in the liquid mixture, so that the material could be heated quickly and evenly and make the ignition possible. Meanwhile, the conductivity of IL also makes them heat up rapidly due to the resistance heating.

In this paper, to maximize the advantages of microwave heating, two kinds of ILs: ADN and 1-allyl-3-methylimidazolium dicyandiamide ([AMIM][DCA]) are used as oxidant and fuel of liquid propellant respectively. By varying the ratio between fuel to oxidizer, the most suitable propellant formulation which could be ignited by microwaves was found. Microwave-controlled and repetitive ignition and combustion of ADN-based propellant was achieved firstly in a customized single mode resonator. The result showed that the ignition process could be divided into two stages: ionic liquid propellant was first heated up and decomposed rapidly after absorbing electromagnetic energy, producing a lot of oxidizing and reducing gases into the air. Then gas phase ignition occurred and the flame quickly spread into the IL propellant. The ignition delay time decreased rapidly with the increase of power and stabilized within a fixed range finally (hundreds of milliseconds), while the extinguishment delay time under

different power was relatively stable. In the case of repeated ignition at the same power, the subsequent ignition delay time decreased rapidly due to the previous heating of the system. This discovery is of great significance for further expanding the application of liquid propellant motors in the field of aerospace propulsion.



Graphical abstract

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