6–7 Membrane Makes IS Process Chemical Reaction Efficiently

—Use of an Ion-Exchange Membrane to Reduce Water Permeation by Cross-Linking—

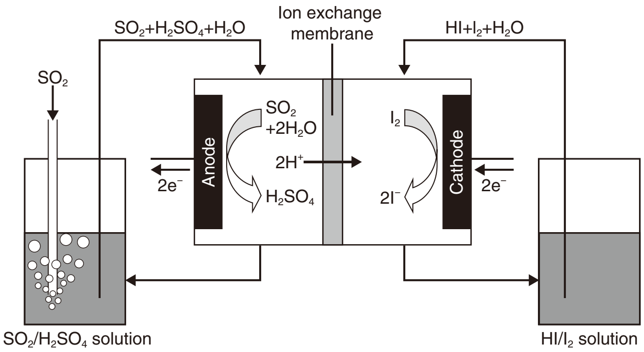

Fig.6-15 Schematic of Bunsen reaction using ion-exchange membrane
Hydriodic and sulfuric acid were produced on the cathode and anode, respectively, in an electrochemical cell equipped with an ion-exchange membrane.

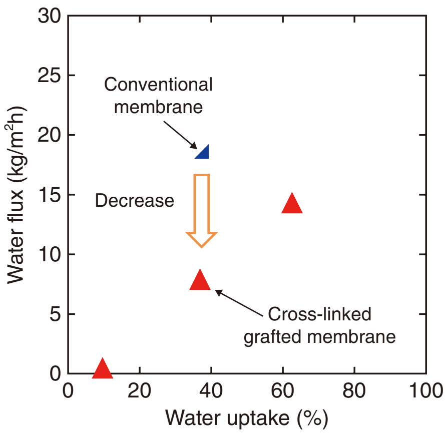

Fig.6-16 Relationship between water permeate flux and water content
The water permeate flux through the cross-linked grafted membrane decreased in relation to that of a conventional membrane having same water content.

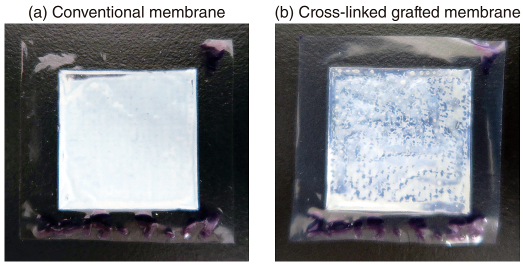

Fig.6-17 Outlook of (a) conventional and (b) cross-linked grafted membrane after membrane Bunsen reaction tests
The cross-linked grafted membrane showed a whitish color, which is evidence of sulfur formation reaction; the conventional membrane did not, indicating a lower water permeation.

In an effort to valorize the heat of high-temperature gas-cooled reactors, the thermochemical iodine-sulfur (IS) water-splitting hydrogen (H_2) production process has been investigated. The IS process is a promising H_2 production method using nuclear and renewable energy sources and is composed of sulfur and iodine chemical reactions. The Bunsen reaction, a key reaction of the IS process, produces sulfuric and hydriodic acids by mixing iodine (I_2) and sulfur dioxide (SO_2) with water. Liquid-liquid (LL) separation occurs by adding excess I_2 to the two acids. However, this excess I_2 decreases process efficiency and increases cost.

One alternative Bunsen reaction method investigated involves using an electrochemical cell equipped with a proton-selective ion-exchange membrane (Fig.6-15). No LL separation is needed, as the two acids can be separately produced in a cell partitioned into two channels by the ion-exchange membrane.

An ion-exchange membrane suitable for this purpose should have a high conductivity and low water permeability. Enhancing conductivity requires higher water content in the membrane however, this causes higher water permeation. A cross-linked ion-exchange membrane was therefore prepared by a radiation grafting technique developed by National Institutes for Quantum and Radiological Science and Technology (QST). The cross-link, in which grafted chains connect, enables the membrane to retain water among the chains.

The relationships between water permeate flux and water content of the trial membranes were then measured (Fig.6-16); a lower flux was found of the ion-exchange membrane than of a conventional membrane having the same water content. Membrane Bunsen reaction tests were carried out using an electrochemical cell introducing the tested membranes, revealing a lesser degree of white turbidness of the cross-linked grafted membrane (Fig.6-17(b)) than that of a conventional membrane (Fig.6-17(a)). Thus, a cross-linked grafted membrane can reduce water permeation and the white turbidness due to sulfur formation associated with SO_2 transportation accompanied with water, indicating that a cross-linked grafted membrane can be adapted to the membrane Bunsen reaction. Future work will involve the development of an ion-exchange membrane to improve performance by using this membrane preparation technology.

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Reference

Nomura, M., Tanaka, N. et al., Development of Ion-Exchange Membranes for the Membrane Bunsen Reaction in Thermochemical Hydrogen Production by Iodine-Sulfur Process, Journal of Chemical Engineering of Japan, vol.51, no.9, 2018, p.726–731.