

to obtain exceptionally high porosity.

After casting and freezing, the frozen tape is diced into sections for freeze-drying, in which the water and any other solvents are removed by sublimation. Because, in sublimation, the solidified solvents are transformed into gases without passing through intermediate liquid phases, there are no capillary forces like those associated with liquid-to-vapor transitions that occur

during drying in traditional tape casting. Because of the absence of capillary forces, the changes in the dimensions of microstructures and in the overall thickness of the tape are negligible and hence processing is simplified with the absence of cracks and other drying defects notable in traditional tapes. After freeze-drying, the sections of tape are cut into the desired shape, then sintered.

*This work was done by Stephen W. Sofie of QSS Group, Inc. for Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17628-1.*

## Electrophoretic Deposition on Porous Non-Conductors

**EPD is simplified and made more widely applicable.**

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A method of electrophoretic deposition (EPD) on substrates that are porous and electrically non-conductive has been invented. Heretofore, in order to perform an EPD, it has been necessary to either (1) use a substrate material that is inherently electrically conductive or (2) subject a non-conductive substrate to a thermal and/or chemical treatment to render it conductive.

In the present method, instead of relying on the electrical conductivity of the substrate, one ensures that the substrate is porous enough that when it is immersed in an EPD bath, the solvent penetrates throughout the thickness, thereby forming quasi-conductive paths through the substrate. By making it unnecessary to use a conductive substrate, this method simplifies the overall EPD process and makes new applications possible. The method is expected to be especially beneficial in enabling deposition of layers of ceramic and/or metal for chemical and electrochemical devices, notably including solid oxide fuel cells.

In the initial application for which this method was invented, there is a requirement to fabricate unitary anode/solid electrolyte structures for solid oxide fuel cells, each such structure comprising the following:

- A porous cermet anode layer made of nickel and yttria-stabilized zirconia (YSZ) and
- A solid electrolyte in the form a thin dense layer of YSZ.

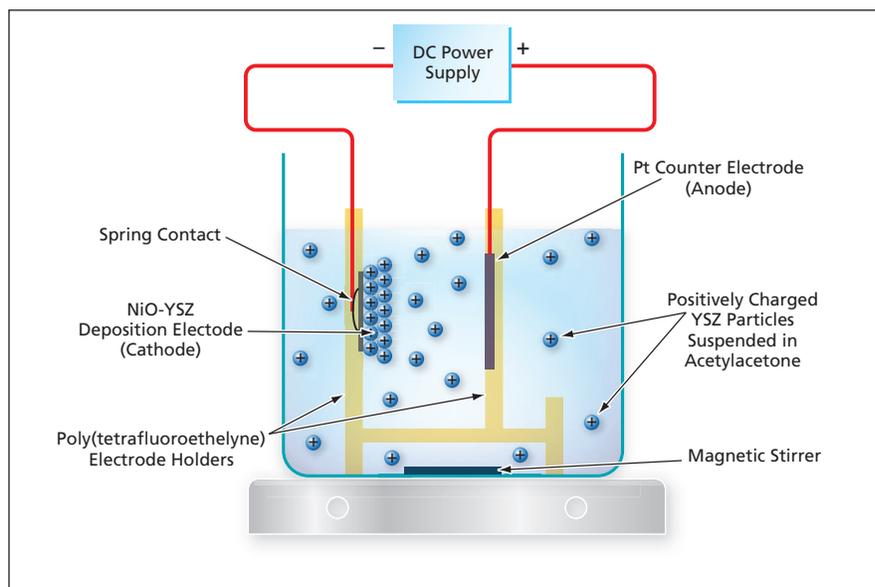
The starting material for fabricating the structure is a porous layer consisting mostly of pellets of a composite of NiO and YSZ. The dense layer of YSZ is deposited on the NiO-YSZ composite later by means of EPD according to the present method, then the resulting

(NiO-YSZ)/YSZ structure is sintered. The final fabrication step takes place after the sintered structure has been placed in a fuel cell: The reducing atmosphere maintained on the anode side of the fuel cell during testing reduces the NiO to metallic Ni, thereby creating the desired Ni anode having the porosity needed for transport of reactant and product gases.

The figure depicts the apparatus used in experiments to develop and demonstrate the present EPD method. The apparatus included a reservoir containing acetylacetone (as a nominally nonaqueous solvent). YSZ powder was stably suspended in the solvent by electrostatic repulsion, and YSZ particles were replenished to the depositing electrode by use of a magnetic stirrer. The YSZ particles acquired positive surface electric

charges in a manner similar to that of surface charging in an aqueous medium. This charging has been conjectured to be a consequence of the presence of residual water in the acetylacetone. Regardless of the exact physical mechanism, the charging was fortuitous in that it contributed to the desired electrophoretic effect.

The NiO-YSZ deposition substrate was mounted on a stationary poly(tetrafluoroethylene) electrode holder and connected via a spring contact to the negative side of a DC power supply so that it became a deposition electrode (cathode). A platinum counter electrode was mounted on a movable poly(tetrafluoroethylene) electrode holder and connected to the positive side of the power supply, so that it became an anode. For most experimental



Particles of YSZ Were Deposited on an NiO-YSZ substrate in this experimental EPD apparatus.

depositions, the distance between the electrodes was kept at 10 mm. The depositions were carried out at various constant applied voltages ranging from 50 to 300 V for periods of 30 s to 5 min. During each deposition, the force of the applied electric field on suspended YSZ particles caused these particles to migrate towards the cathode and even-

tually deposit. A solid-oxide fuel cell containing an anode/solid-electrolyte structure fabricated in part by this method exhibited an areal power density of 611 W/cm<sup>2</sup> in operation at a temperature of 800 °C.

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*Center. Further information is contained in a TSP (see page 1).*

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