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Macroporous–mesoporous alumina supported iridium catalyst for hydrazine decomposition

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ABSTRACT

Decomposition of hydrazine allows the attitude and altitude control of satellite. Macroporous–mesoporous alumina supported iridium catalyst (KCMC-7) has been developed using the fast dehydration of aluminium trihydroxide and subsequent multiple impregnations. The result of data analysis suggested that the obtained alumina was ρ-Al_2O_3 with both macro and mesopores. Significant amount of pentagonal Al sites after rehydration of ρ-Al_2O_3 was responsible for ultra high dispersion for ultra high loading of metal around 30 wt%. The performance of the KCMC-7 measured using 4.5 N dual thruster module was satisfactory until the end of life, providing enough thrust for the attitude and altitude control of satellite in the pressure range of 50–350 psi.

1. Introduction

Telecommunication mediated by satellites is now essential part of human life. Numerous satellites orbit around the Earth to transmit signal one region to another. It is known that the life of satellite is determined by the amount of fuel and the life of catalyst in the propulsion system for the attitude and altitude control of the satellite. The catalytic reaction for propulsion is a simple decomposition of hydrazine as shown in the following equation.

$$N_2H_4(g) \rightarrow N_2(g) + 2H_2(g),\ \Delta H = -95.4\,\text{kJ mol}^{-1} \quad (1)$$

$$3N_2H_4(g) \rightarrow 4NH_3(g) + N_2(g),\ \Delta H = -157\,\text{kJ mol}^{-1} \quad (2)$$

Hydrazine decomposition is a highly exothermic reaction to elevate the temperature to 1273 K [1,2]. Therefore, the catalyst should be durable at such high temperature. Further, the hydrazine decomposition generated a large pressure gradient inside the catalyst pellet because of the conversion of liquid hydrazine to gaseous species such as hydrogen, nitrogen and ammonia. Often, several thousand pressure is achieved, resulting in the breakup of catalyst pellet and consequently wash-out of the catalyst from the thruster [2]. Thus, the catalyst should maintain its decomposition activity at high pressure and high temperature condition with the incorporated noble concept and design for mass transfer and heat dissipation. In fact, no catalytic material seems to be durable under such harsh reaction environment otherwise the suitable structural modification is made. There are two types of commercial catalysts, S-405 and HKC-12GA for hydrazine decomposition [3].

There were distinct morphological characteristics of the S-405 catalyst in which the well defined crystal morphologies were observed and the cubic to hexagonal crystal stuck together to form larger crystal aggregates [4–6]. Also, there are a large number of holes at the surface of the catalyst that can be advantageous for facile diffusion of reactant and product gas. While, there is no such well shaped crystal in KC-12GA catalyst [1]. Further, the surface of the catalyst showed less number of holes for diffusion of reactant and product gas. Fig. 1 shows the morphologies of both catalysts in the SEM micrograph. Still the structural and morphological similarities were shared in both catalysts. The catalysts were supported on a priority alumina that had many holes at the alumina. However, there is limited information on the alumina support though the related patents were disclosed, thus promoting the investigation of alumina support and the catalyst preparation technology.

As hydrazine decomposition reaction proceeds, there were large pressure and temperature gradients inside the catalyst pellet [2]. Thereby, the mechanical stability of the catalyst pellet was very important. The other way to relieve the pressure and temperature gradient can be providing the pathway for the mass and heat transfer. This can be accomplished with the incorporation of various pore sizes from macro to meso even micropore into the alumina using suitable structural modification.

In the present work, the large crystalline aluminium hydroxide of ca. 50 μm was transformed into rehydratable alumina [7,8]

