Improved Cathode Structure for a Direct Methanol Fuel Cell

The improvement is intended to reduce the airflow demand.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved cathode structure on a membrane/electrode assembly has been developed for a direct methanol fuel cell, in a continuing effort to realize practical power systems containing such fuel cells. This cathode structure is intended particularly to afford better cell performance at a low airflow rate.

A membrane/electrode assembly of the type for which the improved cathode structure was developed (see Figure 1) is fabricated in a process that includes brush painting and spray coating of catalyst layers onto a polymer-electrolyte membrane and onto gas-diffusion backings that also act as current collectors. The aforementioned layers are then dried and hot-pressed together. When completed, the membrane/electrode assembly contains (1) an anode containing a fine metal black of Pt/Ru alloy, (2) a membrane made of Nafion 117® or

equivalent (a perfluorosulfonic acid-based hydrophilic, proton-conducting ion-exchange polymer), (3) a cathode structure (in the present case, the improved cathode structure described below), and (4) the electrically conductive gas-diffusion backing layers, which are made of Toray 060™ (or equivalent) carbon paper containing between 5 and 6 weight percent of poly(tetrafluoroethylene).

The need for an improved cathode structure arises for the following reasons: In the design and operation of a fuel-cell power system, the airflow rate is a critical parameter that determines the overall efficiency, cell voltage, and power density. It is desirable to operate at a low airflow rate in order to obtain thermal and water balance and to minimize the size and mass of the system. The performances of membrane/electrode assemblies of prior design are limited at low airflow rates. Methanol crossover increases the required airflow rate. Hence, one way to reduce the required airflow rate is to reduce the effect of methanol crossover. Improvement of the cathode structure — in particular, addition of hy-

drophobic particles to the cathode — has been demonstrated to mitigate the effects of crossover and decrease the airflow required.

The present improved cathode structure and the membrane/electrode assembly of which it is a part differ from prior such structures in the manner in which hydrophobic particles are distributed in the various layers and in the pretreatment of the membrane. The improved cathode is fabricated in a variant of the fabrication process summarized above. The major steps of this variant of the process as they affect the cathode are the following:

1. The polymer-electrolyte membrane is roughened by use of a 600-grit-abrasive-coated paper.
2. For a membrane area of 25 cm^2, an ink comprising 0.18 g of Pt catalyst, 0.72 g of Nafion® (5 percent ionomer solution), and 0.40 g of water is applied to the abraded membrane surface by a paintbrush.
3. Air is blown over the painted membrane surface to dry the ink.
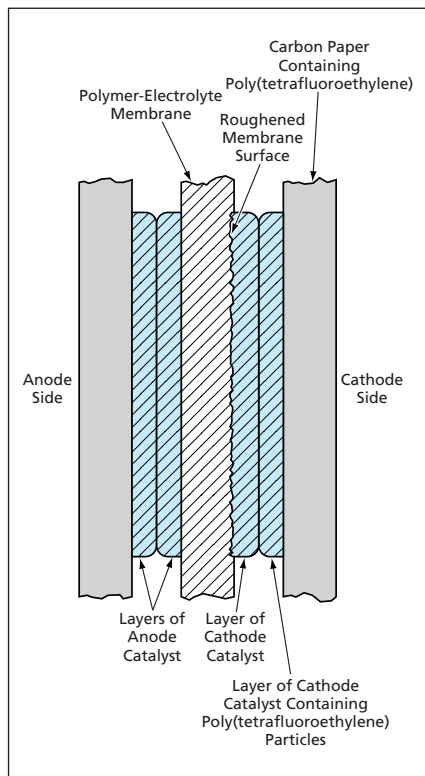4. The gas-diffusion/current-collecting carbon paper is brush-coated with an

