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हाइड्रोजन उत्पादन प्रौद्योगिकी हेतु छिद्रयुक्त पदार्थों का विकास

Development of Porous Materials for Hydrogen Production Technology

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Introduction

Porous materials are a class of materials in which pores of desired size range and volume fraction are introduced intentionally through a suitable powder metallurgy technique. Presence of pores makes significant changes in material characteristics, such as, decrease in thermal conductivity and increase in specific surface area. With increase in interconnected pore fraction permeability for liquid and gas increases significantly in porous materials. These distinctive features of porous materials make them suitable for numerous advanced applications, such as, thermal insulation, catalyst, filtration of hot gas and liquid etc. Many porous ceramics have excellent temperature and corrosion resistance enabling their use in severe conditions.

There are numerous ways to produce porous materials. These include partial sintering, replica methods, sacrificial pore formers, direct foaming, gel-casting and additive manufacturing. Suitability of a process depends on the material, desired pore structure and application. Some porous materials developed at Powder Metallurgy Division of Materials Group, BARC applications in hydrogen programme of DAE programmes are reported here.

Alumina Ceramic Foam

Ceramic foams are high porosity materials with interconnected pores. A process has been developed for making α-alumina based ceramic foam by polymeric sponge replication method. In this process, commercial polymeric foam (template) is dipped into specially formulated ceramic slurry followed by drying and sintering to yield a replica of the original polymeric foam. The properties of ceramic foam can be adjusted by varying the polymeric foam characteristics, viscosity of the ceramic slurry and sintering schedule. The process is capable to making ceramic foam up to 90% porosity. Typical characteristics of the developed alumina ceramic foam are shown in Table 1. Physical appearance of alumina foam and its SEM micrograph is shown in Fig.1. α-alumina based foam can be used at high temperature upto 1200 °C. The alumina foam can be used as catalyst support for various applications, such as catalytic converter, waste water treatment.

γ-Alumina Coated Alumina Ceramic Foam Catalyst for I-S Process

Alpha alumina foam has been used to support Pt catalyst for its application to decompose HI in Iodine-Sulphur process of hydrogen production at Chemical Technology Division, BARC. For this application α-alumina macro-porous support is usually coated with γ-alumina to enhance the surface area. Finally, the ceramic foam is impregnated with platinum salt solution followed by heat treatment resulting in formation of nano-particles of catalytically active phase. SEM micrograph of the Pt catalyst loaded foam and Pt distribution in it is shown in Fig.2.

Iron Oxide Based Foam Catalyst for I-S Process

$(Fe,Cr)_2O_3$ is an efficient catalyst material for sulphuric acid decomposition reaction in I-S process for generation of hydrogen. As in the case of alumina foam preparation polymeric sponge replication method has been used for making foam type $(Fe,Cr)_2O_3$ catalyst. Physical appearance of the foam catalyst and its SEM micrograph is shown in Fig.3. The pores formed in the foam catalyst remain stable after its use at the operating temperature of 900 °C.

Porous Electrodes for Solid Oxide Cell

Solid oxide cells are ceramic electrochemical devices based on oxygen ion conducting electrolyte. These cells can be used in fuel cell mode (SOFC) for direct conversion of chemical energy of fuel (e.g. hydrogen) into electrical energy. In reverse mode of operation with the supply of electrical energy the cell can be used for electrolysis of steam. High temperature operation improves process efficiency. Ni-YSZ cermet electrode supported cell is the most common configuration. Processes

Table 1: Characteristics of alumina foam

Property	Typical value
Density	0.7 – 0.9 g/cm^3
Surface area	>35 m^2/g
Compressive strength	2 – 3MPa

Fig.1(a): α-alumina foam.

