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Oxygen transport in YSZ/LSM composite materials for oxygen separators & syngas membranes

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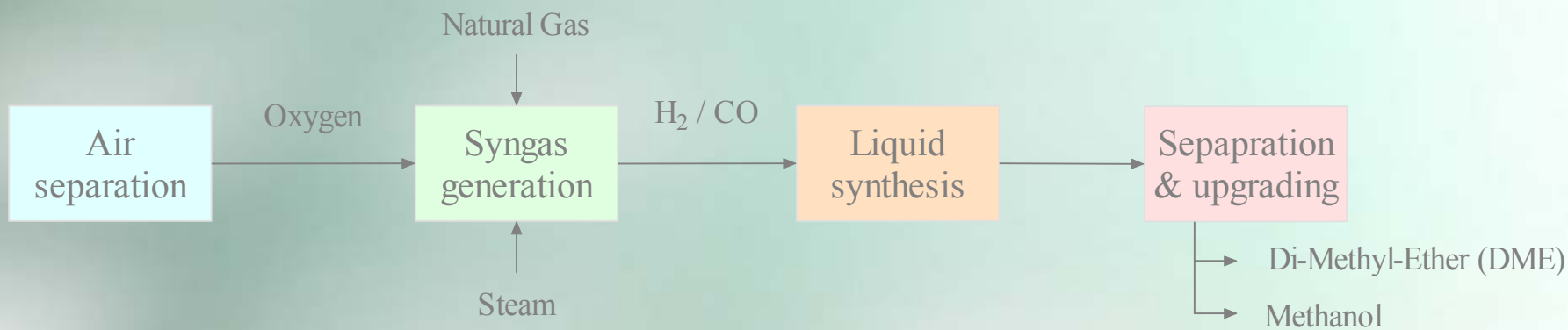
Syngas - Fuel for the future?

- Syngas is produced via a two step process involving partial oxidation & steam reforming of methane.

Partial oxidation: $CH_4 + \frac{1}{2}O_2 \leftrightarrow CO + 2H_2$ $\Delta H_{800°C} = -23 kJ/mol$

Steam reforming: $CH_4 + H_2O \leftrightarrow CO + 3H_2$ $\Delta H_{800°C} = 225 kJ/mol$

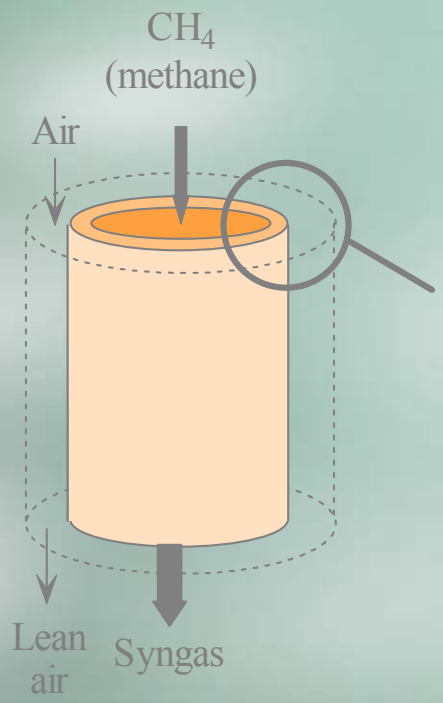
- Current oxygen separation technology can account for upto 60% of total investment costs in a syngas generation plant.

