# Synthesis of a Trimetallic Catalyst for Steam Reforming of Methane to Produce On-Site Ultra-Pure Hydrogen through Membrane Reformer

Anjali Baudh[1], Rahul Sharma[2], Sweta Sharma[1], Rajesh K Upadhyay[1]*

*1 Department of Chemical Engineering & Technology, IIT (BHU) Varanasi, U.P.-221005, India*
2 *GAIL (India) Limited, Gautambudh Nagar, Uttar Pradesh-201301, India*

* Corresponding Author: Rajesh Kumar Upadhyay rku.che@iitbhu.ac.in

***Highlights***

- Synthesis of lanthanum and iron promoted Ni based catalysts for methane steam reforming
- Physiochemical analysis of the catalyst shows good La dispersion
- Addition of Lanthanum and iron was reported to enhance the catalytic activity

## 1. Introduction

Membrane reformers emerge as an efficient technology for on-site ultra-pure hydrogen production. The membrane reformer can be integrated with the PEM fuel cell to provide the power. However, as the PEM fuel cell works at lower temperature and requires hydrogen purity (> 99.999%), such integration requires a low temperature catalyst. Further, for successful integration of membrane reformer with PEM fuel cell a low CO selective catalyst is a must. In literature, several catalysts are proposed for methane steam reforming which performs in the range of 600-800 °C. However, all of these catalysts show high CO selectivity at higher temperature and low conversion at low temperature. In the current work, a trimetallic catalyst of Ni, Fe, and La on alumina support is prepared using wet impregnation method to obtained maximum conversion at low temperature and to promote water gas shift reaction. The synthesized catalysts are tested in a packed bed reactor (ID 11.74 mm) for different temperatures (500-800℃) with a gap of 50℃. A complete characterization of the catalyst is performed using Brunauer Teller Emmett (BET), X-ray Diffraction (XRD), Field Emission Scanning Electron microscopy (FESEM), Energy dispersive X-ray (EDX), X-ray photoelectron spectroscopy (XPS), Fourier transform infrared spectroscopy (FTIR). The results show that Ni-Fe-La (75-15-10) promoted catalyst on alumina support gives high conversion even at low temperature (20% conversion at 500℃). It also shows zero CO selectivity at low temperatures. The response time for this catalyst was also higher compared to the other synthesized catalyst. Promoting the Ni catalyst with Fe and La improved the methane conversion at low temperatures, reduced the CO selectivity by promoting the water gas shift reaction even at higher temperatures.

## 2. Methods

In the current work a $Ni/Al_2O_3$ based trimetallic catalysts were synthesized. The metal loading was varied between 5-15% out of which Ni was 75%. The effect of Fe/La ratio on the performance of the catalyst was studied by varying the Fe/La ratio as 20/5, 15/10, and 10/15 respectively. Effect of other parameters such as W/F(14-26kgcats/mol), and temperature (500-800°C) were also observed. All the catalysts were prepared by wet impregnation method.

## 3. Results and discussion

Figure 1(a) shows the conversion graph of $Ni\text{-}Fe\text{-}La/Al_2O_3$ catalyst of ratios 75-20-5, 75-15-10 and 75-10-15. Ratio 75-15-10 showed maximum conversion (~99% above 700°C). Figure 1(b) shows CO selectivity graph of 75-15-10 ratio at different temperatures. Zero CO selectivity was observed at 500°C. Maximum conversion with maximum $H_2$ production rate was observed at optimum W/F 18.5kgcats/mol as shown in figure1 (c). This catalyst was stable for at least 130 hours with no deactivation as shown in Fig 1(d).

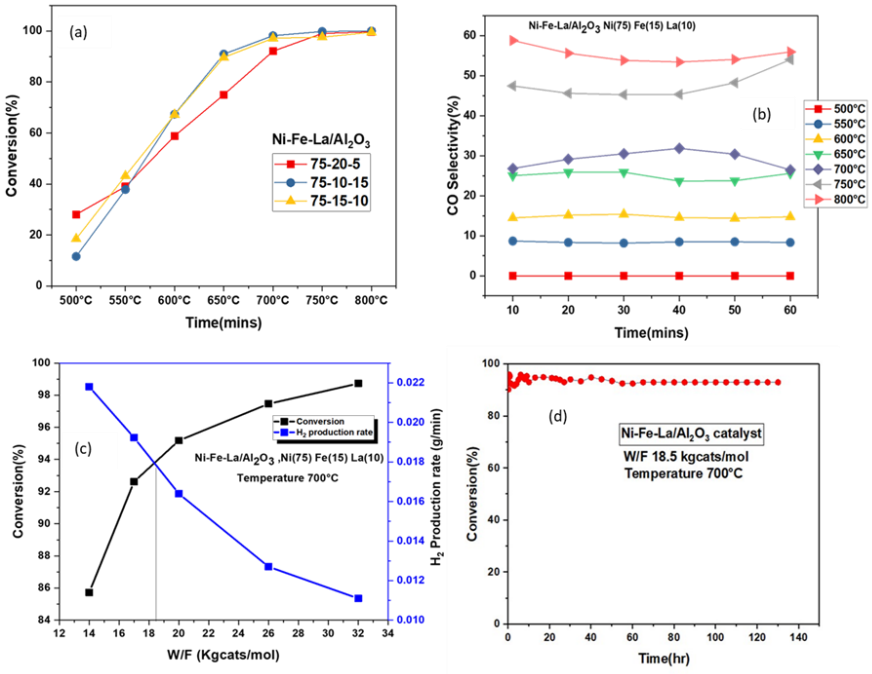


**Figure 1.** (a) Conversion vs time graph of Ni-Fe-La/$Al_2O_3$ catalyst for different ratios (b) CO selectivity vs time graph of Ni-Fe-La ratio of 75-15-10 (c) Effect of W/F on conversion and $H_2$ production rate (d) Life cycle study of Ni-Fe-La catalyst ratio of 75-15-10 for 130 hours

## 4. Conclusions

It was found that the Fe and La Promoted Ni-Fe-La/ $Al_2O_3$ catalyst of 75-15-10 ratio enhanced the catalytic activity, minimized CO selectivity at low temperature and increased the response time of the reaction. The addition of lanthanum will reduce the metal particle size and provide better conversion at low temperatures. With the current observation, we report Ni-Fe-La supported-on alumina as a promising catalyst for steam reforming of methane. In the final manuscript, the complete characterization data for all the catalysts will be presented. Further, activity data for all the catalysts at different temperature, metal loading and W/F ratio will be presented.

## References

[1] C.A Iglesias, G.Baronetti, L.Alemani, F.Marino, Insight into Ni/$Ce_{1-x}Zr_xO_{2-\delta}$ support interplay for enhanced methane steam reforming. International Journal of Hydrogen Energy.

[2] M.Boudjeloud, A.Boulahouache, C.Rabia, N.Salhi, La-doped supported Ni catalysts for steam reforming of methane. International Journal of Hydrogen Energy, pp. 9906-9913, 2019.

***Keywords***

Hydrogen Production, Steam reforming of methane, Catalyst synthesis and testing