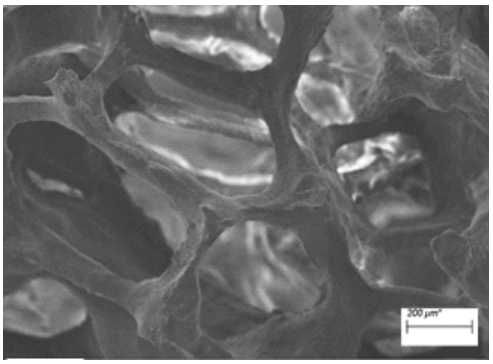

Fig.1(b): SEM micrograph of the foam.

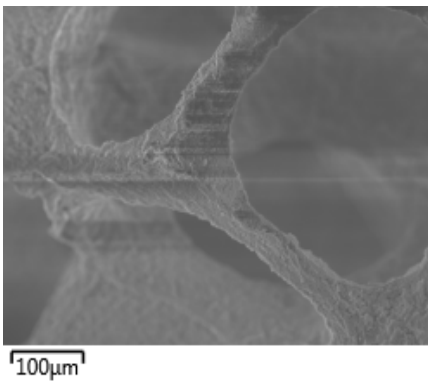

Fig.3(a): $(Fe,Cr)_2O_3$ foam catalyst.

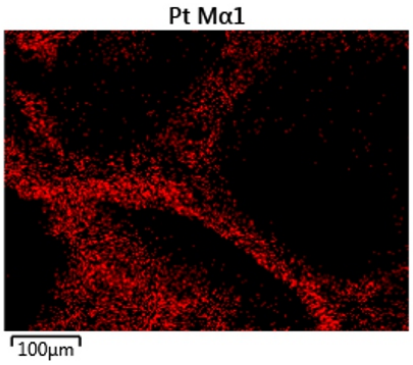

Fig.3(b): SEM photomicrograph of $(Fe,Cr)_2O_3$

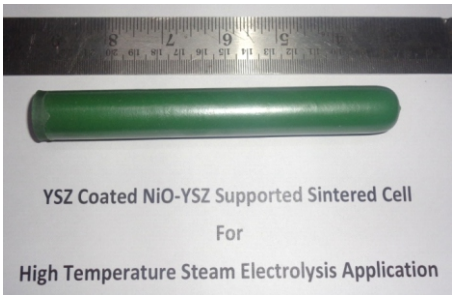

Fig.4(a): NiO-YSZ support tube with dense 8YSZ electrolyte.

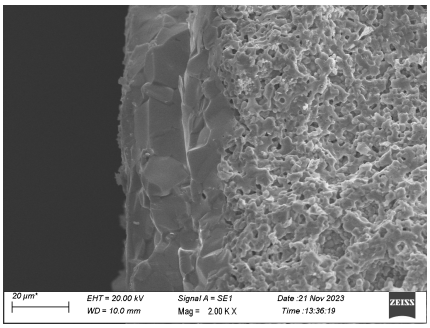

Fig.4(b): SEM micrograph showing bilayer (porous Ni-YSZ electrode with thin and dense 8YSZ electrolyte).

have been established to make porous NiO–YSZ supported cells with dense 8YSZ electrolyte. NiO-YSZ tubes are made by cold isostatic pressing and the green tube is coated with 8YSZ ceramic slurry. The 8YSZ slurry coated NiO-YSZ tube is sintered at around 1350 °C to get dense 8YSZ coating. To make a complete cell Sr-doped lanthanum manganite slurry with suitable pore former is coated over the dense electrolyte and fired at around 1100 °C.'. Ni-YSZ cermet with interconnected pore structure is developed when hydrogen is passed through the tube at high temperature at the start of operation. Typical microstructure of bilayer (porous Ni-YSZ electrode with thin and dense 8YSZ electrolyte) is shown in Fig.4. The cells have been operated at 800 °C in electrolyser mode for generation of hydrogen. Steady performance of single tubular cell for more than 150 h with hydrogen production rate of 4 Nlph has been demonstrated. Work has been initiated to develop porous metal supported cell for better electrical contact.