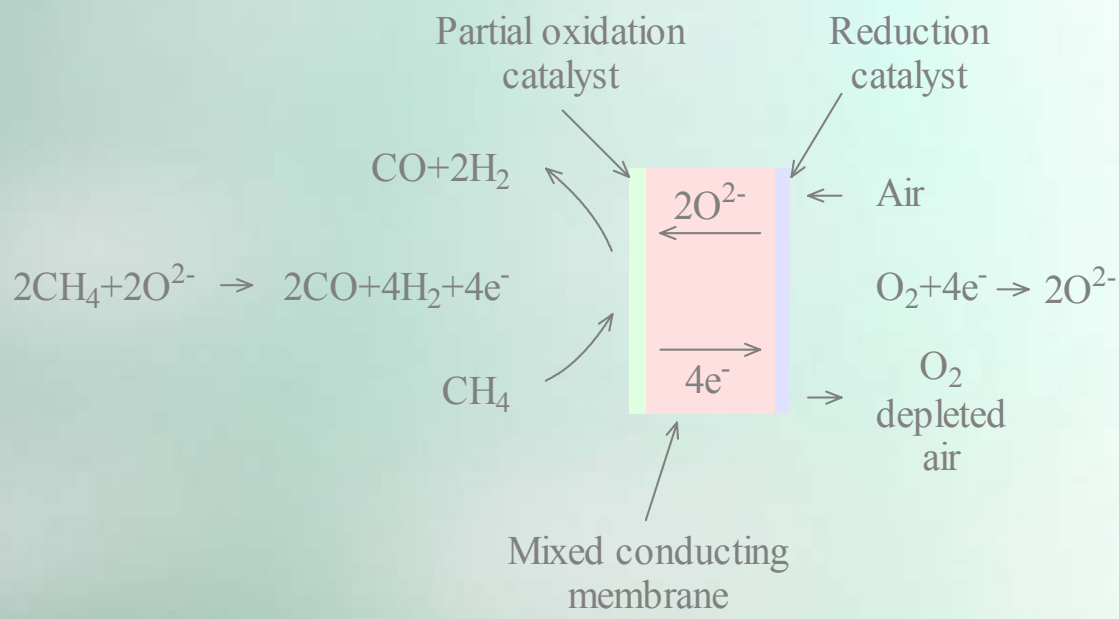


Investment costs (as % of total):	60%	25-30%	10%

Membranes for syngas synthesis

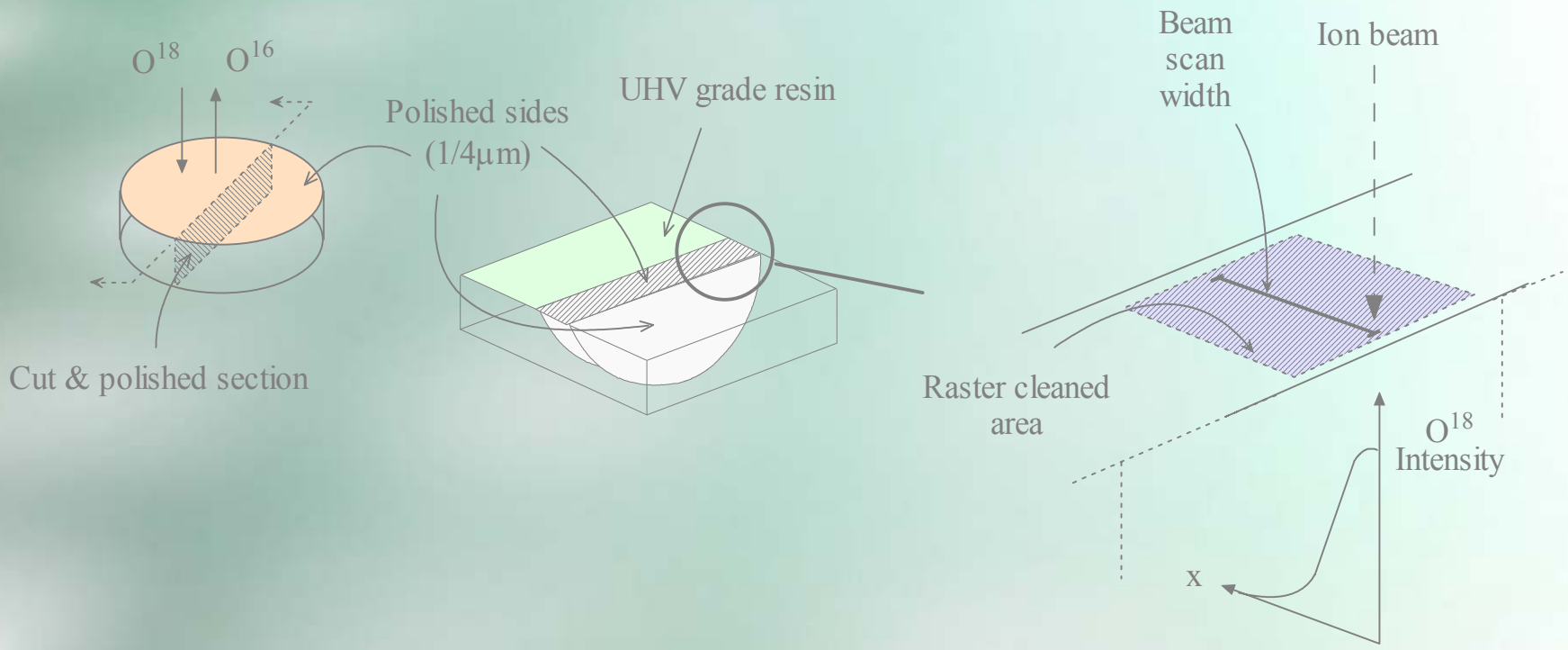
- Ceramic membrane reactors integrate air separation and autothermal reforming in a single step, eliminating need for additional air separation plants.
- Using remotely located sources of natural gas such as in North Alaska would make process more economical. This reserve alone could upgrade the world's oil reserves by an equivalent of 30 years consumption.





