catalysts

Editorial

Application of Metal-Based Nanocatalysts for Addressing Environmental Issues and Energy Demand

Mohamad Hassan Amin

School of Science, RMIT University, Melbourne, VIC 3000, Australia; doctoramin@gmail.com

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As part of the Glasgow Climate Pact, at COP27 in 2021, world leaders of 197 countries agreed to cut carbon dioxide emissions to prevent a "climate catastrophe". The goal is to limit global temperature rise to 1.5 degrees relative to pre-industrial times. To reach this goal, the use of fossil fuels as the dominant global energy must decline globally by 3 per cent each year until 2050 [1]. However, decarbonising the energy supply may increase energy demand [2]. Therefore, additional effort is required to limit global CO_2 emissions to net-zero, and some alternative reliable and cheap energy must be found.

Recently, the application of metal-based nanocatalysts has gained attraction for addressing environmental issues and energy demand. As an example of alternative energy, Fischer–Tropsch synthesis is a promising route for clean and reliable fuel production [3]. This technology involves syngas production (mixture of hydrogen and carbon monoxide) from methane mainly through metal-supported nanocatalysts, converting the syngas to C1-C100 hydrocarbons using heterogeneous metal-based nanocatalysts and refining [3]. The production of syngas from methane is currently carried out using three processes: steam reforming, partial oxidation, autothermal reforming, and a combination of these processes. Some other methods, such as dry and tri-reforming of methane, are still under research [4]. Additionally, some other methods are suggested to reduce emissions and utilise CO_2, such as H_2 generation by ethanol steam reforming, CO_2 methanation, or CO_2 hydrogenation to methanol [5–8].

All of the above processes break strong chemical bonds of the reactant molecules (e.g., C-H or C-C). To overcome the energy barrier of strong bond breakage, metal-based catalysts are needed. Therefore, intensive efforts have been devoted by numerous research groups to the development of catalysts that can achieve high catalytic activity and stability. Most researches have focused on investigating the role of metals, bimetal and synergies, supports, promoters, and preparation methods on activity and stability of catalysts.

The most crucial element of each catalyst is the active component that can adsorb and active CH_4. Over the past few decades, researchers have examined and reported various active components for catalysing these reactions. A vast range of supported and unsupported catalysts, such as different types of metals, metal oxides, carbides, sulphides, and carbon, have been investigated [9].

Many researchers have investigated the simultaneous presence of two metals to modify the primary catalyst with a second metal [10]. Chen et al. showed that pre-reaction reduces the partial deactivation behaviour of the Ni catalyst and the sintering of the Ni nanoparticles [5].

The metal only adsorbs CH_4, but the CO_2 activation step can take place on the support; therefore, the role of support in catalytic activity is vital [11,12]. Ding et al. reported that well-ordered Ni-MCM-41 catalysts might be a promising candidate with anti-sintering and coking ability in partial oxidation of methane [13]. Additionally, Tang et al. demonstrated that the Ni catalyst supported on mesoporous La_2O_3 exhibits higher activity and selectivity in CO_2 methanation than the Ni–La_2O_3 catalyst prepared by a conventional solution combustion method [8]. Amin [14] synthesised a novel tri-modal porous silica (TMS) as a support for a nickel catalyst, which gave excellent activity and stability in comparison to the Ni catalysts supported on a classically ordered mesoporous silicates support reported in the literature at a relatively low temperature (700 °C). It was found that the morphology of mesoporous supports plays a substantial role in determining catalytic performance. Some researchers, such as Li et al., reported that Ni/C nanocatalysts possessed high catalytic activity and stability in dry reforming of methane [15].

Recently, approaches to achieving improvements in the activity and stability of catalysts have focused mostly on discovering suitable promoters [16,17]. The types of promoters that have been studied include alkali, alkaline earth, transition, and rare earth metal oxides [18,19]. For example, Al-Najar et al. studied the effect of La_2O_3 as a promoter on the Pt-Pd-Ni/MgO catalyst in dry reforming of methane, which exhibited the highest activity [20].

This Special Issue's findings will help researchers develop more active catalysts for addressing environmental issues and energy demand. However, more research is still needed to find low-cost, sustainable, and energy-efficient ways to convert existing fossil fuels to carbon-free fuels.

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