**Gas chromatography (GC) data**

**Measurement details:** Oxygen permeation fluxes were measured using a Clarus 580 gas chromatograph (GC) equipped with a thermal conductivity detector (TCD). The pressure of sweep gas (He) was adjusted to 1 bar while the pressure of feed gas (air) was set to 1.4 bars to provide an O2 partial pressure difference across the membrane. Initially the sweep side was purged with He to remove any air. Then N2 gas was supplied into the feed side and the effluent of sweep gas, which consists of He and leaked N2, was analyzed by the GC to assess the leakage. Synthetic air (21 % O2 balanced with N2) was then supplied into the feed side and the permeated oxygen was measured. Oxygen permeation measurements were carried out upon decreasing temperature from 950 oC to 600 oC in 50 oC steps after stabilization for 15 minutes at each temperature. Every .zip file contains all the measured raw data for each membrane. Code names are as follow

|  |  |
| --- | --- |
| BSCF | Permeation measurements of 1 mm Ba0.5Sr0.5Co0.8Fe0.2O3-δ membrane |
| BSCF-stability | Stability data measured at 750oC for 1 mm Ba0.5Sr0.5Co0.8Fe0.2O3-δ membrane |
| BSCF-Mo0.025\_stability | Stability data measured at 750oC for 1.6 mm Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane |
| BSCF-Mo0.375\_stability | Stability data measured at 750oC for 1 mm Ba0.5Sr0.5Co0.5Fe0.125Mo0.375O3-δ membrane |
| BSCF-Mo0.025\_1mm | Permeation measurements of 1mm Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane |
| BSCF-Mo0.025\_0.75mm | Permeation measurements of 0.75 mm Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane |
| BSCF-Mo0.025\_1.4mm | Permeation measurements of 1.4 mm Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane |
| BSCF-Mo0.025\_1.6mm | Permeation measurements of 1.6 mm Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane |
| BSCF-Mo0.05 | Permeation measurements of 1 mm Ba0.5Sr0.5Co0.76Fe0.19Mo0.05O3-δ membrane |
| BSCF-Mo0.125 | Permeation measurements of 1 mm Ba0.5Sr0.5Co0.583Fe0.292Mo0.125O3-δ membrane |
| BSCF-Mo0.25 | Permeation measurements of 1 mm Ba0.5Sr0.5Co0.6Fe0.15Mo0.25O3-δ membrane |
| BSCF-Mo0.375 | Permeation measurements of 1mm Ba0.5Sr0.5Co0.5Fe0.125Mo0.375O3-δ membrane |

Each GC analysis generates 2 files (.raw and .rst) that need to be to be in the same folder to be viewed. Each chromatogram has its own name with the date of the measurement, membrane’s name, temperature and applied he/air (100 ml/min)

Example: 21.07.13\_bscf-mo0.05\_t600\_100he+air\_001.raw

Date: 21.07.13

Membrane: Ba0.5Sr0.5Co0.76Fe0.19Mo0.05O3-δ

Measurement temperature: 600 oC

Gas: He/Air (100/100 ml/min)

**XRD data**

**Measurement details:** All materials were analyzed by XRD before and after the oxygen permeation measurements using a Panalytical X-ray diffractometer with Co Kα1 monochromated radiation source (λ=1.789 Å) in the 5-130o 2θ range. Each has been exported as .ASC type ASCII file that has information about the sample’s name, time that XRD was collected, 2θ range. Name of the file also contains information if the sample is fresh or aged.