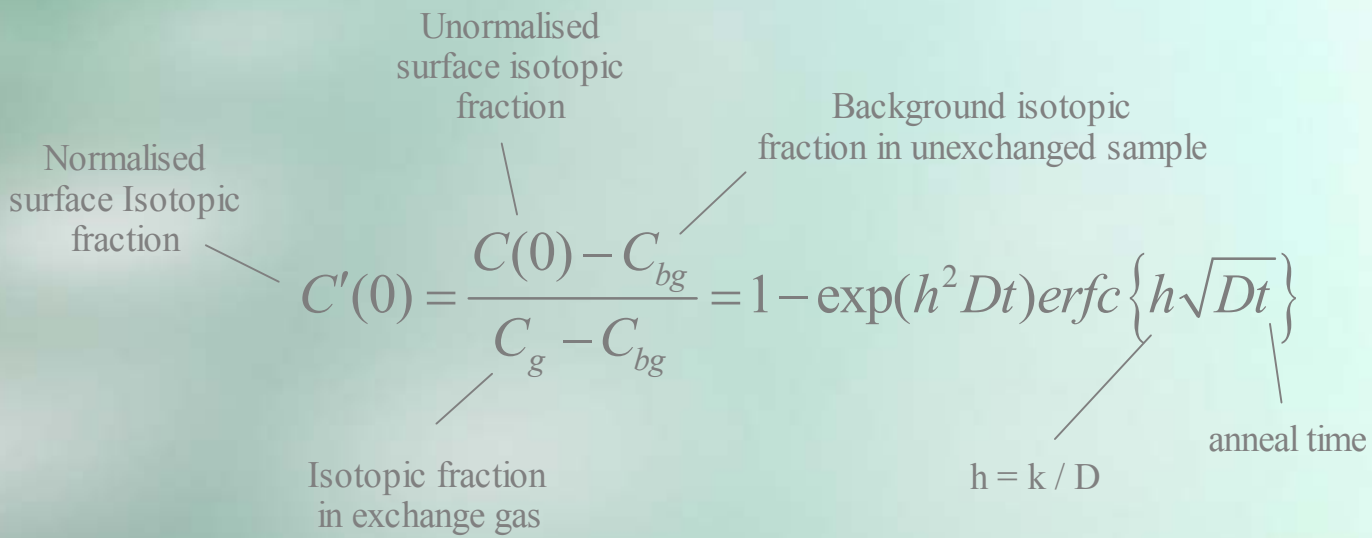
Secondary Ion Mass Spectrometry (SIMS)

- Most direct method of measuring oxygen diffusion coefficient (D) and surface exchange coefficient (k) is by isotopic exchange followed by SIMS.



