Adsorptive On-board Desulfurization of Liquid Fuels and Full Thermal Regeneration of the Adsorbent via Hot Off-gas from a SOFC

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Fuel cells (FCs) are one of the most effective tools to convert chemical to electrical energy. FCs are not only suitable for stationary approaches but are also a promising source of on-board electricity supply for all kinds of vehicles, ships, and aircraft. This technology becomes very attractive when on-board fuel such as diesel and jet fuel is used to produce hydrogen-rich syngas via reforming, which is subsequently fed to the FC. However, the sulfur threshold limit for the reformer and the FC are < 50 and < 1 ppm of total sulfur, respectively. Consequently, FCs as one of the most effective tools for energy conversion are excluded from using the most common types of fuels containing up to 5000 ppm of total sulfur. Adsorptive desulfurization is a promising approach to provide the possibility of on-board desulfurization and thus operating fuel cells with commercial fuels. Several adsorbents have been investigated in recent years. However, adsorbent regeneration is still a major issue. The aim of this work is to identify and prepare a highly thermal stable adsorbent and to develop a fast and efficient on-board regeneration via hot exhaust gases (Fig. 1).

A silver based adsorbent was prepared by incipient wetness impregnation of commercial Al_2O_3 and characterized via different methods. The desulfurization performance of the adsorbent was investigated under a wide range of different conditions and fuels containing different concentrations of polycyclic aromatic sulfur heterocycles (PASHs). In situ regeneration experiments were carried out with hot simulated exhaust gas from a solid oxide fuel cell (SOFC) based auxiliary power unit (APU).

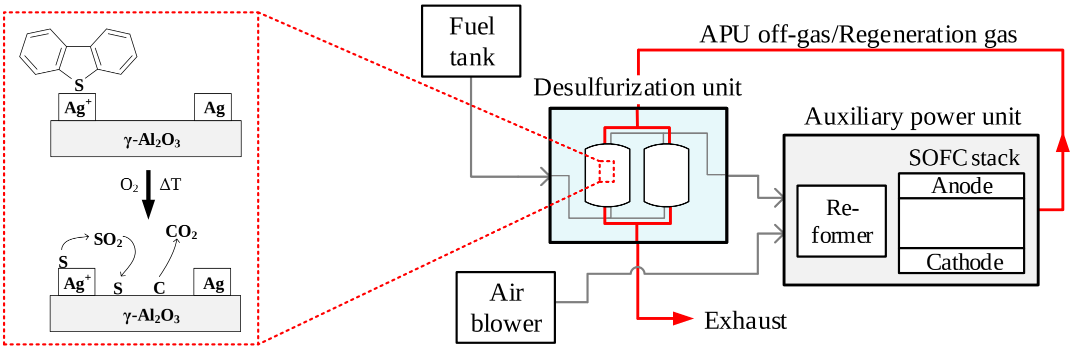

Fig. 1 Flow sheet diagram of novel regeneration strategy using hot APU off-gas for thermal regeneration of the adsorbent (right) and simplified scheme of the overall desorption mechanism of PASHs (left).

Excellent results were obtained for the highly thermal stable Ag-Al_2O_3. Breakthrough experiments showed high adsorption capacities for different kinds of PASHs at 20 °C. Additional equilibrium saturation experiments at -10 and 60 °C showed similar adsorption capacities. Within our research, the role of the acid base interaction via acidic surface groups was identified and gained deeper insight into the overall adsorption mechanism. With this knowledge, a novel concept of adsorbent regeneration was developed and investigated. Within this concept, the adsorbent is regenerated via hot off-gas from a SOFC based APU. The influence of different gas compounds such as O_2, CO_2, and H_2O on the overall desorption mechanism was identified and showed a positive effect of H_2O on the regeneration performance. With this novel on-board and in situ regeneration concept full thermal regeneration was achieved for Ag-Al_2O_3 over 14 cycles. This is an outstanding result as 100% thermal regeneration after adsorption of dibenzothiophene was not reported so far even for the first cycle of any adsorbent.

The observed results are a major step forward to design an efficient on-board desulfurization unit for different types of vehicles and thus providing the possibility to operate fuel cell systems with commercial liquid hydro carbon based fuels.