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Development and Performance of Zirconia Based Oxygen Transport Membranes for Carbon Capture Processes

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Oxygen Transport Membranes (OTMs) can facilitate a more sustainable society by supplying oxygen to combustion processes, leading for example to more efficient Carbon Capture and Storage (CCS) or cement production. OTMs are inorganic, high temperature devices typically formed by dense Mixed Ionic Electronic Conductors (MIECs). The separation mechanism consists of the following steps: on one side of the OTMs molecular oxygen is reduced to oxide ions, which are incorporated into oxygen vacancies of the MIEC and diffused to the other side, where oxide ions are oxidized back to molecular oxygen. The transport of electrons occurs in the opposite direction. Dual-phase membranes are a good option for applications under harsh conditions (e.g. flue gas containing CO_2, SO_2, H_2O) because they consist of a composite of a stable ionic conductor and a stable electronic conductor, which can combine high oxygen flux and chemical stability at the same time.

This work will describe the use and benefits of OTMs for carbon capture processes and present the development and performance of planar zirconia based dual-phase OTMs taking place at the Technical University of Denmark (DTU). Three composite materials based on the ionic conducting phase 10Sc1YSZ ($(Y_2O_3)_{0.01}(Sc_2O_3)_{0.10}(ZrO_2)_{0.89}$): 10Sc1YSZ-$MnCo_2O_4$, 10Sc1YSZ-$Al_{0.02}Zn_{0.98}O_{1.01}$ and 10Sc1YSZ-$LaCr_{0.85}Cu_{0.10}Ni_{0.05}O_{3-\delta}$ were successfully prepared and characterized as planar dual-phase asymmetric OTMs for direct operation (4-end mode membrane module) in oxy-fuel combustion power plants. Stability tests performed under conditions relevant for oxy-fuel combustion (SO_2, CO_2, H_2O) underlined the excellent stability of the three composites. Among the zirconia-based membranes, the 10Sc1YSZ-$MnCo_2O_4$ and 10Sc1YSZ-$LaCr_{0.85}Cu_{0.10}Ni_{0.05}O_{3-\delta}$ composites developed in this work display the two highest oxygen permeabilities (1.41 $mL_N\,cm^{-2}\,min^{-1}$ and 1.11 $mL_N\,cm^{-2}\,min^{-1}$ at 950 °C in air/N_2, respectively), which is 200 % higher than the highest oxygen permeation flux previously reported in literature.