Limitations to SIMS

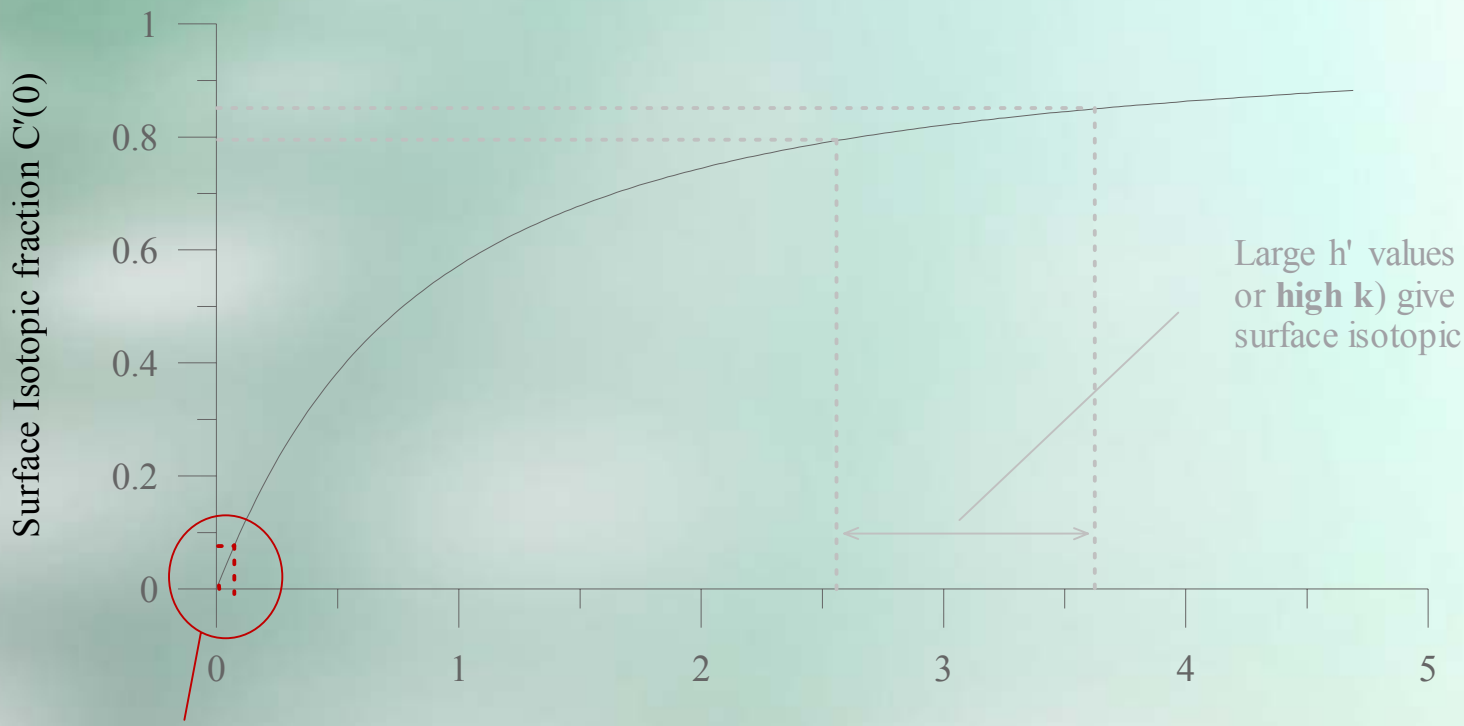
- Subsequent isotope penetration profile has been described by Crank for the case of a semi-infinite solid. Interesting form of solution is at the surface which highlights some limitations to the SIMS technique.



- To obtain reliable values of D and k, one should aim to tailor the diffusion anneal to give C′(0) values in the range 0.1 to 0.8.

Limitations to SIMS

- It is important to selectively choose anneal times which give h′ values in the range 0.1 to 3.0.



