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Current R&D status of thermochemical water splitting iodine-sulfur process in Japan Atomic Energy Agency

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ABSTRACT

Current R&D on the thermochemical water splitting iodine-sulfur (IS) process in Japan Atomic Energy Agency (JAEA) is summarized. Reactors were fabricated with industrial materials and verified by test operations: a Bunsen reactor, a H₂SO₄ decomposer, and a HI decomposer. Component materials of the reactors were stable in the operation environment. Small amount of H₂SO₄ in the anolyte solution in an electro-electrodialysis (EED) cell had no negative impact on cell performance parameters. Relationship between cell solution composition and temperature and cell parameters was formulated by experimental data. Demonstration of the test facility with process design of 100 L/h hydrogen production is performed to verify integrity of process components and stability of hydrogen production. Tests of sections were first conducted individually to show material processing rates were controllable. Based on the result, an 8-h continuous operation of the total IS process was performed in February 2016 with H₂ production rate of 10 L/h. Demonstrations are planned for longer operation period and higher H₂ production rate after improvement of components to prevent troubles.

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Introduction

Thermochemical iodine-sulfur (IS) process is one of the hydrogen production methods from water using heat of 1173.15 K. Hydrogen production with little CO₂ emission is expected in combination with nuclear or solar heat source. High temperature gas-cooled reactor (HTGR) is considered as a candidate, which is a type of nuclear reactor featuring high temperature helium gas from the reactor at 1023.15–1223.15 K [1]. Water is decomposed into hydrogen and by-product oxygen following the reactions.

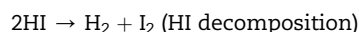
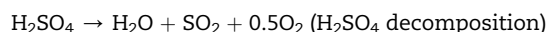
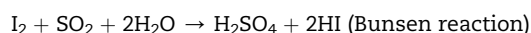


Fig. 1 illustrates a candidate flow diagram of the process proposed in Japan Atomic Energy Agency (JAEA). Solution

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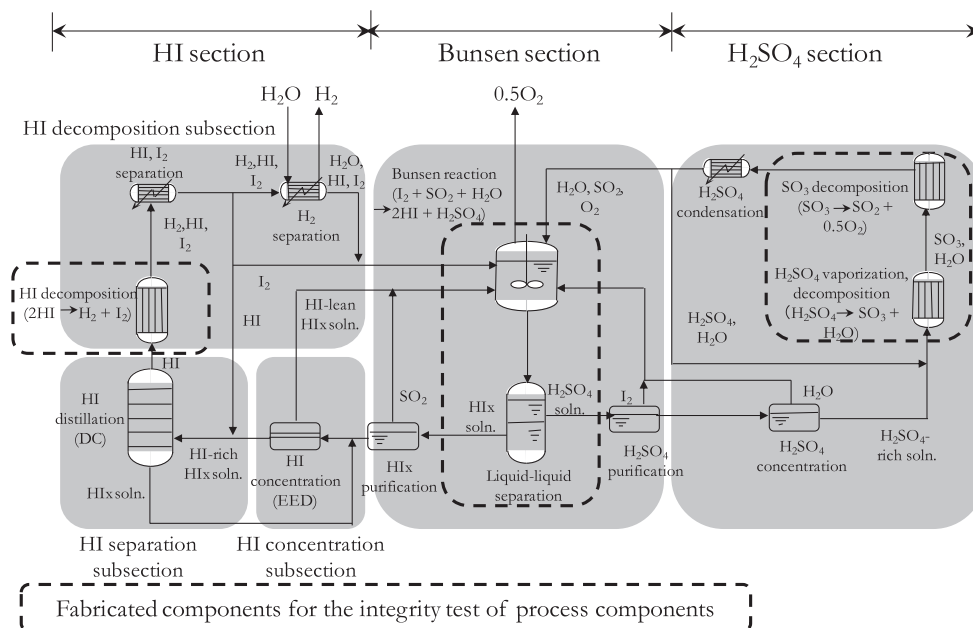


Fig. 1 – Schematic of the IS process proposed in JAEA.

from the Bunsen reactor containing H₂SO₄ and HI is separated into HIx phase and H₂SO₄ phase in the liquid–liquid separator. The HIx phase contains HI, I₂, H₂O and small amount of sulfur compounds. First, the sulfur compounds are removed by changing H₂SO₄ to SO₂ in reverse Bunsen reaction and vaporization of the SO₂. The sulfur free solution is fed to the HI section and HI is concentrated in the electro-electrodialysis (EED) cell stacks. HI rich HIx solution from the stacks is sent to the HI distillation column (DC) and HI is distilled from the solution. The HI vapor is decomposed into H₂ and I₂ in the HI decomposer. Most of I₂ and undecomposed HI are condensed and separated. Then H₂ is purified by removal of the remaining I₂ and HI by contact with H₂O fed from outside. The H₂SO₄ phase from the Bunsen separator contains H₂SO₄, H₂O and small amount of iodine species. HI in the solution is changed to I₂ by the reverse Bunsen reaction and I₂ is removed by vaporization in the H₂SO₄ purifier. The iodine free H₂SO₄ solution is fed to the H₂SO₄ section and concentrated in the H₂SO₄ concentrator(s). The H₂SO₄ rich solution is all vaporized and H₂SO₄ is decomposed into SO₃ and H₂O. Then, some part of the SO₃ is decomposed into SO₂ and O₂. Product gas is condensed and undecomposed SO₃ is recovered as H₂SO₄ in the H₂SO₄ condenser. The remaining H₂O, SO₂ and O₂ return to the Bunsen reactor. O₂ is separated as a by-product of the IS process and the other components are consumed in the Bunsen reaction.

IS process has been studied since the process was first proposed in 1976 [2]. From the end of the 20th century to around 2010, U.S. and France have conducted the study. A closed test loop was constructed and operated from 2008 in a collaboration of these countries [3]. Nowadays, IS process is researched in Korea and China. In Korea, operation in an

individual section was conducted from 2010 using a test facility of the total IS process of the scale of 50 L/h hydrogen production [4,5]. In China, a test facility of total closed cycle successfully operated for 7 h to produce hydrogen at 10 L/h (standard condition) in 2009 [6]. After the operation, a new facility was constructed and operated with about standard 60 L/h hydrogen production for 86 h in 2014.

In addition to these countries, JAEA has been carrying out R&D since around the end of 1980s. Continuous hydrogen production of 31 L/h (standard condition) was demonstrated for 175 h in 2004 with a glass-made apparatus [7]. After the operation, components of larger scale made of industrial materials were operated as preparation of following hydrogen production demonstrations. A larger scale facility has been constructed and operated based on know-how obtained by those components.

Selection of component materials is very important because environment in the IS process is very severe. JAEA has searched for appropriate materials by corrosion tests [8–10]. Fig. 2 summarizes materials of relatively well corrosion resistance [10].

This study discusses a current R&D situation in JAEA including tests of individual components made of practical materials and construction and demonstration of a larger scale integrity test facility. Corrosion resistance of a few materials selected from Fig. 2 was investigated in the components test.

Current R&D status

Test reactors were fabricated to verify application of industrial materials and proper fabrication of the large scale

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