MICROFABRICATED DIRECT METHANOL FUEL CELLS TO POWER ON-BOARD INTEGRATED CIRCUITS

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Portable electronic devices, including those for mobile communications, computations, microsensors, micro-electromechanical systems (MEMS), and microfluidic devices all require advances in energy storage. The availability of higher energy density sources will enable a wider range of usage and functionality for such devices. One possible source of higher energy power is the use of fuel cells. Also, the availability of an on-board sustained-power supply will open many opportunities for portable devices and those in remote locations. Further, the co-fabrication of the portable electronic device with its power source would enable significant advances in the use and function of the devices. The availability of high energy density storage is expected to have significant impact on commercial, industrial, individual, and military applications. The goal of this research is to demonstrate the feasibility of fabricating integrated micro-fuel cells.

Microfabrication techniques are utilized in the construction of novel, miniature direct methanol fuel cells (DMFCs). DMFCs are considered low temperature fuel cells because their typical operating temperatures are 60-120ºC. They usually employ a solid polymer electrolyte membrane (PEM). A methanol-water mixture is fed to the anode in either liquid or vapor form. Methanol is an attractive fuel option because it is stored as a liquid, is inexpensive, and has a high specific energy (1-3).

The design of the fuel cells is based on using a sacrificial polymer to form microchannel structures (4). Figure 1 shows an SEM micrograph of an air-channel encapsulated in a polymer. The sacrificial polymer is deposited, patterned, and covered with an encapsulating material. It is then heated and decomposed, with the decomposition products diffusing through the overcoat material. The encapsulating material for the micro fuel cells is the PEM. The fuel flows through these channels and comes in contact with the catalyst and PEM at the anode. The top of the PEM contains catalyst for the air cathode. A cross section of a fuel cell featuring an array of microchannels is shown in Figure 2.

Porous catalytic electrodes are the reaction sites at both the anode and cathode. The three key properties that must be obtained in the fabrication of the electrodes are porosity (access of the fuel to the membrane), conductivity, and catalytic activity. Platinum is the catalyst at both the anode and cathode. A thin, incomplete layer of Pt is sputtered which leaves holes to allow the reactants to come in contact with the electrolyte. The layer contains enough Pt to be sufficiently catalytic as well as electrically conductive.

The anode and cathode current collectors can be seen in Figure 2 running between the reactive areas of the catalytic electrodes. Their purpose is to gather electrons from the anode, distribute electrons across the cathode, and make connections to the electrical components of the device.

PEM materials are sulfonic acid-containing polyimides. The membrane features that are of importance include the proton conductivity, minimization of methanol permeability, and dimensional stability. The material must also withstand processing conditions, which includes relatively high temperatures during the decomposition of the sacrificial polymer.

One of the major advantages of an integrated power source will be in heat management. Because the practical cell voltage of DMFCs is significantly less than the theoretical value, much of the energy converted is waste heat. Integrated circuits also give off heat. As shown in Figure 3, the heat from both the IC and the fuel cell can be used to heat and vaporize the liquid fuel feed.

The power output and fuel efficiency of the micro fuel cells are tested and compared for different micro fuel cell designs, fabrication processes, and materials. The main areas of the design and fabrication that are tested include the fuel channels, current collectors, and the catalytic electrodes. Different membrane materials and thicknesses will also be compared. The experiments include testing the devices in three categories: temperature, fuel flowrates, and water:methanol ratios. Tests will also be performed to determine the practicality of extended use, integrated micro fuel cells.

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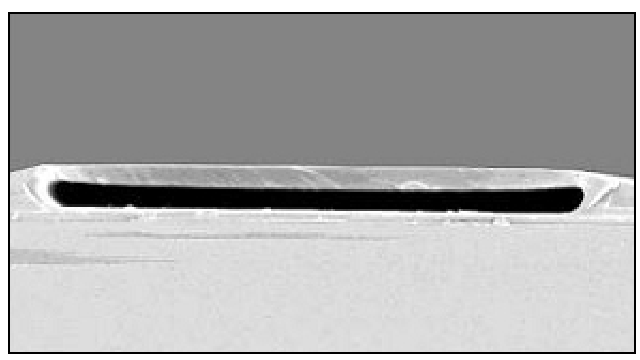

Figure 1: Air-channel encapsulated in a polymer

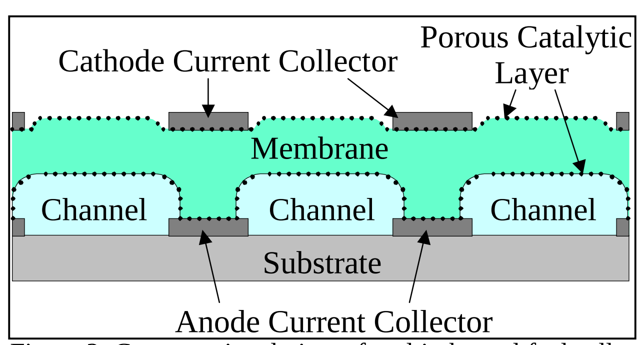

Figure 2: Cross-sectional view of multi-channel fuel cell

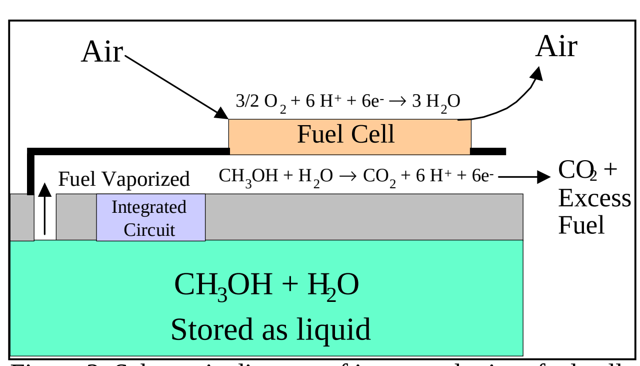

Figure 3: Schematic diagram of integrated micro fuel cell