Composite materials

- Perovskite type oxides have been at the fore-front of ceramic based gas separation technologies owing to the high oxygen fluxes permeable through these membranes

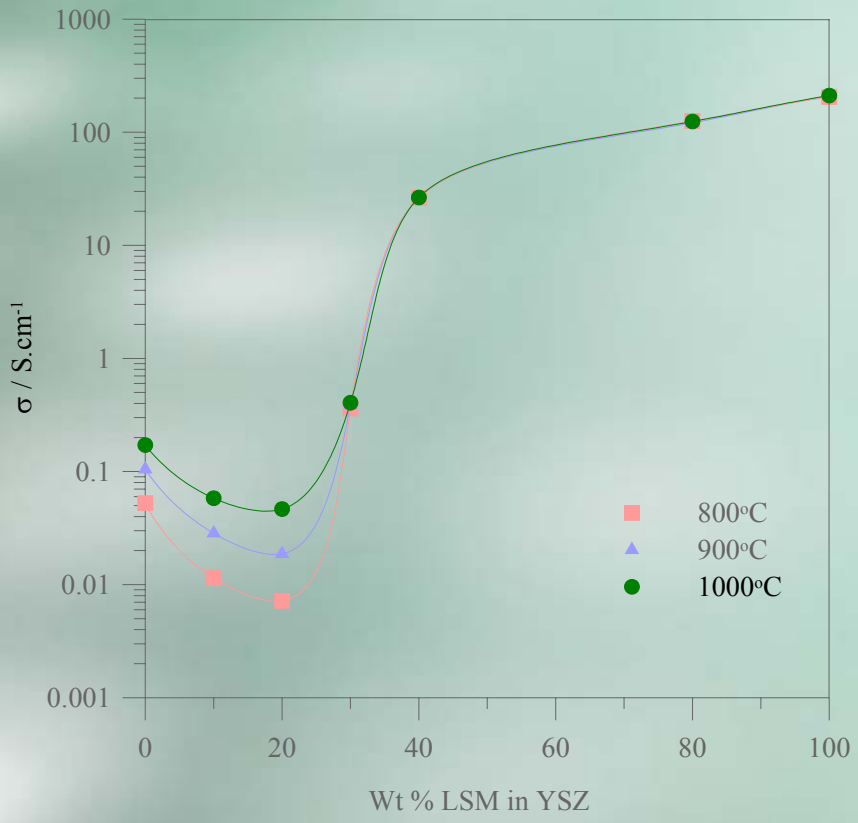
- Instability of these membranes under an oxygen partial pressure gradient often leads to their decomposition over time. Thus there is a need to seek alternative materials.

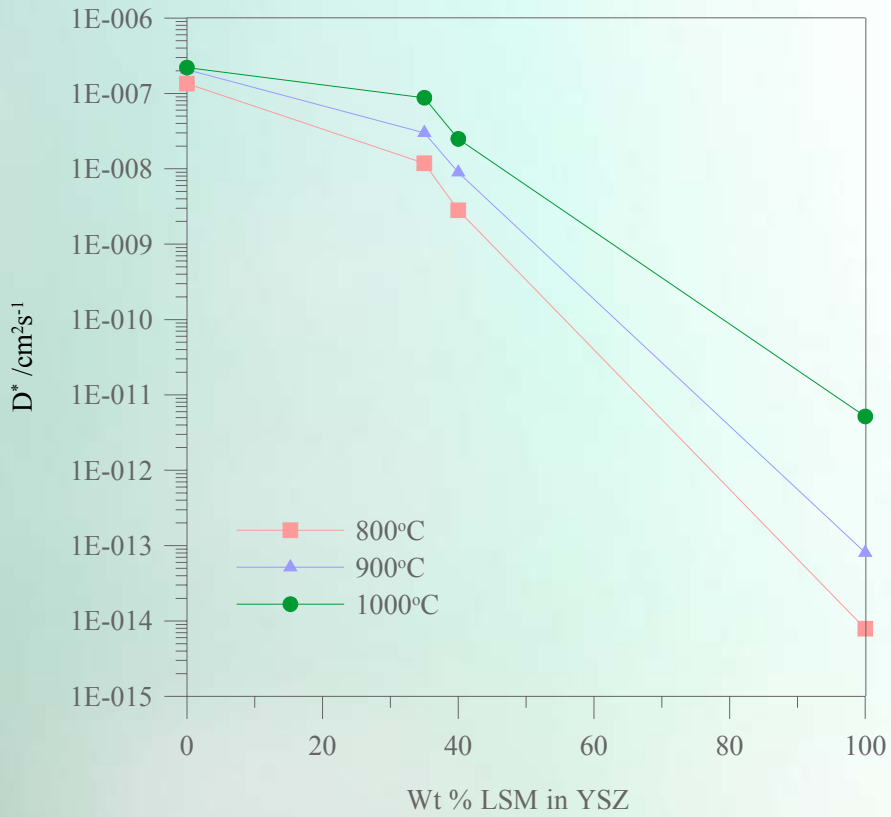
- Composite materials consisting of dual phase ionic and electronic conductors are possible candidate materials for use in gas separation applications.

