

CURRENT MHI POROUS ELECTRODE DEVELOPMENT FOR FUEL CELLS

Fuel cells are electrochemical devices that convert the chemical energy of a reaction directly into electrical energy. A variety of fuel cells are in different stages of development. They can be classified by use of diverse categories, depending on the combination of type of fuel and oxidant, whether the fuel is processed outside (external reforming) or inside (internal reforming) the fuel cell, the type of electrolyte, the temperature of operation, whether the reactants are fed to the cell by internal or external manifolds, etc. The most common classification of fuel cells is by the type of electrolyte used in the cells and includes 1) proton exchange membrane (polymer) electrolyte fuel cell (PEMFC), 2) alkaline fuel cell (AFC), 3) phosphoric acid fuel cell (PAFC), 4) molten carbonate fuel cell (MCFC), and 5) solid oxide fuel cell (SOFC).

The basic physical structure or building block of a fuel cell consists of an electrolyte layer in contact with a porous anode and cathode on either side. The functions of porous electrodes in fuel cells are: 1) to provide a surface site where gas/liquid ionization or de-ionization reactions can take place, 2) to conduct ions away from or into the three-phase interface once they are formed (so an electrode must be made of materials that have good electrical conductance), and 3) to provide a physical barrier that separates the bulk gas phase and the electrolyte. In order to increase the rates of reactions, the electrode material should be catalytic as well as conductive, porous rather than solid.

Porous electrodes are key to good electrode performance. The reason for this is that the current densities obtained from smooth electrodes are usually in the range of a single digit mA/cm² or less because of rate-limiting issues such as the available area of the reaction sites. Porous electrodes, used in fuel cells, achieve much higher current densities. These high current densities are possible because the electrode has a high surface area, relative to the geometric plate area that significantly increases the number of reaction sites, and the optimized electrode structure has favorable mass transport properties. In an idealized porous gas fuel cell electrode, high current densities at reasonable polarization are obtained when the liquid (electrolyte) layer on the electrode surface is sufficiently thin so that it does not significantly impede the transport of reactants to the electroactive sites, and a stable three-phase (gas/electrolyte/electrode surface) interface is established. The porous electrodes used in low-temperature fuel cells consist of a composite structure that contains platinum (Pt) electrocatalyst on a high surface area carbon black and a PTFE (polytetrafluoroethylene) binder. In the MCFC, the stable interface is achieved in the electrodes by carefully tailoring the pore structures of the electrodes and the electrolyte matrix (LiAlO₂) so that the capillary forces establish a dynamic equilibrium in the different porous structures. In an SOFC, A critical requirement of porous electrodes for SOFC is that they are sufficiently thin and porous to provide an extensive electrode/electrolyte interfacial region for electrochemical reaction.

Applications of the porous metallic foam materials in fuel cells

Porous metallic materials in SOFC

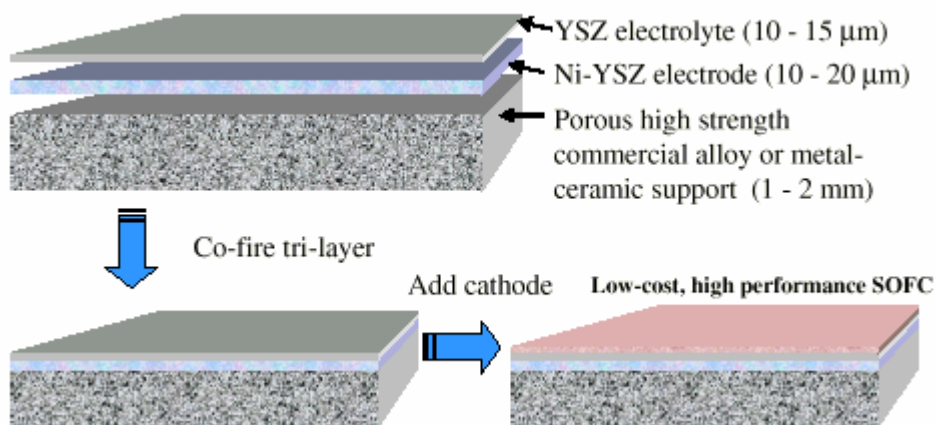
Among the strategies for SOFC cost reduction is lowering of cell operating temperature through the use of a thin electrolyte membrane supported on a porous electrode support.

