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Corresponding author: BONNAL Christophe
e-mail of corresponding author: emre.ercan@roketsan.com.tr
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Title

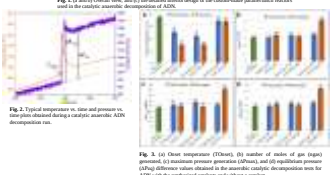
Fundamental Understanding Catalytic Decomposition of ADN based Green Propellants with Advanced Spectroscopic Techniques

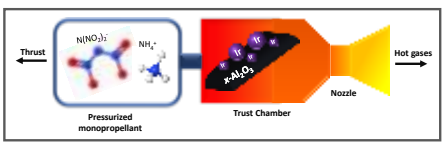
Authors

Kerem Emre Ercan[1], Ahmet Koc[1], Hacı Esiyok[1]*
** Corresponding author*
[1] Roketsan Inc., 06780 Elmadag, Ankara, Turkey, emre.ercan@roketsan.com.tr

Abstract

Propellants are highly energetic chemicals widely used in spacecraft propulsion such as satellite maneuvering in the orbit [1]. Hydrazine (N_2H_4) is the most commonly used propellant for such applications [1]. However, utilization of hydrazine in space missions has challenges associated with health, environment and safety risks. As a result, environmentally friendly, safer and less toxic alternative propellants have attracted a great interest in the recent years. Ionic liquids such as ADN (ammonium dinitramide) present itself as a promising alternative fuel to hydrazine [1,2]. Catalytic technologies developed for spacecraft propulsion systems should be resilient to high temperatures and should also be stable enough to be used in many consecutive cycles without a significant loss of activity [3,4]. In this contribution, monometallic catalysts containing Ir and Al_2O_3 were synthesized using both wetness impregnation and incipient to wetness impregnation methods, and the structural properties of these catalysts were investigated. Furthermore, the effects of the Al_2O_3 support material on Ir dispersion and catalytic performance of anaerobic ADN decomposition were studied. In order to improve the Ir active site dispersion on the Al_2O_3 support material, promoters such as La and Ce were added to the catalyst systems and different pretreatment conditions were applied to the synthesized catalysts. Catalysts with high performance, 5Ir/TH100, 5Ir/L3, and 5Ir/Sir10 were investigated with in-situ X-ray Absorption Near Edge Spectroscopy (XANES), in-situ Extended X-ray Absorption Fine Structure (EXAFS), in-situ Fourier Transform Infrared Spectroscopy (in-situ FTIR), Temperature Programmed Desorption (TPD), X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), Pressurized monopropellant Nozzle Trust Chamber Thrust Hot gases NH^{4+} Energy Dispersive X-ray (EDX), Pyridine adsorption via FTIR, CO Chemisorption, X-ray Photoelectron Spectroscopy (XPS) and X-ray Fluorescence (XRF) analysis techniques [5]. Our findings revealed that 5Ir/TH100 and 5Ir/L3 catalysts favorably lowered the onset temperature of the ADN decomposition reaction, whereas 5Ir/Sir10 boosted the pressure generation during the reaction (Fig 3). The formation of mostly metallic Ir nanoparticles on 5Ir/TH100 and 5Ir/L3 enables the lowering of the activation energy of the reaction. On the other hand, enhancement in the pressure generation for 5Ir/Sir10 catalyst is associated with the generation of small oxidic Ir^{nx+} clusters which are strongly interacting with the SiO_x-AlO_x surface domains of the support material. The fundamental structure-functionality relationships unraveled in the current work may allow design of novel catalytic systems for aerospace monopropellant propulsion systems with higher performance by simultaneous exploitation of Ir active sites with different electronic properties. properties of the catalysts at the nanometer scale, providing molecular level insight for the design of next-generation catalysts for anaerobic ionic liquid decomposition.





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