Ultrasonic Bonding of Membrane Electrode Assemblies for Low Temperature Proton Exchange Membrane Fuel Cells

by

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ABSTRACT

The depletion of the world's fossil fuels has forced an emphasis on green, alternative energy sources. One solution is through the use of fuel cells, which generate electricity and heat through a chemical reaction converting hydrogen and oxygen into water. Affordable, high volume production of the operational component of a fuel cell, membrane electrode assembly (MEA) is a limiting factor preventing adoption of fuel cell technologies. Manufacturing energy and cycle times are inhibiting a fuel cell solution to green energy. This research is focused on reducing the manufacturing inputs required to bond the components of a standard 5-layer MEA for low temperature Polymer Exchange Membrane Fuel Cell (PEMFC) through the use of ultrasonic welding while maintaining performance characteristics.

Ultrasonic welding converts electrical energy into heat through high frequency mechanical oscillations, and in combination with pressure, bonds MEA materials. Cycle times can be reduced by over an order of magnitude, including a similar reduction in energy consumption, by localized heating generated from friction between components. Previous research has shown ultrasonics is a viable alternative to traditional thermal pressing of MEAs for high temperature PEMFC applications with phosphoric-acid PBI membranes. This research investigates ultrasonic MEA bonding and performance characterization for low temperature Nafion fuel cells.

Fuel cell material effects and interaction with ultrasonics were studied initially. Electrode architecture is an important factor affecting performance. The ultrasonic bonding process was optimized, along with thermal pressing, using commercially available gas diffusion electrode. Analysis of Variance estimated no main effects of energy flux or bonding pressure for the ultrasonic process. While not statistically significant, an interaction effect between the two factors may be non-negligible. Temperature was estimated to be a main effect of the thermal pressing process while pressure and the interaction were not. Performance characteristics between ultrasonic and thermally bonded MEAs were compared using custom made electrodes. Catalyst loading and membrane preconditioning are controlled through the design of experiments. Loss contributions were contrasted between the two bonding methods facilitated by the use of diagnostic techniques including impedance spectroscopy and cyclic voltammetry.

The resulting conclusion is that ultrasonics is an effective alternative method for MEA bonding. The advantages of ultrasonic bonding include order-of-magnitude reductions in both cycle time and manufacturing energy compared to conventional thermal pressing while maintaining performance metrics. The marginal costs of MEA production are reduced by using the alternative process. Efficient, localized heating from ultrasonics results in cycle time and bonding energy reductions of 93% and 98% respectively, making fuel cell technologies a more affordable solution to current global energy demands.