6–4 Upgrading H_2 Production Efficiency in the IS Process

—Corrosion Stability Improvement of the H_2 Separation Membrane for HI Decomposition—

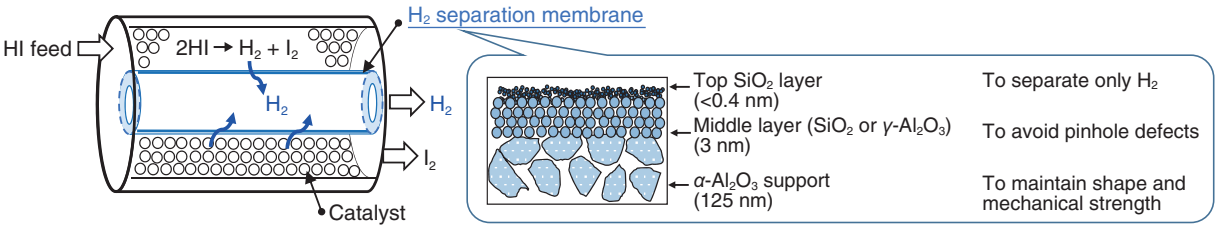

Fig.6-7 Schematic of a membrane reactor equipped with an H_2 separation membrane for HI decomposition
In a membrane reactor, HI gas is catalytically decomposed into H_2 and I_2, and the H_2 produced is separated by a membrane, thereby driving HI decomposition. The membrane consists of three layers: a base α-Al_2O_3 support tube, a middle layer (γ-Al_2O_3 or SiO_2), and a top H_2-selective SiO_2 layer.

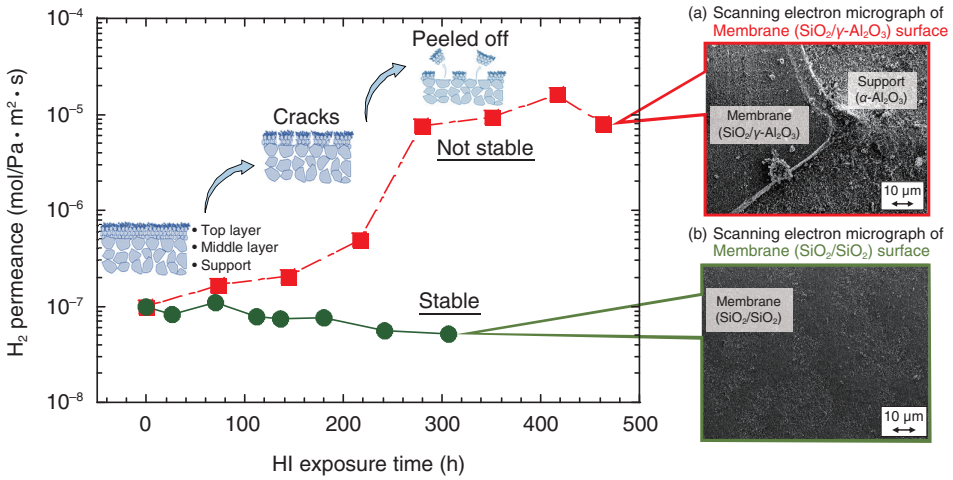

Fig.6-8 Change in the H_2 permeance of membranes with middle layers composed of (a) γ-Al_2O_3 and (b) SiO_2 under corrosive HI exposure
The new H_2-separation membrane with the middle layer changed from the conventional γ-Al_2O_3 to SiO_2 showed stable performance in a corrosive HI environment.

Thermochemical iodine–sulfur (IS) process, which employs nuclear heat to decompose water, is considered the most suitable solution for producing large amounts of H_2 without emitting CO_2. The IS process consists of three coupled chemical reactions (the Bunsen reaction, sulfuric acid decomposition reaction, and hydrogen iodide decomposition reaction).

One of the technical challenges in the development of the IS process is the separation of H_2 from the mixture of corrosive gases hydrogen iodide and iodine during hydrogen iodide decomposition ($2HI \rightarrow H_2 + I_2$). To solve this problem, there is a need for a membrane reactor with an H_2 separation membrane (Fig.6-7) that is capable of equilibrium shifting and can handle corrosive environment.

The conventional H_2 separation membranes used for HI decomposition consist of three layers: a base α-Al_2O_3 support tube (average pore size: 200 nm) that maintains mechanical strength, middle γ-Al_2O_3 layer (3 nm) to avoid pinhole defects in the top layer, and top SiO_2 layer (<0.4 nm) to selectively separate H_2.

In the HI exposure tests of these conventional membranes, a considerable increase in the H_2 permeance was observed after 200 h. This is because the middle γ-Al_2O_3 layer was corroded by HI gas and partially peeled off (Fig.6-8(a)). In other words, the large increase in H_2 permeance was attributed to the lack of corrosion stability of the middle layer to HI gas. Therefore, to improve corrosion stability against HI exposure, the fragile middle γ-Al_2O_3 layer should be replaced by a more corrosion-resistant material. For this purpose, a new H_2-separation membrane was developed with a middle SiO_2 layer that is thermally and chemically stable and has excellent pore size controllability. The new membrane with this middle SiO_2 layer showed only a slight decrease in H_2 permeance after 300 h of exposure to HI gas, and there were no significant changes on the membrane surface (Fig.6-8(b)); the middle SiO_2 layer remained unchanged and stable. Thus, we successfully developed an H_2 separation membrane with high corrosion stability in an HI environment. The membrane with middle SiO_2 layer is suitable for membrane reactors that produce H_2 via HI decomposition.

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(Odtsetseg Myagmarjav)

Reference

Myagmarjav, O. et al., Fabrication, Permeation, and Corrosion Stability Measurements of Silica Membranes for HI Decomposition in the Thermochemical Iodine-Sulfur Process, International Journal of Hydrogen Energy, vol.46, issue 56, 2021, p.28435–28449.