Example 1: FDS\_6hr\_5-130\_BSCF-Mo0.375\_1140oC\_5h.xrdml

Membrane: Ba0.5Sr0.5Co0.5Fe0.125Mo0.375O3-δ

Membrane thickness: if no indication then 1 mm

Mode: FDS

Length: 6 hr scan

2θ range: 5-130o,

Sintering temperature= 1140oC for 5h,

Example 2: 15-80\_2h\_BSCF-Mo0.025\_1.6mm\_after stability\_750oC\_250h\_bulk.xrdml

Membrane: Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ

Membrane thickness: 1.6 mm

Mode: ADS

Length: 2 hr scan

2θ range: 5-80o,

Aged temperature= 750oC for 250h,

Bulk: XRD scan of the membrane that was grinded into a powder after stability test

Sweep/Feed: XRD scan of the sweep/feed side of the membrane after stability test

**Synchrotron X-ray diffraction**

Synchrotron X-ray diffraction data were obtained on beamline I11 at Diamond Light Source, UK, over 2≤2θ/o≤ 90 (λ= 0.827127 Å) at room temperature.

Code names are as follow

|  |  |
| --- | --- |
| 248355-mythen-summed\_N2.dat | Synchrotron X-ray diffraction data of the Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ powder aged in the flow of N2 at 750oC for 170 hours |
| 248358-mythen-summed\_air.dat | Synchrotron X-ray diffraction data of the Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ powder aged in the ambient airat 750oC for 170 hours |

**SEM images**

**Measurement details:** The morphology of the membranes was characterized using scanning electron microscopy (Hitachi S-4800 Field-Emission Scanning Electron Microscope). Code names are as follow

|  |  |
| --- | --- |
| BSCF feed after stability | SEM image of the feed side of Ba0.5Sr0.5Co0.8Fe0.2O3-δ membrane after stability test |
| BSCF sweep after stability | SEM image of the sweep side of Ba0.5Sr0.5Co0.8Fe0.2O3-δ membrane after stability test |
| BSCF\_1140oC\_5h | SEM image of the fresh Ba0.5Sr0.5Co0.8Fe0.2O3-δ membrane sintered at 1140oC for 5h |
| BSCF-Mo0.025 \_1140oC-5h | SEM image of the fresh Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane sintered at 1140oC for 5h |
| BSCF-Mo0.025\_1.6mm\_sweep after stability | SEM image of the sweep side of Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane after stability test |
| BSCF-Mo0.025\_1.6mm\_feed after stability | SEM image of the feed side of Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ membrane after stability test |
| BSCF-Mo0.05 \_1140oC\_5h | SEM image of the fresh Ba0.5Sr0.5Co0.76Fe0.19Mo0.05O3-δ membrane sintered at 1140oC for 5h |
| BSCF-Mo0.125 \_1140oC-5h | SEM image of the fresh Ba0.5Sr0.5Co0.583Fe0.292Mo0.125O3-δ membrane sintered at 1140oC for 5h |
| BSCF-Mo0.25\_1140oC-5h | SEM image of the fresh Ba0.5Sr0.5Co0.6Fe0.15Mo0.25O3-δ membrane sintered at 1140oC for 5h |
| BSCF-Mo0.375\_1140oC\_5h | SEM image of the fresh Ba0.5Sr0.5Co0.5Fe0.125Mo0.375O3-δ membrane sintered at 1140oC for 5h |
| BSCF-Mo0.375\_feed after stability | SEM image of the feed side of Ba0.5Sr0.5Co0.5Fe0.125Mo0.375O3-δ membrane after stability test |
| BSCF-Mo0.375\_sweep after stability | SEM image of the sweep side of Ba0.5Sr0.5Co0.5Fe0.125Mo0.375O3-δ membrane after stability test |

**Thermal Expansion Coefficient (TEC)**

TEC measurements were carried out in a NETZSCH DIL402C dilatometer in air over the 25-1000 oC temperature range. Each scan contains 2 segments (heating and cooling). During exporting data files it was required by the software to break 2 segments and export them separately. Each exported data contains the name of the tested material, temperature range, heating /cooling rate and the length of the sample. The TEC values were averaged from heating and cooling segments.

Example 1: ExpDat\_HG\_BSCF-Mo0.025\_1000oC-RT\_rate3\_8mm.txt

Material: Ba0.5Sr0.5Co0.78Fe0.195Mo0.025O3-δ

Sample’s length: 8 mm

Temperature range: from 1000 oC to room temperature (cooling segment)

Cooling/heating rate: 3 K/min