Decomposition of Energetic Ionic Liquid over Pt/Sr-Hexaaluminate Catalyst

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Abstract:

Ammonium dinitramide(ADN)-based liquid monopropellant and hydroxylammonium nirate(HAN)-based liquid monopropellant are eco-friendly propellants that have been actively studied since they do not generate halogen products through decomposition. However, there is a disadvantage that it is difficult to ignite because of the high moisture content. Therefore it is necessary to decompose ADN or HAN-based liquid monopropellant using catalysts. The onset temperature in catalytic decomposition over Pt/Sr-hexaaluminate catalyst of ADN-based liquid monopropellant and HAN-based liquid monopropellant was 122.1 °C and 71.5 °C, respectively, which were much lower than those of thermal decomposition. Pt/Sr-hexaaluminate catalyst shows excellent activity in ADN-based liquid monopropellant and HAN-based liquid monopropellant.

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Keywords: Energetic ionic liquid, Ammonium dinitramide, Hydroxylammonium nirate, Catalytic decomposition

1. Introduction

Hydrazine has been used for liquid propellant in the aerospace industry. However, due to the toxicity of hydrazine, it is necessary to develop an eco-friendly propellant that replaces hydrazine [1]. Ammonium dinitramide(ADN) and hydroxylammonium nitrate(HAN) are very strong oxidant and high energetic compounds. Moreover, they do not lead to halogen acid decomposition products [2]. With these advantages, ADN and HAN-based liquid monopropellants draw attention as green propellants [3]. Unfortunately, there is a drawback in the ADN and HAN-based liquid monopropellant that their ignition is very difficult because they have high moisture contents [4]. Therefore, catalysts capable of decomposing the liquid monopropellants at low temperature are needed. Our objective in the present research was to compare the catalytic performance of various types of catalysts in ADN and HAN-based liquid monopropellants decomposition.

2. Experimental

Sr-hexaaluminate was synthesized by co-precipitation method. The catalysts were prepared by using strontium, carbonate and aluminium isopropoxide as starting materials and obtained the hexaaluminate phase after calcination at 1200 °C. After the synthesis of Sr-hexaaluminate, Pt was loaded by incipient wetness method.

The catalytic decomposition of ADN-based liquid monopropellant was performed in the specially-made batch reactor. 80 mg of powder type hexaaluminate catalysts are added to the constant volume reactor and 50 μL of ADN-based liquid monopropellant is injected. The decomposition temperature and pressure were recorded versus time, at a temperature rate of 10 °C/min upto 200 °C.

3. Results and discussion

Figure 1 shows the profiles of the thermal decomposition and catalytic decomposition of ADN-based and HAN-based liquid monopropellant decomposition. The decomposition initiation temperature at thermal decomposition of ADN-liquid monopropellant is 167.6 °C and when using the Pt/Sr-hexaaluminate catalyst the initiation temperature is 122.1 °C. The result shows different trends between the thermal decomposition and the catalytic decomposition. This study shows that Pt/Sr-hexaaluminate catalysts exhibit excellent activity in ADN-based liquid monopropellant decomposition.

In thermal decomposition profile of HAN solution, the broad endothermic peaks correspond to the vaporization of water, whereas the strong and rapid weight loss is related to the exothermic catalytic decomposition of HAN-based loquid monopropellant. A low decomposition temperature means a high catalytic activity. The thermal decomposition happens at 142.4 °C. The pressure increase (232.9 mbar) is due to the formation of gaseous products. In the case of catalytic decomposition of HAN-based liquid monopropellant over Pt/Sr-hexaaluminate catalyst, the decomposition occurs at 71.5 °C which is much lower than that of thermal decomposition. The decomposition is very rapid with a strong exothermic peak. The presence of catalytic active phases lead to a drop of the onset temperature, revealing that decomposition can be triggered at lower temperature, even in the presence of water.

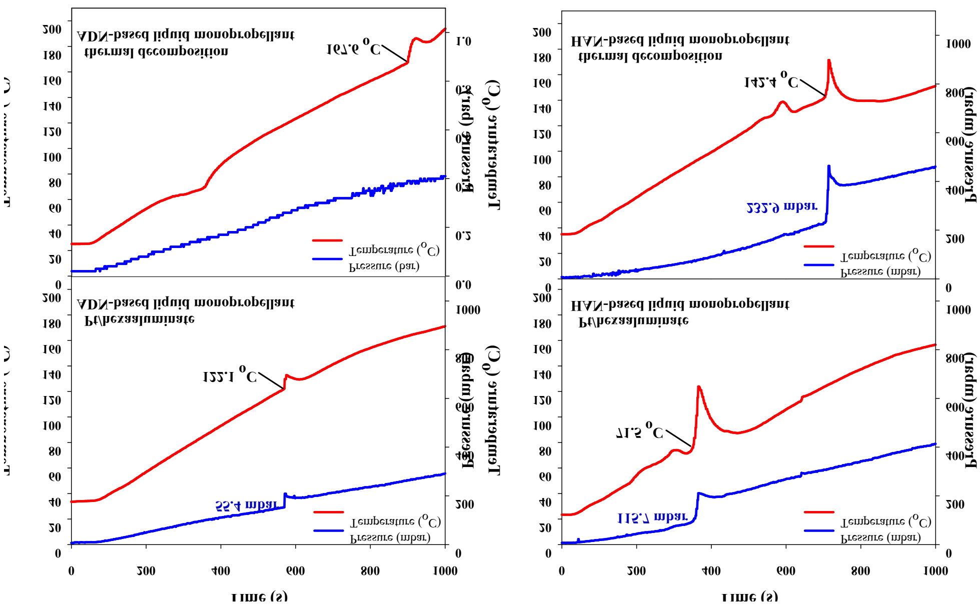

Figure 1. Decomposition of ADN-based liquid monopropellant and HAN-based liquid monopropellant.

4. Conclusions

A Sr-hexaaluminate structure was successfully synthesized via co-precipitation method and Pt/Sr-hexaaluminate catalyst was prepared by incipient wetness method. The thermal decomposition temperature of ADN-based liquid monopropellant and HAN-based liquid monopropellant was 167.6 °C and 142.4 °C, respectively. The onset temperature in catalytic decomposition of ADN-based liquid monopropellant and HAN-based liquid monopropellant over Pt/Sr-hexaaluminate catalyst was 122.1 °C and 71.5 °C, respectively, which was much lower than that of thermal decomposition. Pt/Sr-hexaaluminate catalyst shows excellent activity in ADN-based liquid monopropellant and HAN-based liquid monopropellant.

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