Stress Relaxation Behavior of Nafion® 112 Measured with Controlled Humidity Dynamic Mechanical Analysis

ABSTRACT

This paper discusses the stress relaxation behavior of Nafion 112 measured using dynamic mechanical analysis under varying conditions of temperature and relative humidity.

INTRODUCTION

Recent research has focused on alternative fuel technologies including Proton Exchange Membrane Fuel Cells (PEMFC) which contain polymeric membranes such as Nafion 112. PEM properties can significantly change as functions of time and exposure to elevated temperatures and humidity, as water is the primary by-product of the electrochemical reaction of the fuel cell. Nafion is widely used in PEMFC technology developed for automotive applications, where the required operational range is from 80°C to 110°C. It has a high power density and is well known in the industry. It is understood that the Nafion membrane will experience various hydration levels within the fuel cell environment during operation. As such, stress relaxation experiments at different combinations of temperature and relative humidity can help characterize polymer swelling, and the resultant impact on mechanical characteristics.

The TA Instruments DMA-RH Accessory allows the mechanical properties of a sample to be analyzed under constant and/or varying conditions of both relative humidity and temperature. It is designed for use with the Q800 Dynamic Mechanical Analyzer. The DMA-RH accessory is an integrated unit and contains the following components:

Figure 1: The TA Instruments Q800 Dynamic Mechanical Analyzer and DMA-RH Accessory

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1. The sample chamber mounts to the DMA in place of the standard furnace and encloses the sample. Peltier elements in the chamber precisely control the temperature to within ±0.1°C. The sample chamber accommodates standard DMA clamps including tension, cantilever, and 3-point bending, and can be easily removed for rapid conversion back to the standard DMA furnace.
2. The DMA-RH Accessory contains the humidifier and electronics which continuously monitor and control temperature and humidity of the sample chamber. The DMA Q800 and the DMA-RH Accessory are fully software-integrated.
3. A heated vapor transfer line is maintained above the dew point temperature of the humidified gas in order to avoid condensation and provide accurate results.

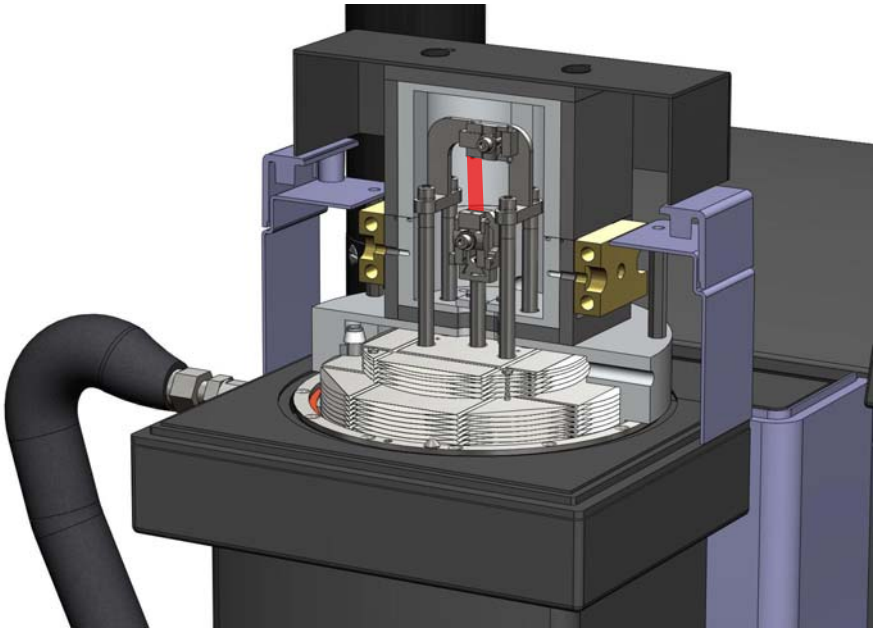

Figure 2: Sample Chamber of the DMA-RH Accessory

The DMA-RH accessory allows for the control of temperature over the range 5-120°C, and humidity over the range 5-95% RH. As such, it is well-suited to investigate polymeric materials which exhibit structural and mechanical instability within this temperature range.

RESULTS & DISCUSSION

The results in Figure 3 show the stress relaxation modulus of the Nafion® 112 membrane at two different combinations of temperature and relative humidity. The upper blue curve was measured at 25°C/50% RH, to simulate typical ambient conditions. The lower red curve was measured at 85°C/85% RH, a more aggressive atmosphere nominally chosen as it represents an electronic materials standard. From the data in Figure 3 it is clear that the mechanical properties of the Nafion material are strongly influenced by the surrounding environment. Under the simulated ambient conditions, the relaxation modulus is relatively stable. Increasing the temperature and pressure effectively decreases the initial relaxation modulus by 4X. In addition, the time-dependence of the relaxation modulus is more profound, exhibiting a considerable decrease between 1 and 20 minutes, ultimately resulting in a relaxation modulus approximately 10X lower than that measured under ambient conditions.

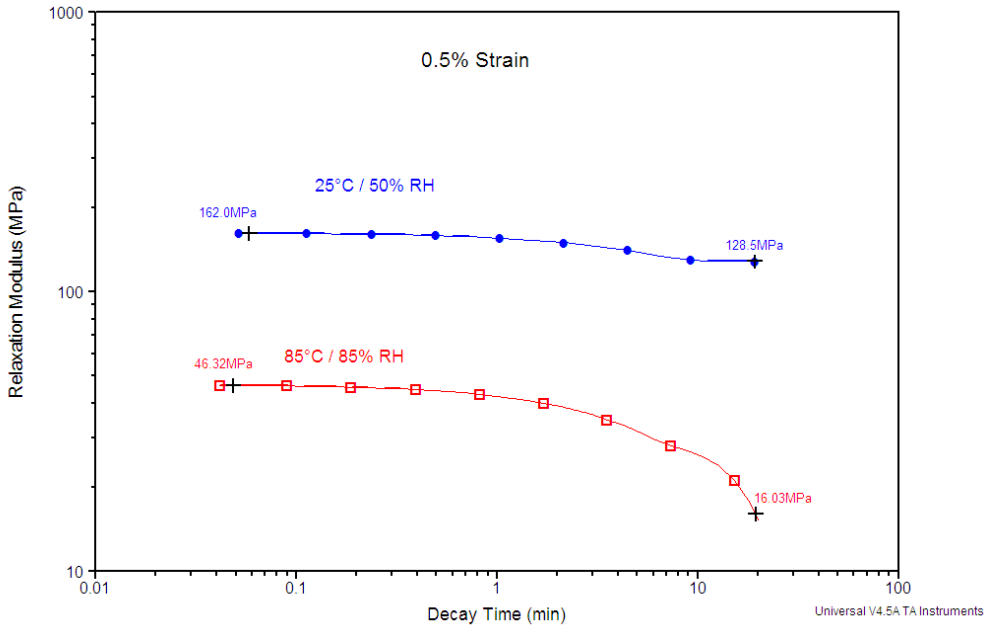

Figure 3: Stress Relaxation of Nafion® 112 at Varying Conditions of Temperature and RH

CONCLUSIONS

The data presented illustrate the effect of temperature and relative humidity on the stress relaxation behavior of Nafion membrane. From these results, it is clear that the complete analysis of PEM materials should include mechanical evaluation under a variety of temperature and relative humidity combinations. The TA Instruments Q800 DMA and DMA-RH Accessory provide the ideal platform for this investigation.

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