Electrode Materials and Structures in Polymer Electrolyte and Direct Methanol Fuel Cells

Shimshon Gottesfeld

MTI Microfuel Cells
Albany, NY

Electrode compositions and structures found in polymer electrolyte fuel cells (PEFCs) and direct methanol fuel cells (DMFCs), are quite complex. The requirement of achieving and maintaining high power output at minimized cost, has presented a significant challenge in the development of electrodes based on precious metal catalysts. Maximizing catalyst utilization requires fabrication of "catalyst layers" of mixed electronic/ionic conductivity, which allow, at the same time, high rates of reactant access and product removal. The art in this specific area of the technology developed strongly between the mid 1980's and mid-1990's, enabling lowering of the precious catalyst loadings per kW generated by an order of magnitude. This has still left a need at present for further reduction of precious metal loading by about factor 5, to enable mass market entry in transportation. The nature of required improvements in the catalyst layer component of the PEFC will be described, together with some thoughts on possibilities of further advancements.

Maximizing catalytic activity and reducing precious metal loading have been highlighted as the major issues in PEFC electrode technology. However other components of the electrode in such fuel cells are as important in achieving the impressive power densities (1 kW/liter around 80 deg C) and ensuring long term performance stability. One such key component is the "backing layer" (or "gas diffuser"), placed adjacent the catalyst layer> It is responsible for maintaining gas phase transport of the reactant practically all the way from the air, or hydrogen flow channel to the catalyst surface. This is achieved by maintaining at least part of a pore network in a carbon paper, or cloth, free of liquid water. This requires, in turn, proper engineering of microporous, hydrophobic layers, that prevent liquid penetration while allowing significant gas permeability. Such microporous layers and the "skeleton" of the carbon paper or cloth on which they are supported, are at the heart of the so-called GDE (gas diffusion electrode) technology. This technology remains somewhat imperfect to date. The apparent reasons are high sensitivity to the fine details of the GDE fabrication process and significant sensitivity of surface properties in the GDE to surface active contaminants. Consequently, efforts are still ongoing to further improve quality control and achieve predictability of properties, particularly of the conditions leading to electrode "flooding" .

Another family of materials of interest for PEFC and DMFC electrode technologies, are structural metals. Metals offer advantages in minimizing unit cell thickness in the stack while maintaining mechanical integrity , and in allowing simple and inexpensive processing of bipolar plates for fuel cell stacks. The key requirement to implementation of metal stack technology, is to minimize drastically any corrosion susceptibility under either cathode or anode conditions, while controlling cost.

Finally, specific materials requirements arise for the polymer electrolyte based DMFCs. Some of the most intensively discussed requirements, are the need of membranes of minimized methanol crossover and the even stronger requirement in the case of the DMFC for high precious metal catalyst loadings. The possibility of operating DMFCs with conventional ionomeric membranes while achieving high fuel utilization, will be described. Also will be discussed some attractive DMFC applications where the catalyst demands of this technology do not at all present a serious barrier to commercialization. These applications are in the area of portable power sources for consumer electronics applications.