Chapter 6

Ammonium Dinitramide (ADN) Decomposition as Green Propellant:
Overview of Synthesized Catalysts

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ABSTRACT

Thermal decomposition of eco-friendly propellants such us ammonium dinitramide (ADN) aims to replace hydrazine in satellite systems. ADN, with formula [NH4]+[N(NO2)2]−, is a promising high-performance rocket propellant. It decomposes cleanly, producing gases such as NH3, H2O, NO, N2O, NO2, HONO, and HNO3, making it an attractive alternative to ammonium perchlorate (AP) and hydrazine. This chapter reviews catalyst systems for ADN decomposition, focusing on efficiency and thermal stability. Various catalysts, including metal oxides, transition metal complexes, and nanomaterials, enhance ADN decomposition. Iron and copper oxides lower decomposition temperatures, crucial for energy-efficient propellant compositions. Ruthenium and palladium complexes support homogeneous catalysis. Nanomaterials with high specific surface areas and distinct electronic activity improve ADN decomposition. Alloying carbon nanotubes with metals or using noble metal nanoparticles enhances decomposition rates at lower temperatures while maintaining thermal stability.

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INTRODUCTION

Propellants are essential for satellite and rocket engines, and their decomposition properties directly influence the engine's durability and efficiency. Therefore, scientists aim to increase the energy produced by propellants while reducing charges and environmental pollution.

Ammonium perchlorate (AP) is the most usually used oxidizer as solid propellants, but among its toxic, carcinogenic, and corrosive decomposition products during launch are halogens, such as hydrogen chloride (HCl), which can cause environmental damage. At the moment, ammonium dinitramide has attracted more attention as a promising green alternative because it is less expensive, less toxic, and halogen-free. Since its first synthesis in 1971, its manufacturing process has been less toxic.

Ammonium dinitramide, with its formula $[NH_4]^+[N(NO_2)_2]^-$, presents numerous advantages such as a high enthalpy of formation, a higher specific impulse similar to or better than hydrazine-based propellants, a faster combustion rate. ADN is significantly less toxic, reducing health risks for personnel and minimizing the need for extensive safety protocols during manufacturing, storage, and usage. ADN-based propellants, on the other hand, decompose into environmentally benign products, primarily nitrogen, water, and trace amounts of carbon dioxide, leading to a much cleaner combustion process. In comparison with hydrazine decomposition, which generates nitrogen oxides and unburnt hydrazine, ADN decomposition results in significantly less air pollution and does not contribute to ozone depletion. These ADN-based propellants offer a great specific impulse and allow precise regulation of the jet's flow and direction, making them suitable for applications such as satellite attitude control and orbital line adjustments. The table 1 summarize the comparison between ADN and hydrazine:

Table 1. ADN and Hydrazine comparison

Properties	ADN	Ref	Hydrazine	Ref
Density (at 25 °C), ρ	1.81 $g.cm^{-3}$	(Wingborg, 2006)	1.004 $g.cm^{-3}$	(Troyan, 1953)
Enthalpy of formation ΔH_f	-149.887 $kJ.mol^{-1}$	(Yang et al., 2005)	52.335 $kJ.mol^{-1}$	(Makled, 2009)
Melting point	91.5 °C	(Wingborg, 2006)	2.0 °C	(Troyan, 1953)
Molecular weight, M	124.06 $g.mol^{-1}$	(Wingborg, 2006)	32.045 $g.mol^{-1}$	(Troyan, 1953)
Oxygen balance	+25.79%	(Wingborg, 2006)	-	-
Specific impulse	259 Sec	(Wingborg, 2006)	239 sec	(Desantis, 2014)
Toxicity	Safe	-	Toxic	-

Ammonium Dinitramide presents disadvantages such as its high water (H_2O) content, requiring preheating for decomposition and the addition of active and stable catalysts to increase the decomposition of ammonium Dinitramide at a lower temperature and improve efficiency.

This chapter summarizes the decomposition of ammonium dinitramide (ADN) as an eco-friendly propellant, focusing on the various synthesized catalysts to improve this reaction. In recent years, significant progress has been made in the catalysts development for the catalytic decomposition of ADN, an environmentally friendly oxidizer. Among these advancements, CuO particles have shown great promise for facilitating the decomposition of ADN, as demonstrated by Harimech et al. (2023). Similarly, bi-metallic spinel catalysts have been investigated for their effectiveness in allowing low-temperature decomposition of ADN, as reported by Shamjitha et al. (2023). Further innovations include the use of

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