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Typically a YSZ membrane is co-fired onto a Ni-YSZ support, and the air electrode is deposited in a later step. The use of Ni-YSZ as the structural support has a number of drawbacks including the high cost of thick Ni-YSZ electrodes, and the need to maintain a reducing atmosphere on stack cool-down to avoid oxidation of the Ni to NiO. This can be remedied somewhat by co-firing of the YSZ membrane onto a porous metal alloy support. Suitable alloys for metal supported SOFCs include those compositions that form highly adherent, electronically conductive scales in oxidizing environments, identical requirements to those for metal interconnects. The co-firing of the metal support/ceramic film structure is accomplished in reducing atmospheres as is commonly done for sintering porous metal structures.



Porous Metal Supported Thin Film SOFC

MCFC Fuel Cells

MCFC is that the real operating voltage is higher than the operating voltage for the PAFC at the same current density. The higher operating voltage of the MCFC means that more power is available at a higher fuel efficiency from a MCFC than from a PAFC of the same electrode area. The state-of-the-art high performance MCFC anode requires either the use of expensive pre-alloyed powders or costly physical mixtures of fine metallic particles requiring expensive heat treatment procedures for alloying the metal powders. The anode of MCFC is a highly porous sintered nickel powder, alloyed with chromium to prevent agglomeration and creep at operating temperatures. The cathode is a porous nickel oxide material doped with lithium.

The advantage of the MHI porous metallic electrode are:

The high cost of metallic Ni electrodes is one of the major drawback for the commercialization of the fuel cell technology. For example, U.S Department of Energy's Solid State Energy Conversion Alliance (SECA) has targeted a cost of \$400/kW for SOFC power generating systems. Allowable SOFC stack cost must be on the order of 5¢/cm. This aggressive cost reduction must achieved by the new technology

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development on the low cost electrode. The unique processing of MHI porous electrodes allows for rapid continuous processing which is being refined in the MHI SBIR program.

A further advantage is that no toxic nickel is employed.. Ni powder is rate as a cancer hazard material by EPA and MSDS's. The national toxicology program has listed nickel as reasonably anticipated to be a carcinogen based on the production of injection-site tumors. The metallic foam of the MHI electrode has large surface area compared to conventional electrodes, due to the novel fractal pore structure. The density of MHI porous electrode can ranges from 50 to 90% of the theoretical density. The surface area and the reactivity is much higher. The unique microstructure of nano-particle containing MHI porous electrodes appear to have better mechanical properties compared to the current available Ni foam. The microstructure of MHI porous electrode is mixed open and close cell structure, while the current Ni foam is an open cell structure. The networking of the individual close cells gives the better mechanical properties. The MHI porous electrode may be manufactured in sizes, which are not available in current Ni foams. The MHI porous electrode can made from 0.25" thick to 2" thick. No thickness greater than 0.3" is available today and typically electrodes require the higher thickness. The MHI foam process may also be used to manufacture alloyed porous electrodes, such as Ni-Fe, and Ni-Cu electrodes.

Summary of advantage of MHI porous metallic electrodes

- Low cost processing.
- Environmental friendly - no health hazard
- Higher surface area of the electrode -nano technology
- MHI porous Ni foam has better mechanical property compared to others porous electrodes due to the unique stacking and necking structure of the pores.
- MHI porous electrodes can be manufactured in various pore size and size distributions.
- MHI porous electrode may be produced in various alloy composite forms - such as Ni-Cr, Ni-Fe, and Ni-Cu and may easily be integrated to the electrolytes.