

[0112] The combustion channel is coated with first layer of active metals consisting of praseodymium and palladium at 4 to 1 atomic ratio using precursors in the form of nitrate. The solution is introduced into the combustion channel and then removed in the same way as previously described for the La step. The device is dried at 100° C. for 1 hour with hydrocarbon free air flowing at 150 cc/min, followed by calcination at 1000° C. for 1 hour with a heating and cooling rate of 10° C./min.

[0113] The second layer of active metal consisting of platinum is coated in the combustion channel with 10% by weight Pt(NH₃)₄(NO₃)₂ using the syringe pump. The solution is introduced into the combustion channel and then removed in the same way as previously described for the La step. Then, the SMR channel is coated with a second active metal layer consisting of 10% by weight rhodium in nitrate solution using the syringe pump. The solution is introduced into the SMR channel and then removed in the same way as previously described for the La step. The device is dried at 100° C. for 1 hour with hydrocarbon free air flowing at 150 cc/min, followed by calcination at 1000° C. for 1 hr with a heating and cooling rate of 3.5° C./min.

[0114] The entire reactor is operated inside a 15 cm clamshell Ni—Cr ceramic heater which is held at a temperature about 25-50° C. below the maximum combustion web temperature to offset the effect of thermal losses. Preheat is provided to the reactant and air streams via external heaters.

[0115] Each reactant gas is fed via Brooks 5850e and 5851e series mass flow controllers. Pressure is measured using NoShok pressure transducers model 1001501127 and 1003001127. Gas compositions are analyzed via a thermal conductivity detector gas chromatograph. All equipment is calibrated and verified for proper operation. Flow rates are calibrated against a primary standard calibrator, the Dry-Cal DC-2M Primary Flow Calibrator, which is calibrated and certified by BIOS International. Pressure transducers are calibrated using a Fluke pressure calibrator model 718 1006 with a Fluke 700P07 or 700P06 pressure module which are calibrated and certified by Fluke. The gas chromatograph is calibrated against calibration gases blended and certified by Praxair Distribution Inc. Neat hydrogen is used as the combustion fuel and 5-27% excess air is used. Combustion exhaust analysis consistently show 100% hydrogen conversion.

[0116] “Average area heat flux” is defined as the endothermic reaction heat duty divided by the planar area of the heat transfer surface adjacent to the base of the fin. This area is the path for heat transfer from the heat exchange channel to the base of the fin.

[0117] “Web” is defined as the wall that separates the endothermic reaction (fin containing) process microchannels and the heat exchange combustion reaction chamber.

[0118] “Equilibrium conversion temperature” (Table 1) is the temperature required for the given inlet composition to produce an equilibrium methane conversion equal to the measured methane conversion at the measured process outlet pressure. Similarly, the “equilibrium selectivity temperature” (Table 1) is the temperature required for the given inlet composition to produce an equilibrium selectivity to CO value equal to the measured selectivity to CO at the measured process outlet pressure. Equilibrium gas compositions are calculated using the NASA LEWIS thermodynamic equilibrium code or ChemCAD. Methane conversion and selectivity to carbon monoxide are calculated from the dry product gas composition as measured by gas chromatograph according to Equations 1 and 2

$$\text{CH}_4 \text{ Conversion} = 1 - (Y_{\text{CH}_4} + Y_{\text{CH}_4} + Y_{\text{CO}} + Y_{\text{CO}_2}) \quad (1)$$

$$\text{Selectivity to CO} = Y_{\text{CO}} / (Y_{\text{CO}} + Y_{\text{CO}_2}) \quad (2)$$

[0119] where Y is the mole fraction of each indicated component.

[0120] The contact time (CT) is the inverse of the gaseous hourly space velocity (GHSV), multiplied by a conversion factor to convert inverse hours into milliseconds:

$$\text{CT} = (1/\text{GHSV})(3600000 \text{ ms/hr})$$

[0121] where GHSV is the space velocity in inverse hours. The rate of volumetric flow rate fed to the reactor is defined at the standard condition of 0° C. and 1 atmosphere of pressure for the purposes of calculating either contact time or GHSV. Thus the contact time and GHSV depend only on the inlet molar flowrate and the reaction chamber volume.

[0122] The performance data for the reactor is shown in Table 1 and FIGS. 13 and 14. For maximum metal web temperatures of 950 and 900° C., equilibrium SMR conversion and selectivity are achieved at an apparent SMR temperatures of 925 and 875° C., respectively and heat fluxes of >25 W/cm² at a contact time of less than 5 milliseconds (ms). For faster contact times, fluxes up to 90-140 W/cm² are achieved, showing the ability of the SMR fin supported catalyst to keep up with the higher heat demand at the upstream section of the catalyst. Data taken at 14 atmospheres with a combustion metal web temperature of 875° C. show ~800° C. equivalent conversion, although the same temperature condition at 25 atm shows ~840° C. equivalent conversion.

[0123] The fin supported SMR process microchannel is used to test the maximum heat flux achievable at the upstream end of the SMR reactor. At a total flow rate of 7.4 standard liters per minute (SLPM) of reactant (0.5 ms contact time in the 1.78 inch catalyst bed), 25 atm, and maintaining a maximum combustion web temperature of 950° C., an average heat flux exceeding 140 W/cm² is achieved, giving conversion and selectivity values equivalent to about 700 and 800° C. equilibrium values, respectively (see Table 1).

TABLE 1

Condition (Temperature and Contact Time)	950° C.	900° C.	950° C.	900° C.	950° C.
Contact Time	5.0 ms	2.7 ms	2.7 ms	0.7 ms	0.7 ms
Time on stream (hr)	75	25	20	92	72.5
Contact time (ms)	4.9	2.7	2.7	0.7	0.7
Maximum web temperature (° C.)	953	906	953	900	950