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INFLUENCE OF TAR AND HCL ON SOFC ANODES IN INTEGRATED BIOMASS GASIFIER SOLID OXIDE FUEL CELL SYSTEMS

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***Abstract* - Integrated Biomass Gasifier Solid Oxide Fuel Cell Systems represent an alternative to fossil fuel based power plants. Hot gas cleaning and direct internal tar reforming are fundamental to achieve high efficiency and decrease system complexity. In this paper, we mainly present the results of short-term experiments on the cross-influence of HCl and tar on Ni-GDC SOFC. The cell was fed with humidified hydrogen and an increasing concentration of toluene (2.5, 4.2 and 8.5 g/Nm^3) and HCl (8, 42 and 82 ppmv). Successively, 8.5 g/Nm^3 of toluene and an increasing concentration of HCl were fed to the cell. We used Current-Voltage curves and outlet gas composition to evaluate the contaminants effects. The cell seems not to be affected by the tested concentration of HCl and toluene but HCl decreases the concentration of CO_2 and CO. The results suggest the feasibility of tar internal reforming and the importance of studying contaminants cross-influence.**

***Index Terms* – Biomass Gasifier, HCl, SOFC, Tar**

I. Introduction

Integrated biomass gasifier SOFC systems have received considerable attention for sustainable micro-CHP generation. Tar direct internal reforming represent a relevant option to decrease system complexity and further increase the efficiency thus easing the market penetration of these systems. Nonetheless, tar might cause performance losses due to carbon deposition and thermal stress. Despite internal tar reforming has been investigated with thermodynamic equilibrium calculations (e.g., [1] and [2]), and with experiments using both humidified hydrogen (e.g., [3] and [4]) and syngas (e.g., [5], [6] and [7]), there is not yet general agreement on the fate of this contaminant in the anode chamber. Furthermore, the cross influence with other biosyngas contaminants such as HCl has not been studied yet in detail, but preliminary tests have been performed in TU Delft [8]. In this paper, we mainly present the results of short-term experiments on the cross-influence of HCl and tar on Ni-GDC SOFC.

II. Methodology

To determine the cross-influence of tar and HCl we used an electrolyte supported Ni-GDC/YSZ/YSZ-LSM cell (H.C. Starck, Germany). After having reduced the cell at 950 °C, we fed the cell with an increasing concentration of HCl first and afterward of toluene (2.5, 4.2 and 8.5 g/Nm^3 corresponding to 611, 1022 and 2059 ppmv) carried by a mixture of 40%vol H_2, 4.2%vol H_2O and balance N_2. The cell was then exposed to 8.5 g/Nm^3 of toluene and an increasing amount of HCl (8, 42 and 82 ppmv). The exposure time to each concentration was 30 minutes for HCl, and 60 minutes for toluene and combined HCl + toluene. The cell was operated at 750 °C under a mild current of 80 mA/cm^2. The anode flow rate was maintained at 1400 NmL/min while the cathode one at 1800 NmL/min air. The desired concentrations of toluene were obtained by bubbling part of the dry nitrogen flow in anhydrous toluene 99.8% (Sigma Aldrich, USA). The remaining part of N_2 and the H_2 were passed in a humidifier to reach the desired concentration of steam. HCl was added using a gas bottle containing 300 ppmv of the contaminant in H_2 (Linde, Germany). Initially, thermodynamic equilibrium calculations were performed using the software FactSage version 5.4.1 (Thermfact/CRCT, Montreal, Canada and GTT-Technologies, Aachen, Germany) to assure the cell was operated outside the possible carbon formation region of the ternary diagram. The cell performances were evaluated by means of i-V curve recorded using an external load PLZ603W (Kikusui Electronics Corp., Japan) and a DC power supply SM120–25D (Delta Elektronika B.V.,

The Netherlands). The extent of reforming was evaluated by monitoring the outlet gas composition using a microGC Agilent 490 with a CP-Molsieve 5Å capillary for measuring CO, H_2, N_2 and CH_4 and a PoraPlot U capillary for measuring CO_2 (Agilent, USA). The outlet gas composition was monitored during the whole duration of the test. The total anode outlet flow rate was back-calculated from the inlet N_2 flow rate and the N_2 outlet concentration.

III. Results

The cell performance seems not to be aggravated by the tested concentration of HCl and toluene separately. The presence of toluene increases the cell voltage indicating the occurrence of reforming. There was no observable negative effect on current and power production when the two contaminants were jointly fed to the cell, as visible in Fig. 1. Indeed, the voltage results higher due to toluene reforming.

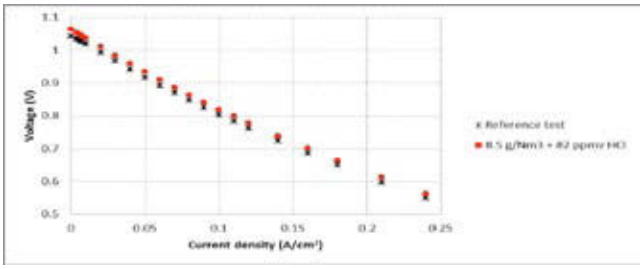

Fig. 1. Cell performances with 40%vol H_2, 4.2%vol H_2O and balance N_2 (Reference test) and after 60 minutes exposure to 8.5 g/Nm^3 toluene + 82 ppmv HCl

It appears toluene is converted into H_2, CO and CO_2. A very small amount of CH_4 (less than 0.05%vol) is also detected at the cell outlet. When HCl is fed together with toluene, the amounts of CO_2 and CO decrease indicating an effect of hydrogen chloride on tar reforming, even at low concentrations. The outlet flow rates are presented in Table 1. Quantification of toluene extent of reforming is suggested as part of future work.

TABLE I
MOLAR FLOW RATES (MOL/MIN) OF CO AND CO2 WHEN 8.5 G/NM^3 TOLUENE ARE FED TO THE CELL WITH INCREASING CONCENTRATION OF HCL

[HCl]	0 ppmv	8 ppmv	42ppmv	82 ppmv
CO (mol/min)	4.89E-04	4.41E-04	4.41E-04	3.84E-04
CO_2 (mol/min)	8.63E-05	7.88E-05	7.77E-05	7.11E-05

IV. Conclusion

Toluene is reformed inside the anode chamber. Concentrations up to 8.5 g/Nm^3 do not aggravate the cell performances on the short term. However, the feasibility of direct internal tar reforming has to be confirmed by long term tests using biosyngas as tar gas carrier. Hydrogen chloride does not affect the cell performance but it hinders toluene reforming. Therefore, contaminants cross-influence is fundamental to assure safe and efficient operation of Integrated Biomass Gasifier SOFC systems.

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