Macroporous Silicon Steam Reformer for Hydrogen Production

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A macroporous silicon (MPS) micromonolith was functionalized and tested for the production of green hydrogen by steam reforming (SR) of several fuels. These microstructured reactors have some intrinsic properties which make them of great interest in the field of energy technology [1]. In particular, heat and mass transfer properties are improved in comparison to conventional reactors (which have larger chamber volumes). Furthermore, these microreactors are compact, safe, and modular, thus allowing for process intensification [2]. Given these appealing characteristics, several research groups have studied microreformers to convert hydrocarbons, alcohols or ammonia to hydrogen-rich streams [3,4]. The micromonolith consisted of a porous membrane in a silicon substrate, 17 mm in diameter and 210 μm thick, with cylindrical pores of 3.3 μm diameter arranged in a 4 μm square lattice. This geometry leads to a dramatic increase of the geometric surface area exposed to reactants per reactor volume in the range of $10^5 - 10^6\ \mathrm{m^2/m^3}$, which is two orders of magnitude higher than for conventional monoliths. The pores where functionalized with a cerium oxide coating decorated with palladium nanoparticles 100 nm in diameter. The pores constitute the channels through which the fuel flows reacting with the catalyst on the surface. The gas contact time was measured to be between 5 ms to 9 ms, and the working temperature ranged from 823 K to 1023 K. The maximum hydrogen selectivity was recorded to be 53% and the best $\mathrm{H_2}$ production rate was found to be $110\,\mathrm{L_{H_2}\cdot mL^{-1}\cdot cm^{-3}}$ (normalized to reactor volume), the results shown in **Figure 1**. The reactor was tested for a prolonged time under reaction conditions without showing symptoms of clogging or performance decrease. The tested fuels were ethanol, acetic acid, propanone (acetone), 2-propanol (isopropanol), 2-methoxyethanol (methyl cellosolve, $\mathrm{C_3H_8O_2}$) and a diesel surrogate (equivalent formula $\mathrm{C_{12}H_{23}}$) [5]. To avoid the formation of carbonaceous deposits, overstoichiometric water/fuel ratios were tested [1]. For ethanol and acetic acid steam reforming tests, the water/fuel ratio was kept at 6 and for the other fuels, which are composed of longer C chains, the ratio was increased up to 15, to prevent the deactivation of the catalyst due to coke deposition. The feasibility and suitability of using silicon micromonoliths to generate hydrogen from the steam reforming with MPS microreactors was confirmed, and appear as a valuable technology to power portable and mobile devices.

References

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Figures

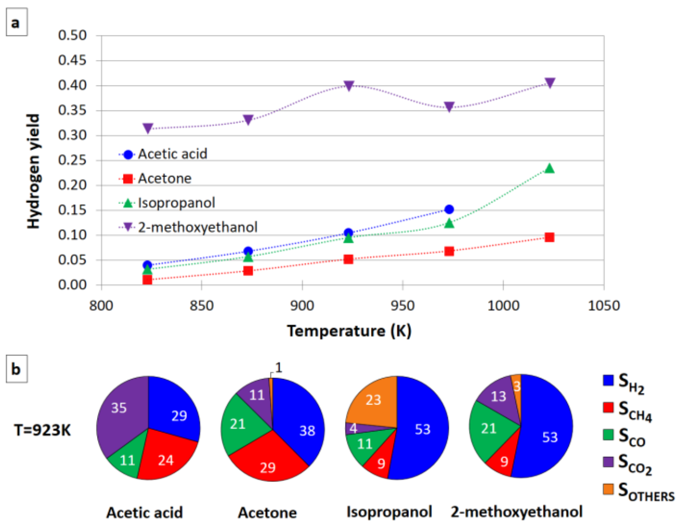

Figure 1: a) Hydrogen yield for the steam reforming tests of the indicated fuels. b) Selectivity obtained at 923 K.