- The individual materials within in a composite system must be carefully selected so as to minimize any chemical & mechanical stresses between the two phases.

YSZ-LSM composite materials

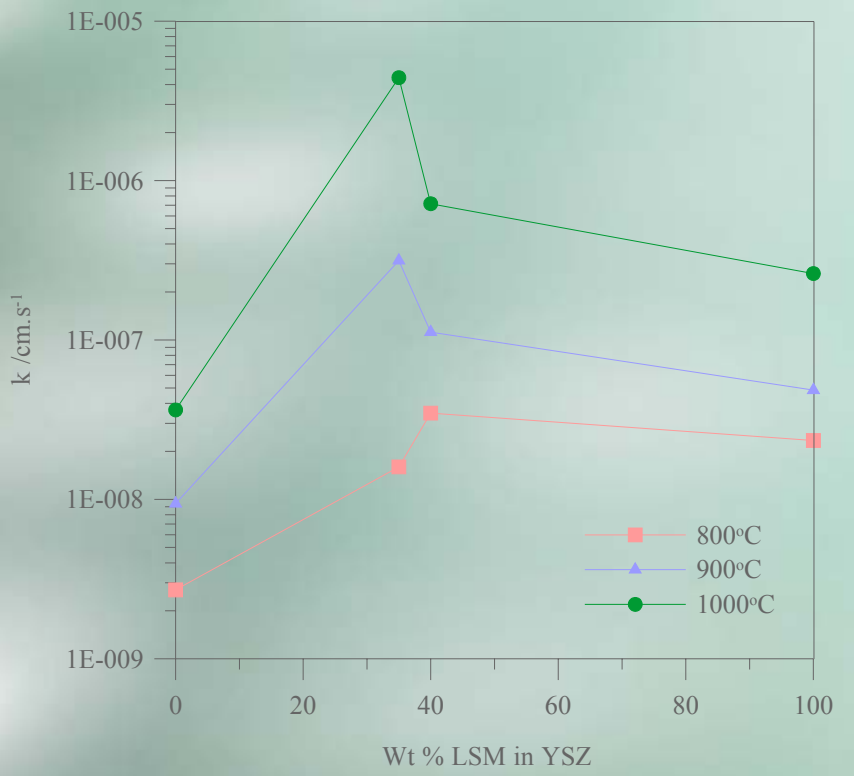
- Composite exhibits good mixed ionic-electronic characteristics with high electrical conductivity and fast oxygen ion transport through the oxides.

