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AmmoniaSHIP: Ammonia powered Ship with Proton conducting solid oxide fuel cells

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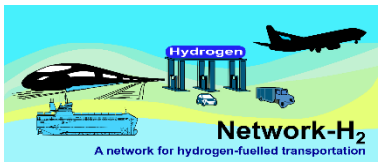

Executive Summary

The shipping industry is becoming aware of its long-term environmental responsibility. The International Maritime Organization (IMO) vowed in 2018 to cut greenhouse gas emissions by 50% by 2050 compared to 2008. To accomplish these ambitious targets, the marine sector must develop fuels with low or no SO_X, NO_X, and CO_2 emissions. A high energy density, low flammability, ease of storage, and low manufacturing cost make ammonia an attractive option for marine applications, according to the research community. The decarbonisation of the marine sector might be accomplished with the use of fuel cell technology. It is less polluting and more efficient than standard internal combustion engines, yet it has a higher energy density than batteries. Green fuels (hydrogen, ammonia) may also be used to power fuel cells, enhancing their potential even more. Ammonia is one of the most promising alternative green fuels since it has less complex and safer energy storage than hydrogen.

The ammonia-fed oxide ion based solid-oxide fuel cell (SOFC) is approaching commercial status, with major developments underway by IHI Corporation in Japan. Due to the high conductivity of protons and the ability to operate at intermediate temperatures, protonic ceramic solid oxide fuel cells (PCFCs) are currently more appealing than oxygen ions-based SOFCs. Despite the fact that hydrogen is frequently used as a fuel for PCFCs, widespread adoption of hydrogen energy is hampered by the high financial investment and safety risk associated with storage and transportation due to technological challenges in liquefaction or compression of hydrogen. As a result, alternative fuels for PCFCs have been proposed, such as ammonia. The PCFC has a huge advantage, in that it can directly use NH_3 as fuel for ship propulsion system. The efforts to build ammonia PCFCs are quite restricted, and the current results are unsatisfactory. Studies on the durability of ammonia PCFCs, in particular, are inadequate. As a result, further efforts are required to produce high-performance and long-lasting ammonia PCFCs.

Power generation with NH_3-fueled PCFC systems comprises mostly of four steps: (i) NH_3 adsorption on the surface of the anode; (ii) catalytic breakdown of NH_3 into H_2 and N_2; (iii) generation of protons and electrons from the electrochemical reaction of H_2; and (iv) transfer of protons and electrons to the cathode through the dense electrolyte and an external circuit. However, because to the nitridation of nickel particle, cell endurance in ammonia is a major worry. Nitridation is dependent on experimental circumstances (such as pressure and temperature), but it results in adverse changes to the anode microstructure and, as a result, cell performance loss. Decomposing NH_3 into H_2 before contact with nickel anodes is a highly successful approach for mitigating the critical problem and maintaining stable fuel cell performance. This reduces nickel's direct exposure to pure ammonia. A feasible strategy is to develop a SOFCs, where an internal catalyst layer is utilised to decompose NH_3 to H_2, by add another catalytic layer to assist the breakdown reaction of ammonia.

In this project, PCFCs based on a Ni-$BaZr_{0.1}Ce_{0.7}Y_{0.1}Yb_{0.1}$ (BZCYYb) anode support and a BZCYYb electrolyte were successfully fabricated in this study using cost-effective dry pressing and drop coating processes. Outstanding cell performance has been realised in hydrogen, in particular. Furthermore, the simple addition of an internal catalytic iron layer has substantially enhanced the durability of cells in ammonia.