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Dynamic mechanical characteristics of five elastomeric gasket materials aged in a simulated and an accelerated PEM fuel cell environment

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ABSTRACT

Elastomeric materials are used as gaskets or seals in polymer electrolyte membrane (PEM) fuel cells and stacks. These gaskets/seals in PEM fuel cells are exposed to acidic, humid air, mechanical compressive pressure and cyclic temperature environment. Both the physical and chemical long-term stabilities of these gaskets/seals are therefore crucial to the overall performance of the fuel cell. Chemical degradation of five elastomeric gasket materials in a simulated and an aggressive accelerated fuel cell solution at 80 °C up to 63 weeks was investigated in this work using dynamic mechanical analysis (DMA) which assesses the change of dynamic mechanical properties of the five materials samples as they aged. The storage, loss modulus, and tan δ of the materials were presented that can reveal the glass transition temperature and other properties.

The five materials tested are copolymeric resin (CR), liquid silicone rubber (LSR), fluorosilicone rubber (FSR), ethylene propylene diene monomer rubber (EPDM), and fluoroelastomer copolymer (FKM).

1. Introduction

An automotive application of PEM fuel cells may contain over a hundred individual fuel cells in a stack. Each single cell consists of a membrane electrode assembly (MEA), gas diffusion layers, flow field channel plates, current collectors, and end plates, as shown in Fig. 1. All these components must be carefully assembled and sealed with gaskets or seals. The gaskets/seals are typically placed between bipolar plates (see Fig. 1) and must be chemically and physically stable and durable for the intended life of the fuel cell. If any gasket degrades or fails during operation or standby, the reactant gases (O_2 and H_2) can leak overboard or mix each other directly. This will affect the overall operation and performance of the fuel cells, e.g., the cathode cannot be electrically insulated to anode.

Gaskets in PEM fuel cell are typically made of elastomeric materials and are exposed to acidic liquid solution, humid air and hydrogen, as well as subjected to mechanical stress. The long-term stability and durability of the gaskets materials are therefore critical to both sealing and the electrochemical performance of the fuel cells.

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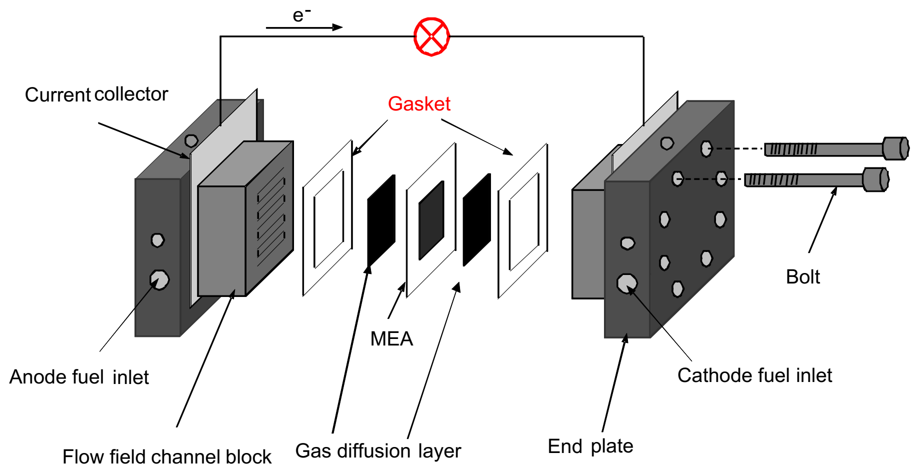

Fig. 1 – Schematic of various components in a PEM fuel cell.

Table 1 – Material properties.

Material	CR[a]	FSR[a]	LSR[a]	EPDM[b]	FKM[c]
Exterior					
Sample thickness/mm	1.5	2.0	2.0	2.0	2.0
Color	White	Straw Yellow	Slate Gray	Black	Black
Hardness /Shore A	60–75	35–45	66	40–90	75
Elongation/%	400	≥300	451	100–600	200
Relative density/g cm^{-3}	1.08	1.43	1.14	0.90 to >2.00	2
Tear strength/ppi	241	100	241	200	144
Tensile strength/Mpa	9	8	10	25	9
Work temperature/°C	−40 to 316	−60 to 220	−40 to 205	−20 to 250	−7 to 200

a Dow Corning Company [56].
b AZo Journal of Materials Online [59].
c ThomasNet [61].

In open literatures, there are many reports emphasizing the thermal and irradiative degradation of polymeric materials [1–17]. For instance, Youn and Huh [3] reported the surface degradation of silicone rubber and EPDM under accelerated ultraviolet weathering condition. A severe degradation of the silicone elastomer in a sub-station environment was studied by Liu et al. [17]. Chemical degradation of elastomeric materials was reported in Ref. [18–27]. A review on the effects and degradation process of silicones in outdoor environment can be found in Graiver et al. [18]. Mitra et al. [19,20] investigated the chemical degradation of cross-linked EPDM rubber in 20% Cr/H_2SO_4 acidic environment. Time-dependent chemical degradation of a fluoroelastomer in an alkaline environment can be found in [21,22]. Achenbach [23–25] studied seal life using a numerical simulation for stress relaxation and degradation in different environment. Kim et al. [26] presented degradation results of NBR compound based rubber gaskets in acidic environment. More fundamental studies have been performed by Gillen et al. [27–39] on polymeric seal materials for revealing its degradation mechanisms and developing seal life models.

Although there is a substantial literature discussing chemical degradation of elastomeric gasket materials, only a few results were reported concerning the degradation and its

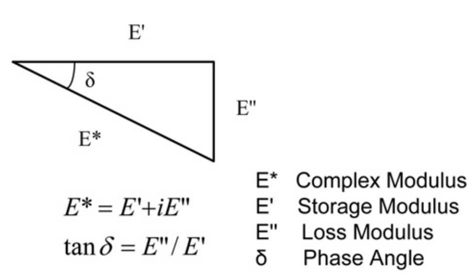

Fig. 2 – Relationships of dynamic mechanical properties determined from DMA [63].