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From direct use of ammonia in solid oxide fuel cells to the next generation of ammonia fuel cell systems

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Abstract

One of the most interesting alternatives in hydrogen carriers is represented by ammonia. Ammonia represents a considerable part of the hydrogen market, where about 45% of the total pure hydrogen produced is employed for ammonia synthesis[1]. Along with the employment as a chemical intermediate for fertilizer production, ammonia could be used directly as a fuel presenting better characteristics if compared to hydrogen, like volumetric energy density and storage conditions. In particular, ammonia could feed solid oxide fuel cells (SOFC) directly, presenting high conversion efficiencies and no nitrous oxide emissions [2]. SOFC can exploit ammonia in two ways, either preliminarily cracked into molecular nitrogen and hydrogen or directly fed into the cells. The latter is called Direct Ammonia Solid Oxide Fuel Cell (DA-SOFC). In this case, when the temperature rises above 600K, the ammonia is thermally cracked almost totally. However, the kinetics of the decomposition is slow and accelerates with higher temperatures.

The sustainable energy centre of Bruno Kessler Foundation, an independent research centre in Trento (Italy), has conducted several experimental activities on the exploitation of ammonia as a fuel directly feeding SOFC. The test facility is equipped with a test bench SSTB-01, provided by SolydEra, capable of working with short stacks, i.e. six anode supported SOFC. In this context, Zendrini et al. [3] compared the performances of cells provided by Solydera with pure hydrogen, ammonia and H_2-N_2 in a stoichiometric ratio of 3:1. The results showed that performances present, in the case of pure ammonia, a bend that limits the maximum power to ca 0.29W/cm^2 lower than the corresponding hydrogen flow (0.32W/cm2), at 760°C and fuel utilization of 68%. This phenomenon increases at lower temperatures and at higher fuel utilizations. To explain this effect, the authors proposed that the ammonia is not completely cracked inside the stacks, thus reducing the voltage by concentration over losses and activating the safety threshold. In this work, additional tests were conducted with the same test platform on a new six-cell stack with similar characteristics, reproducing the performances presented by Zendrini, with a similar voltage drop at high current densities if fed by pure ammonia. Additionally, this test campaign included a long-term test with pure ammonia in galvanostatic mode conducted at 760°C and fuel utilization of 63% (0.4A/cm2).

The results, reported in Figure 1, show no particular degradation of performances, where the power produced maintain the same level, i.e. 0.317W/cm^2, during the 500h of the test. The absence of degradation is also confirmed by benchmark test, i.e. polarization curves, that denote similar performance before and after the long-term test. Further tests should be conducted to characterize better the stack fed by ammonia, which could be a 2000h long test or evaluate the cracking of ammonia inside the SOFC.

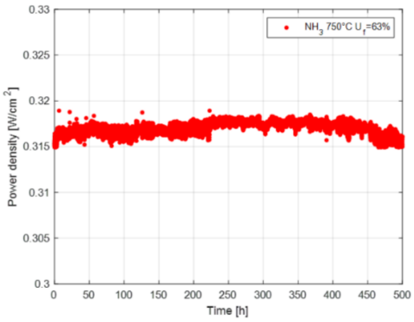

Figure 12- Power density level during 500h long-term test conducted in galvanostatic mode at 750°C, Uf equal to 63% and 0.4A/cm2

Furthermore, FBK activities are now focused on the "Horizon Europe" project AMON, which aims to develop an innovative system that efficiently converts ammonia into electric power using a SOFC. The project will focus on designing essential components of the system, such as the fuel cell, ammonia cracker, ammonia burner, and anode gas recirculation. Additionally, the entire Balance of Plants will be engineered, and compliance with ammonia use will be verified for all specific parts and components. The SOFC employed in the final system is based on an 8kW G8x Stack from SolydEra. Although the pilot demonstration will be conducted on a small scale, the AMON project aims to scale up the engineering to create a system suitable for applications in ports, the maritime environment, and autonomous power systems. The consortium is formed by several research and industrial partners like DTU, EPFL, VTT, SolydEra, Alfa Laval, HSLU, EFCF and Sapio.

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References

[1] 'The future of hydrogen', IEA, 2019. [Online]. Available: https://www.iea.org/reports/the-future-of-hydrogen

[2] S. S. Rathore, S. Biswas, D. Fini, A. P. Kulkarni, and S. Giddey, 'Direct ammonia solid-oxide fuel cells: A review of progress and prospects', *International Journal of Hydrogen Energy*, vol. 46, no. 71, pp. 35365–35384, 2021.

[3] M. Zendrini, M. Testi, M. Trini, P. Daniele, J. Van Herle, and L. Crema, 'Assessment of ammonia as energy carrier in the use with reversible solid oxide cells', *International Journal of Hydrogen Energy*, vol. 46, no. 58, pp. 30112–30123, Aug. 2021, doi: 10.1016/j.ijhydene.2021.06.139.