Figure 1. This **Membrane/Electrode Assembly** resembles prior such assemblies but contains the improved cathode structure described in the text. The layers are not drawn to scale: thicknesses are exaggerated.
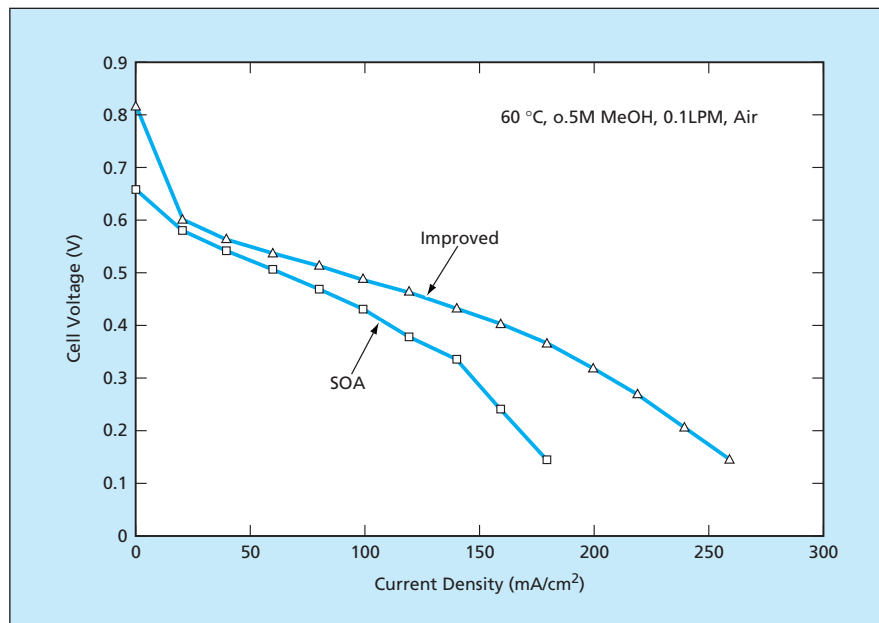
Figure 2. The **Performance of the Membrane Electrode Assembly** produced with the new process shows improvement from that produced by the state-of-the-art process (SOA) that was used at the time of this development.

ink that contains the ingredients described for step 2, plus 0.035 g of poly(tetrafluoroethylene) particles.

5. The membrane coated with catalyst layer is bonded to the gas-diffusion/current-collecting carbon paper by use of heat and pressure.

The performance of membrane electrode assemblies prepared by the new process is compared with those prepared by the state-of-art (SOA) process in Figure 2. The current density at 0.49 V has been raised from 70 mA/cm^2 to 100 mA/cm^2. This results in an increase in power density of 43 percent. At an applied current density of 100 mA/cm^2, the cell voltage for the SOA cell and improved cell are 0.43 and 0.49, respectively. The increase in cell voltage between the SOA and improved cell resulted in an increase in cell efficiency of 8 percent when the effects of crossover are included.

This work was done by Thomas Valdez and Sekharipuram Narayanan of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

X-Band, 17-Watt Solid-State Power Amplifier

This is a smaller, lighter, less expensive alternative to prior X-band amplifiers.

NASA's Jet Propulsion Laboratory, Pasadena, California

An advanced solid-state power amplifier that can generate an output power of as much as 17 W at a design operating frequency of 8.4 GHz has been designed and constructed as a smaller, lighter, less expensive alternative to traveling-
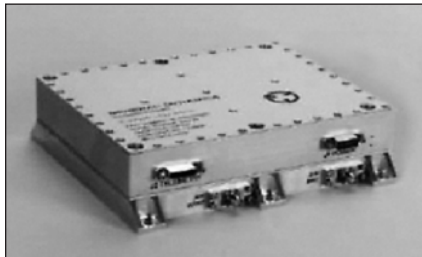

Figure 1. The **Complete Amplifier Package** has dimensions of 6.75 by 5.25 by 1.75 in. (about 17.1 by 13.3 by 4.4 cm).

wave-tube X-band amplifiers and to prior solid-state X-band power amplifiers of equivalent output power. This amplifier comprises a monolithic microwave integrated circuit (MMIC) amplifier module and a power-converter module integrated into a compact package (see Figure 1).

