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/cm² to 100 mA/cm². This results in an increase in power density of 43 percent. At an applied current density of 100 mA/cm², 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).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-30829, volume and number of this NASA Tech Briefs issue, and the page number.

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-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 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).

Figure 2. This Block Diagram shows only major functional blocks of the amplifier and power-converter modules.
The power-converter module contains
a high-efficiency (nominally 90-percent
efficient) DC-to-DC power converter plus
analog signal-conditioning circuitry for
use in remote monitoring (e.g., telemetry)
of temperature, and of radio-frequency
input and output power levels.

The power converter contains a trans-
former in a push-pull, pulse-width-modu-
lated buck regulator circuit. Feedback
for regulation of power-converter output vol-
tages is provided by a transformer winding
that is in addition to the primary and sec-
ondary winding. Feedback-loop compen-
sation is provided by an error amplifier
and associated resistors and capacitors
within the pulse-width modulator. To
maximize efficiency, the output voltages
are obtained via synchronous rectifiers
connected to the secondary winding of
the transformer. The ripple in the outputs
of the rectifiers is attenuated by use of in-
ductance-capacitance filters.

The output power of 17 W is obtained
with a nominal input radio-frequency
power of 1 dBm (≈1.3 mW) and an input
DC power of 59 W. The amplifier and
power-converter modules are configured
and stacked in a manner that provides
the best thermally conductive path for
dissipating heat generated in the final
power stage. The amplifier can operate
over a temperature range from –40 to
+70 °C, from sea-level to Mars’ atmos-
phere and even to a vacuum.

This work was done by Anthony Mittkus
and Ernest Stone of Caltech and William
Boger, David Burgess, Richard Honda, and
Carl Nucholls of General Dynamics Decision
Systems for NASA's Jet Propulsion Labora-
From further information is contained in a
TSP (see page 1). NPO-30663

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Improved Anode for a Direct Methanol Fuel Cell

Electrical resistance is decreased and utilization of catalyst is increased.

NASA’s Jet Propulsion Laboratory, Pasadena, California

A modified chemical composition has been
designed to improve the perfor-
mance of the anode of a direct
methanol fuel cell. The main feature of
the modified composition is the incor-
poration of hydrous ruthenium oxide
into the anode structure. This modifica-
tion can reduce the internal electrical
resistance of the cell and increase the
degree of utilization of the anode cata-
lyst. As a result, a higher anode current
density can be sustained with a smaller
amount of anode catalyst. These im-
provements can translate into a smaller
fuel-cell system and higher efficiency of
conversion.

Some background information is help-
ful for understanding the benefit afforded
by the addition of hydrous ruthenium
oxide. The anode of a direct methanol fuel
cell sustains the electro-oxidation of
methanol to carbon dioxide in the reac-
tion
\[
\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-.
\]

An electrocatalyst is needed to enable this
reaction to occur. The catalyst that offers
the highest activity is an alloy of approxi-
mately equal numbers of atoms of the
noble metals platinum and ruthenium.

The anode is made of a composite mater-
ial that includes high-surface-area Pt/Ru-
alloy particles and a proton-conducting
ionomeric material. This composite is usu-
ally deposited onto a polymer-electrolyte
(proton-conducting) membrane and onto
an anode gas-diffusion/current-collector
sheet that is subsequently bonded to the
proton-conducting membrane by hot
pressing.

Heretofore, the areal density of
noble-metal catalyst typically needed
for high performance has been about
8 mg/cm². However, not all of the cata-
lyst has been utilized in the catalyzed
electro-oxidation reaction. Increasing
the degree of utilization of the catalyst
would make it possible to improve the
performance of the cell for a given cata-
lyst loading and/or reduce the catalyst
loading (thereby reducing the cost of
the cell).

The use of carbon and possibly other
electronic conductors in the catalyst
layer has been proposed for increasing
the utilization of the catalyst by increas-
ing electrical connectivity between cata-
lyst particles. However, the relatively low
density of carbon results in thick catalyst
layers that impede the mass transport
of methanol to the catalytic sites. Also, the
electrical conductivity of carbon is less
than 1/300th of typical metals. Further-
more, the polymer-electrolyte mem-
brane material is acidic and most metals
are not chemically stable in contact with
it. Finally, a material that conducts elec-
trons (but not protons) does not con-
tribute to the needed transport of pro-
tons produced in the electro-oxidation
reaction.

Hence, what is needed is an additive
that is stable in contact with the polymer-
electrolyte membrane and that conducts
both electrons and protons. Hydrous

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These Plots of Anode Overpotential Versus Current Density were obtained in tests of direct methanol fuel cells operated at a temperature of 90 °C and a methanol concentration of 1 M.