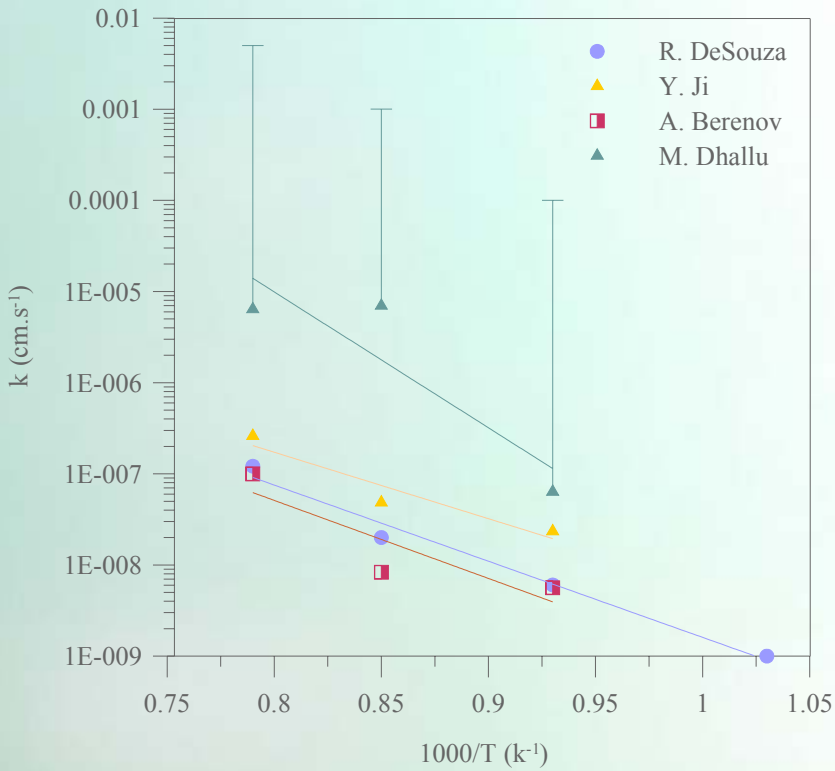




YSZ-LSM composite materials

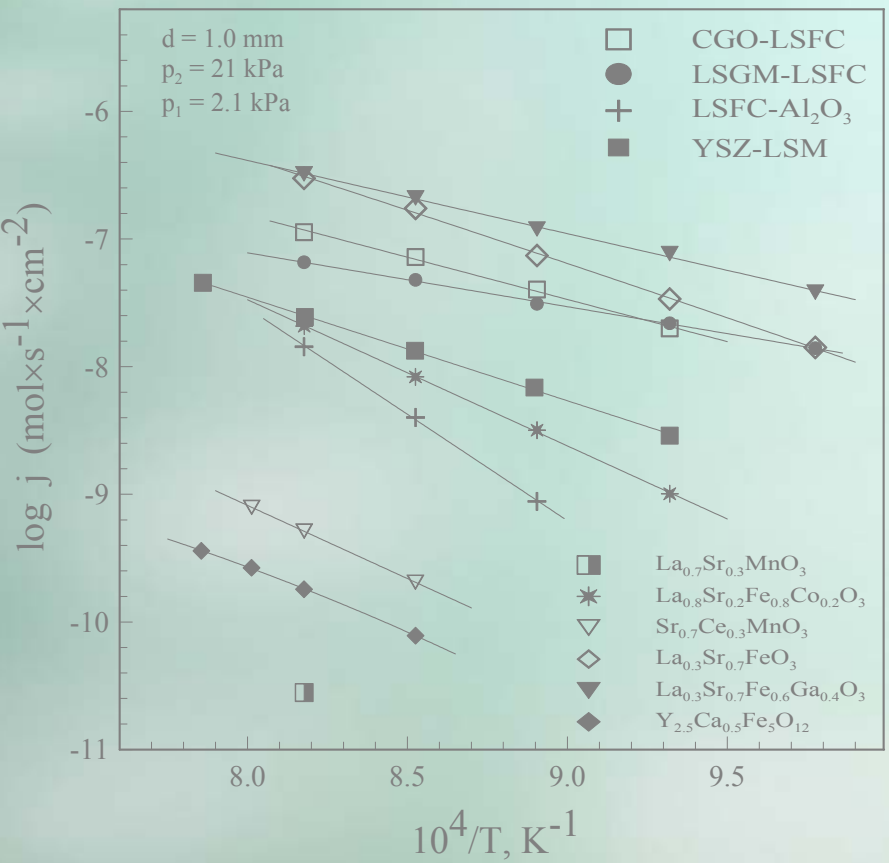
- Surface exchange data for composite is significantly higher than the individual materials. High accuracy SIMS measurements on LSM indicate the surface exchange data for this material has been most likely under-estimated by previous authors due to limitations in the SIMS technique.





YSZ-LSM composite materials

- High oxygen fluxes permeable through these composite membranes render these as candidate materials for applications requiring pure oxygen.



Future work

- Determination of an optimum YSZ-LSM phase distribution.
- Microstructural and sintering studies.
- Oxygen permeation measurements through selected membranes.

Acknowledgements

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