The amplifier module contains an input variable-gain amplifier (VGA), an intermediate driver stage, a final power stage, and input and output power monitors (see Figure 2). The VGA and the driver amplifier are 0.5-µm GaAs-based metal semiconductor field-effect transistors (MESFETs). The final power stage contains four parallel high-efficiency, GaAs-based pseudomorphic high-electron-mobility transistors (PHEMTs). The

gain of the VGA is voltage-variable over a range of 10 to 24 dB. To provide for temperature compensation of the overall amplifier gain, the gain-control voltage is generated by an operational-amplifier circuit that includes a resistor/thermistor temperature-sensing network. The driver amplifier provides a gain of 14 dB to an output power of 27 dBm to drive the four parallel output PHEMTs, each of which is nominally capable of putting out as much as 5 W. The driver output is sent to the input terminals of the four parallel PHEMTs through microstrip power dividers; the outputs of these PHEMTs are combined by microstrip power combiners (which are similar to the microstrip power dividers) to obtain the final output power of 17 W.
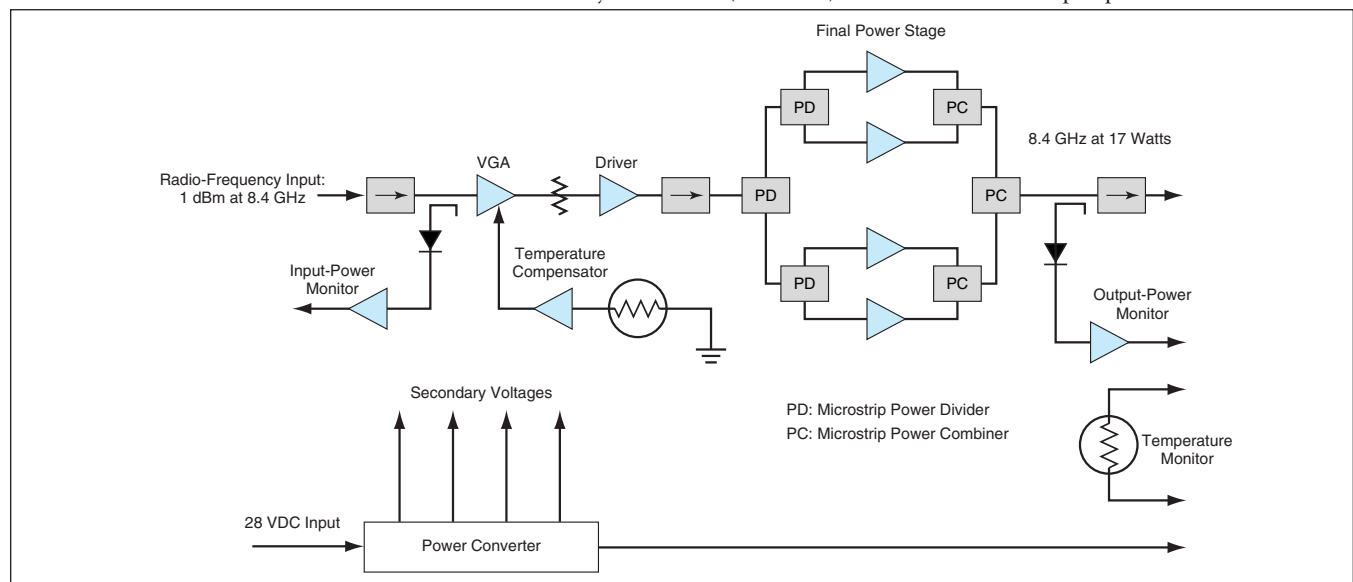

Figure 2. This **Block Diagram** shows only major functional blocks of the amplifier and power-converter modules.