

Catalyst Stability in Fuel-Cell Electrodes

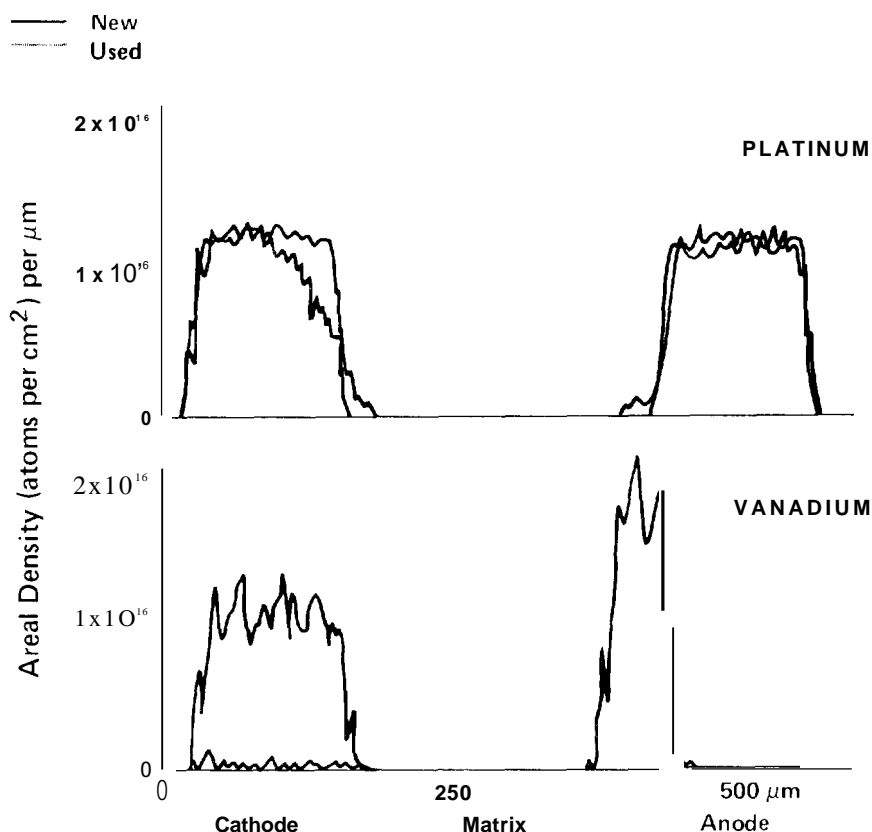
Applications

A fuel cell is a device that converts chemical energy directly to electrical energy, thus bypassing the usual intermediate and energy-wasting conversions to thermal and mechanical energy. A fuel cell based on the reaction of hydrogen and oxygen was conceived and constructed as early as 1839, but the idea was not pursued with much enthusiasm until more than a hundred years later. In recent times the development of fuel cells has been spurred by the search for more efficient and nonpolluting sources of electricity.

Basically, the hydrogen-oxygen fuel cell consists of porous electrodes separated by an electrolyte. Hydrogen and oxygen diffuse through the anode and the cathode, respectively, and undergo reactions that create a potential difference across the cell. At the anode hydrogen molecules dissociate into atoms and then release electrons. The hydrogen ions flow to the cathode through the electrolyte, and the electrons flow through the external circuit. At the cathode oxygen molecules dissociate and accept electrons from the external circuit. The hydrogen and oxygen ions then combine to form water.

To achieve high rates of dissociation and oxidation or reduction of the gases, a platinum catalyst is embedded in the electrodes. Platinum is costly, and, further, its activity for oxygen reduction at the cathode is less than ideal. An attempt has been made to reduce the amount of platinum required and increase the cathode activity by using an intermetallic platinum-vanadium compound as the cathode catalyst. The intermetallic compound shows an initial activity for oxygen reduction greater than that of platinum, but during operation its activity decreases to that of the pure metal.

