MEA Accelerated Testing and Lifetime Modeling

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Introduction

For the successful commercialization of fuel cell technology, it is imperative that membrane electrode assembly (MEA) durability is understood and quantified. MEA lifetimes of 40,000 hours remain a key target for stationary power applications. Since it is impractical to wait 40,000 hours for durability results, it is critical to learn as much information as possible in as short a time period as possible to determine if an MEA sample will survive past its lifetime target. Consequently, 3M has utilized accelerated testing and statistical lifetime modeling tools to develop a methodology for evaluating MEA lifetime.

Accelerated Testing Set Up and Conditions

Accelerated testing of MEAs requires fuel cell operation at harsher conditions than field conditions in order to accelerate membrane or other component failure. The difficulty is in understanding whether failure modes remain unchanged in an accelerated test and how to determine the relationship between accelerated testing conditions and actual field conditions.

To produce more data and generate stronger statistics, a multi-cell stand was built to evaluate single cells under accelerated test conditions. The multi-cell test stand (Figure 1) can operate 10 single cells simultaneously at different load settings and cell temperatures. Several parameters have been investigated including cell temperature, inlet humidity, load settings and MEA designs. Since the gases are delivered from a common manifold, each cell has the same dew point. However, by varying cell temperature, the relative humidity of the inlet gases for each cell can be varied.

Figure 1. Accelerated testing stand with 10 fuel cells operating simultaneously

Data and Results

Changing the load profile of an MEA was found to have a significant effect on lifetime of MEAs. Figure 2 shows the three different load profiles that were investigated: (A) load cycle with open circuit voltage (OCV) setting, (B) constant load, and (C) load cycle without OCV setting. The results of the load cycling shown in Figure 3 clearly indicate that the OCV setting has a significant negative impact on MEA lifetime.

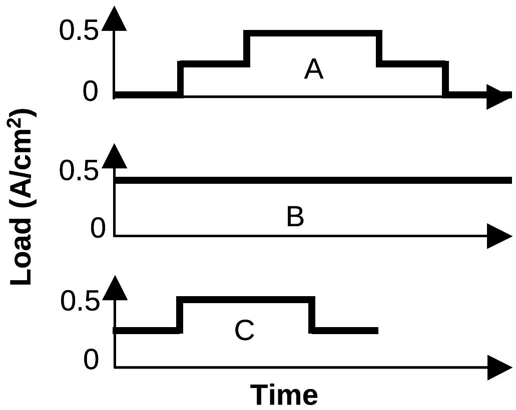

Figure 2. Load profiles used in accelerated tests.

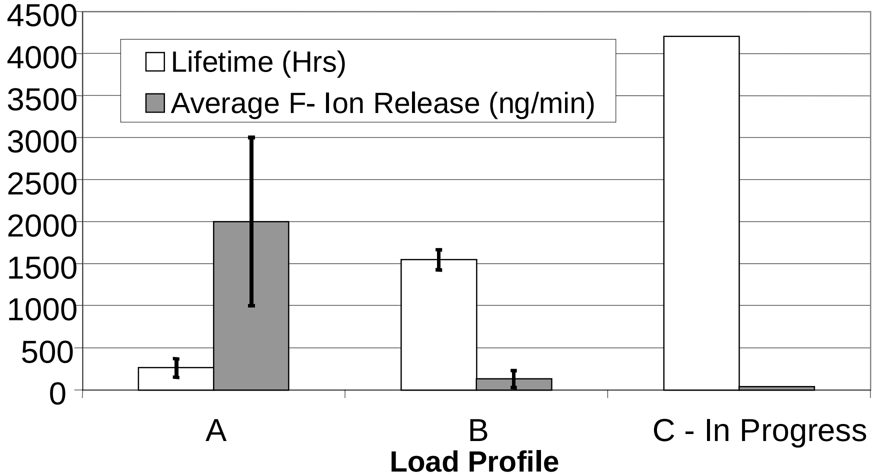

Figure 3. Effect of load profile on MEA lifetime in accelerated tests. Test conditions: 90°C cell temperature, 60°C gas dew points, H_2/Air, Pt/Pt dispersed catalyst, and multiple identical MEAs tested.

Another observation for Figure 3 is that the MEA lifetime is inversely proportional to the fluoride ion release. To investigate the fluoride ion - lifetime relationship, multiple single cell accelerated lifetime tests were completed and the fluoride data were collected and analyzed. The results of the data analysis are compiled in Figure 4. It was found that the initial fluoride ion release (fluoride collected in the first 30 hours, Figure 4) as well as average fluoride ion release (average of fluoride for the life of the sample) were both strongly correlated with lifetime. Using this relationship offers the ability to predict MEA life from early fluoride ion release data as well as determine the relative health of cells while they are running.