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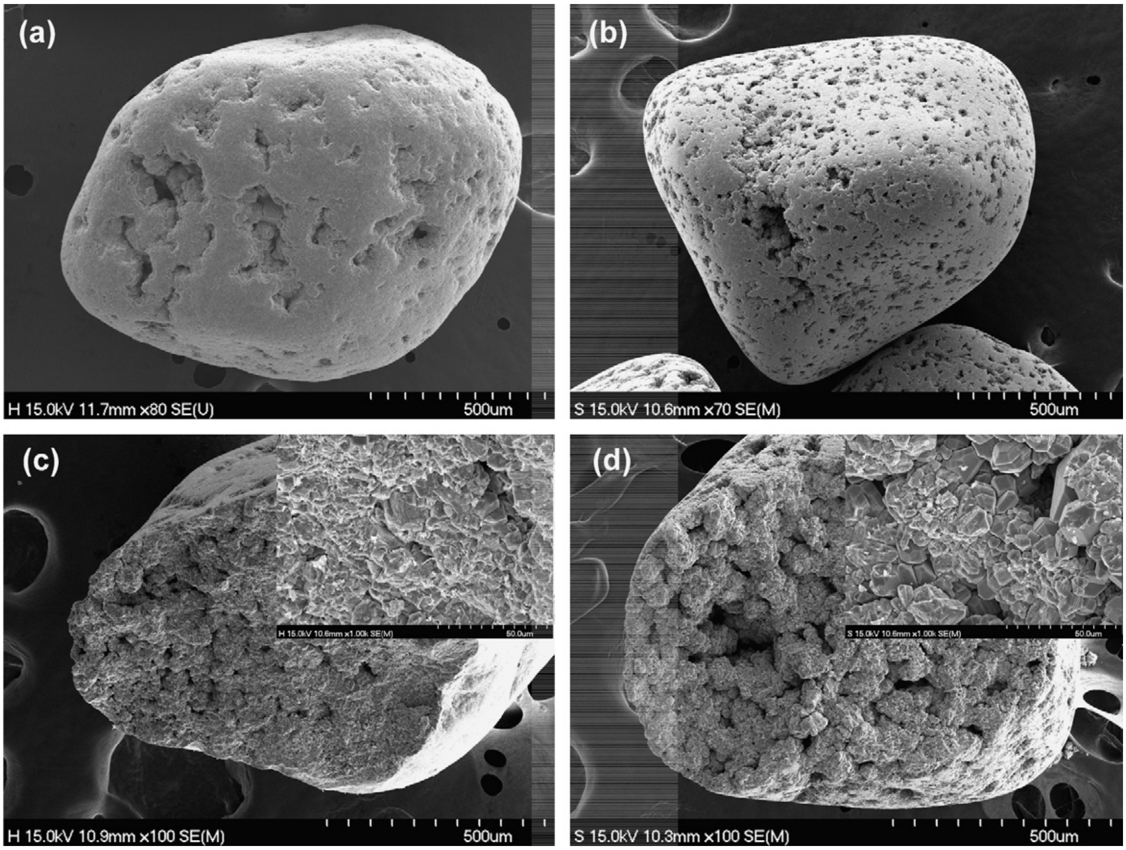

Fig. 1. (a and c) Scanning electron micrograph of the KC-12GA and (b and d) Shell-405.

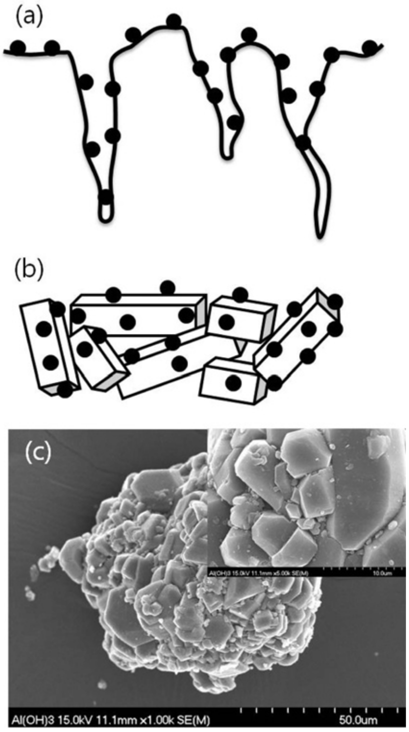

Fig. 2. Schematic feature of (a) amorphous alumina support and (b) crystalline alumina support. The dark circle indicates the Ir nanoparticle. The micrograph of the polycrystalline $Al(OH)_3$ was shown in (c).

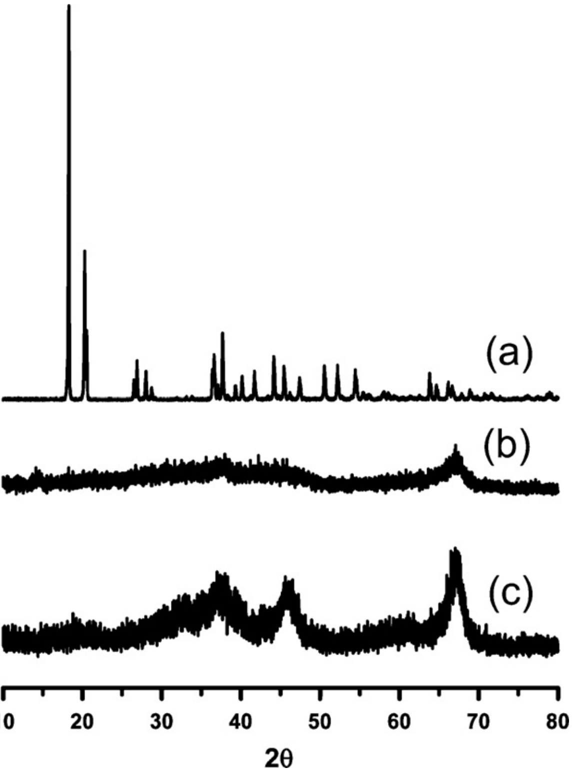

Fig. 3. XRD patterns of (a) $Al(OH)_3$, gibbsite, (b) dehydrated alumina powder and (c) the support granule.