Recent developments in ceramic membranes for gas separation and membrane reactors

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Ceramic membranes are used to separate gases from gas mixtures or to produce chemicals (e.g., syngas, commodity chemicals, or synthetic energy carriers) in situ within membrane reactors [1]. These membrane reactors are modular and can theoretically be utilized wherever unexploited heat or power is readily available, making them highly efficient and flexible.

There are two different types of ceramic gas separation membranes: porous membranes and dense membranes. In microporous membranes, the process of molecular separation is based on the principles of size exclusion and/or competitive adsorption effects. Ceramic membranes are more expensive to produce than polymer membranes and are therefore used in applications where polymer membranes cannot perform due to the operating conditions (high temperature and/or transmembrane pressure, aggressive environment). Potential applications of microporous ceramic membranes include the purification and treatment of wastewater and organic solvents as well as the dehydration of alcohols. While ceramic membranes with pore sizes above 1 nm are commercially available and already utilized in a variety of sectors, gas separation membranes with a pore size of ca. 0.5 nm and lower are still in the research and development stage. In contrast to microporous membranes, material separation in dense ion-conducting ceramic membranes is based on diffusion processes. These involve the movement of ions through the crystal lattice. Electron transport may also take place in the lattice. The diffusion process is thermally activated, requiring operating temperatures of several hundred degrees Celsius. Since there is almost no limit to the selectivity of the separation mechanism, these membranes are equally suited to producing high-purity gases and chemicals in reactors [2,3].

The lecture will provide an overview of selected potential fields of application for ceramic porous and dense membranes and, in addition, highlight some new development directions regarding material selection and thin-film concepts as well as their manufacturing technologies.

In the case of porous membranes, both the classic amorphous oxide ceramic membranes (silica-based) and graphene-based or bio-inspired carbon membranes will be presented. Furthermore, zeolite and metal-organic framework membranes (MOFs) will be briefly presented.

In the case of dense membranes, the current developments of mixed-conducting oxygen transport membranes and hydrogen-conducting proton-conducting membranes will be presented. This includes the single-phase membranes and dual phase membrane systems.

1. W. Deibert, M.E. Ivanova, S. Baumann, O. Guillon, W.A. Meulenberg "Ion-Conducting Ceramic Membrane Reactors for High-Temperature Applications" ***Journal of Membrane Science 543* (2017),** 79-97, https://doi.org/10.1016/j.memsci.2017.08.016
2. W. A. Meulenberg, F.Schulze Küppers, W. Deibert, T. Van Gestel, Stefan Baumann, "Ceramic Membranes: Materials – Components – Potential Applications", **ChemBioEng Reviews 6, No.6 (2019),** 198-208**,** https://doi.org/10.1002/cben.201900022
3. W. A. Meulenberg, F.Schulze Küppers, W. Deibert, T. Van Gestel, Stefan Baumann, „Keramische Membranen – Materialien - Bauteile - potentielle Anwendungen" ***Chemie, Ingenieur, Technik* 91 (8) (2019)** 1091-1100, https://doi.org/10.1002/cite.201900019