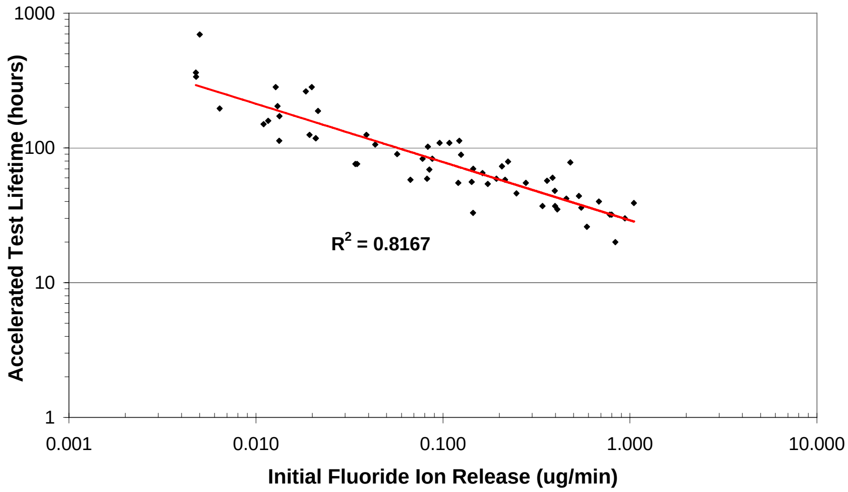

Figure 4. Exponential relationship between initial fluoride ion release and MEA lifetime in accelerated tests. Test conditions: 90°C cell temperature, 60°C gas dew points, H_2/Air, Pt/Pt dispersed catalyst, and multiple MEAs of different designs.

Lifetime Modeling

Implementing multivariate statistics and the information gained from the multi-cell test stand, lifetime modeling has enabled 3M to develop a stronger understanding of MEA degradation mechanisms. Consequently, lifetime projections can now be more confidently assessed using data collected in a few hundred hours. Figure 5 illustrates the use of statistical lifetime modeling to predict MEA lifetime at end use conditions from accelerated test results. To validate the model, the predicted lifetimes contain data for samples that are presently running (often referred to as "censored data"). To date the samples running at 70°C and 100%RH have accumulated over 8000 hours of testing.

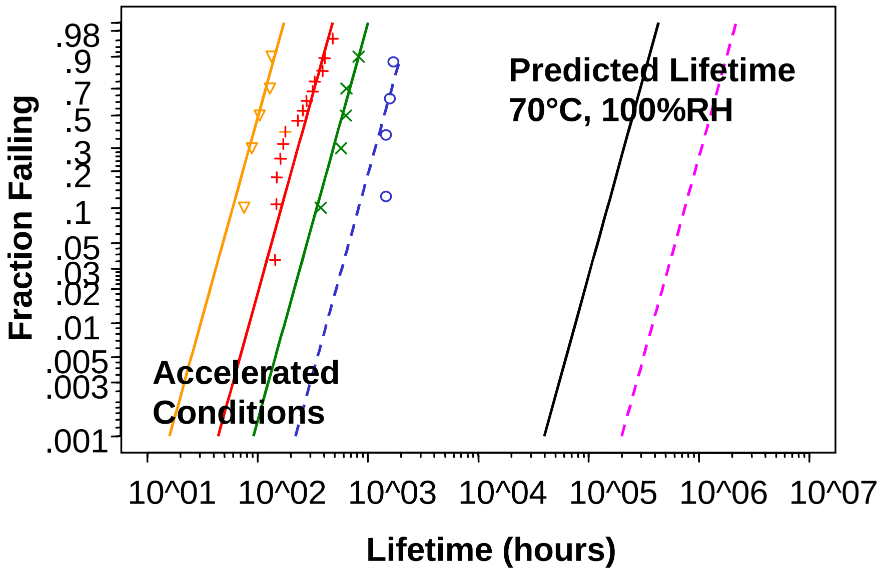

Figure 5. Example of using statistical lifetime modeling to predict MEA lifetime. Solid lines -load profile A, dashed lines - load profile B, symbols – data points.

Summary
Construction and implementation of the multi-cell test stand have allowed for multiple accelerated tests and stronger statistical data for learning about durability. Important information about load cycle and OCV conditions will be instrumental towards developing a better MEA and defining benign operating conditions. Utilizing tools such as statistical lifetime modeling and initial fluoride ion release data has allowed for early predictions of MEA durability. The ability to learn about durability in a shorter time period has, in turn, allowed 3M to make key advances in developing more durable MEAs for the fuel cell market.

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