The performance of a fuel cell may degrade during use, possibly because of loss of the catalyst from the electrodes. In fact, such losses are to be expected since the cathode operates at a potential close to the oxidation potential of the catalyst. We studied the migration process with the microprobe by



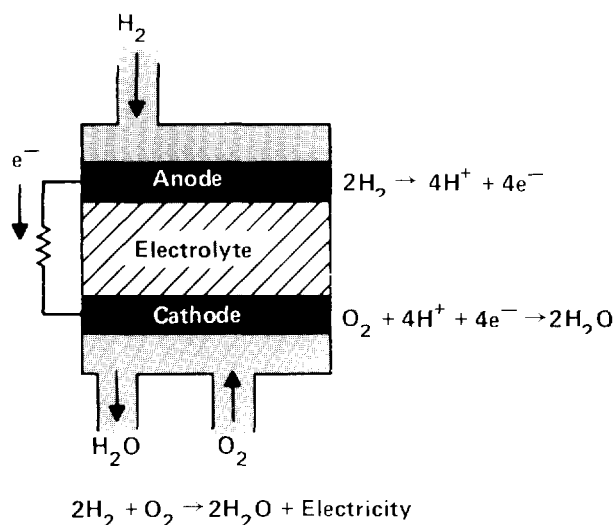
Distribution of catalyst in the electrodes of a fuel cell before use and after about 3000 hours of operation. Initially, the cathode and anode contained catalysts of platinum-vanadium and pure platinum, respectively. Note the loss of vanadium from the cathode and its buildup in the matrix near the anode of the used fuel cell.

measuring the catalyst depth distributions in new and used electrodes. The signals detected were backscattered protons from an incident beam of 3-MeV protons. To obtain the depth distribution throughout the regions where the chemical reactions take place, we made a small-angle cut through the electrode and performed a line scan across the bevel.

For electrodes containing a catalyst of

pure platinum, the catalyst was found to be fairly stable, although there was some loss of catalyst from the cathode after several thousand hours of operation.

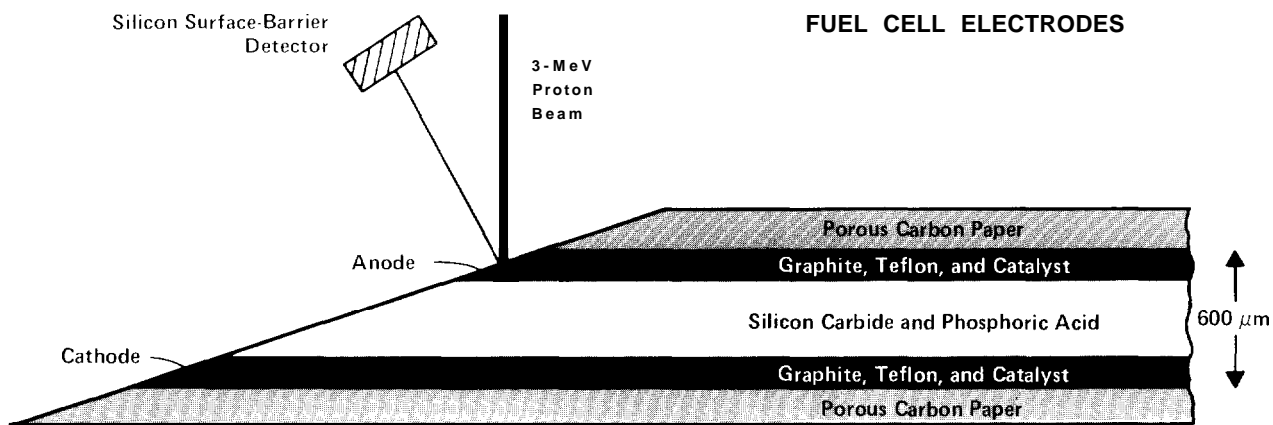
More interesting results were obtained for electrodes with platinum-vanadium as the cathode catalyst and platinum as the anode catalyst. In this case we determined simultaneously the depth distributions of



Schematic diagram of a hydrogen-oxygen fuel cell.

platinum, vanadium, silicon, phosphorus, oxygen, fluorine, and carbon in the cathode, anode, and matrix. (The accompanying figure gives the depth distributions of platinum and vanadium.) Our results showed that the vanadium component of the platinum-vanadium catalyst is not stable. The vanadium dissolves in the phosphoric acid, migrates through the silicon carbide matrix, and accumulates near the anode. We are now studying several other intermetallic catalysts with a view to improved and more stable fuel-cell performance.

This work was performed in conjunction with Philippe J. Hyde and S. Srinivasan of Los Alamos.



Experimental setup for using the nuclear microprobe to determine the distribution of catalyst in a fuel-cell electrode of current design. The concentration of catalyst in the electrodes is about 1 part in 2000. The Teflon particles prevent flooding of the electrodes by the phosphoric acid electrolyte. The

chemical reactions take place close to the three-phase regions where the gases react on the solid graphite-catalyst surface and the liquid electrolyte provides mobility for the hydrogen ions. The conducting carbon paper and graphite provide a path for the electrons.