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Decay in mechanical properties of sulfonated poly (ether-ether-ketone) membrane in an ex situ hygrothermal cycling test

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Statement of the Problem: One of the key challenges facing the commercialization of fuel cell technology is the durability of proton exchange membranes (PEM) especially in automotive application. Even though PEMs suffer from chemical degradation in real fuel cell condition, Mechanical degradation shouldn't be overlooked. PEMs are exposed to humidity fluctuation and tend to swell in high humidity or shrink in low humidity. It is shown in the figure 1 that repetition of these tensile and compression forces leads to fatigue failure. Additionally, temperature affects mechanical behavior of polymeric membranes for sure, thus, accelerated hygrothermal cycles would end up to membrane failure because of the reactant cross-over through the membrane or crack formation at the end.

Methodology & Theoretical Orientation: In this work, sulfonated poly(ether-ether-ketone) (sPEEK) membrane as an alternative to state of the art PFSA membranes was used due to low manufacturing cost, high operating temperature and fairly good electrochemical performance. Membranes were prepared, treated and characterized, i.e. sulfonation degree of 64.75% was calculated from H-NMR spectroscopy and ion exchange capacity and cross-linking ratio were calculated respectively. Then, hygrothermal cycles were implemented by home-made setup contains single cell with serpentine flow channels to simulate membrane's constraint at the in situ condition.

Findings: As it was shown in figure 2, membranes have a slight increment in their elastic modulus and act more brittle when exposed to these cycles and as a result, chance of crack formation or propagation increases. On the other hand, water uptake of membranes has increased dramatically up to 184%.

Conclusion & Significance: PEMs in harsh fuel cell condition; according to figure 3 are in a vicious circle which can lead to its failure. Humidity fluctuation triggers the circle, and degradation continues with the increment of young module and stress every cycle. Also, the more the membrane swells, the more stress amplitude we would expect.

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